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.

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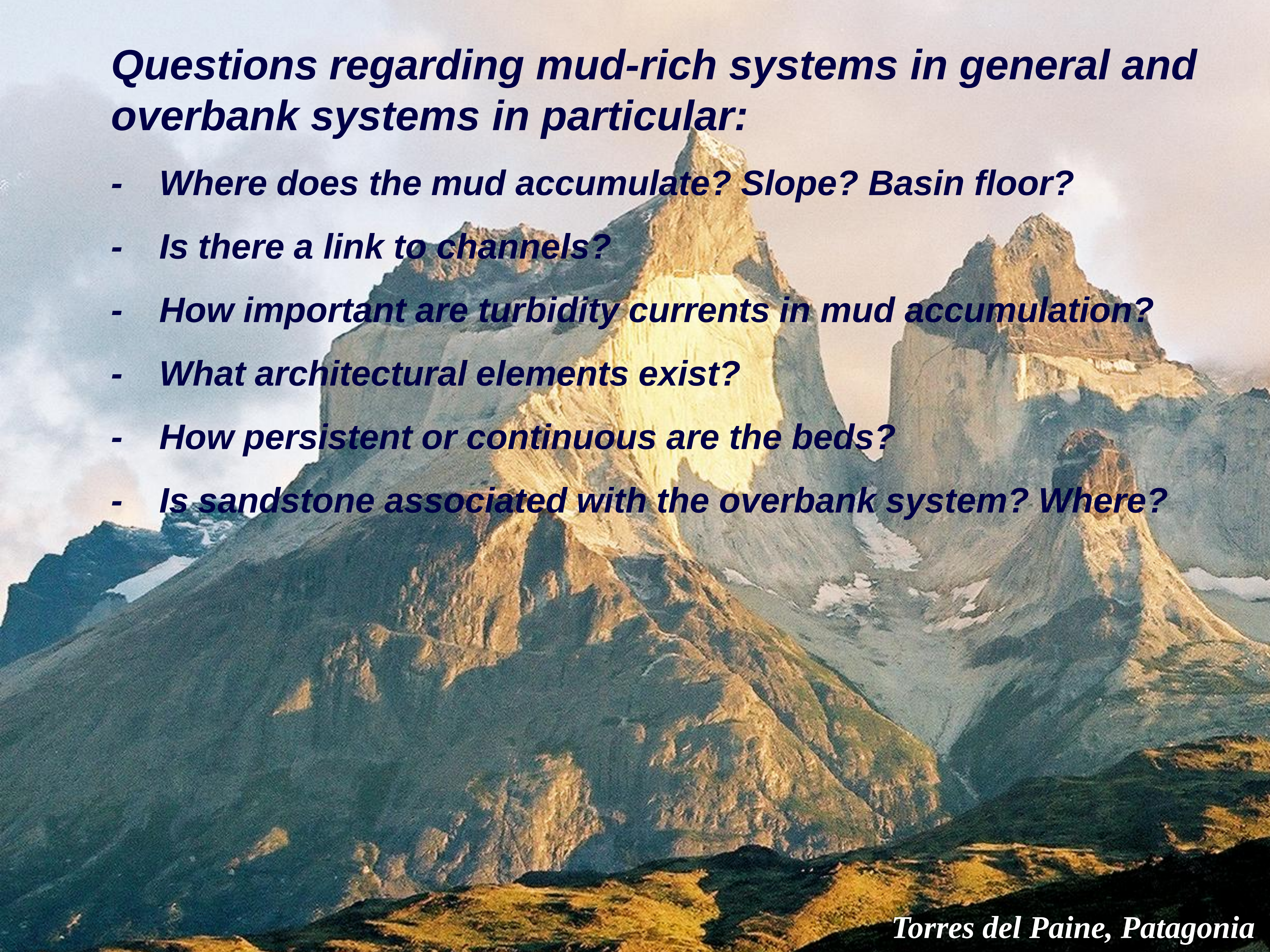
Outline

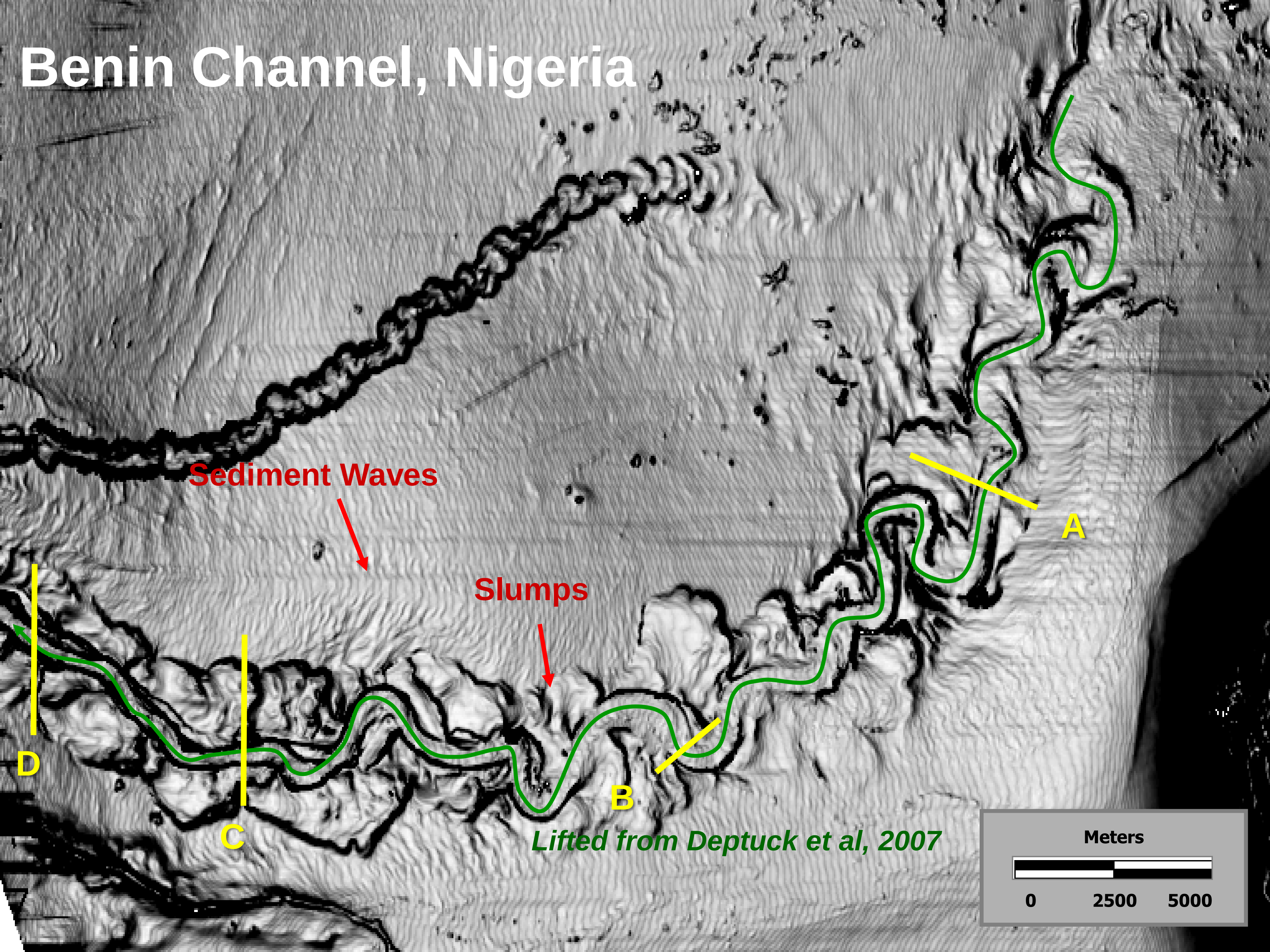
- A few questions regarding mud-rich systems
- Architecture of Quaternary systems
  - Benin Major Channel – Channel stacking, sediment waves and levee growth
  - Var Sedimentary Ridge – details of levee architecture and lithofacies distribution
- Cerro Toro stratigraphy
  - Architectureal elements and 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?*

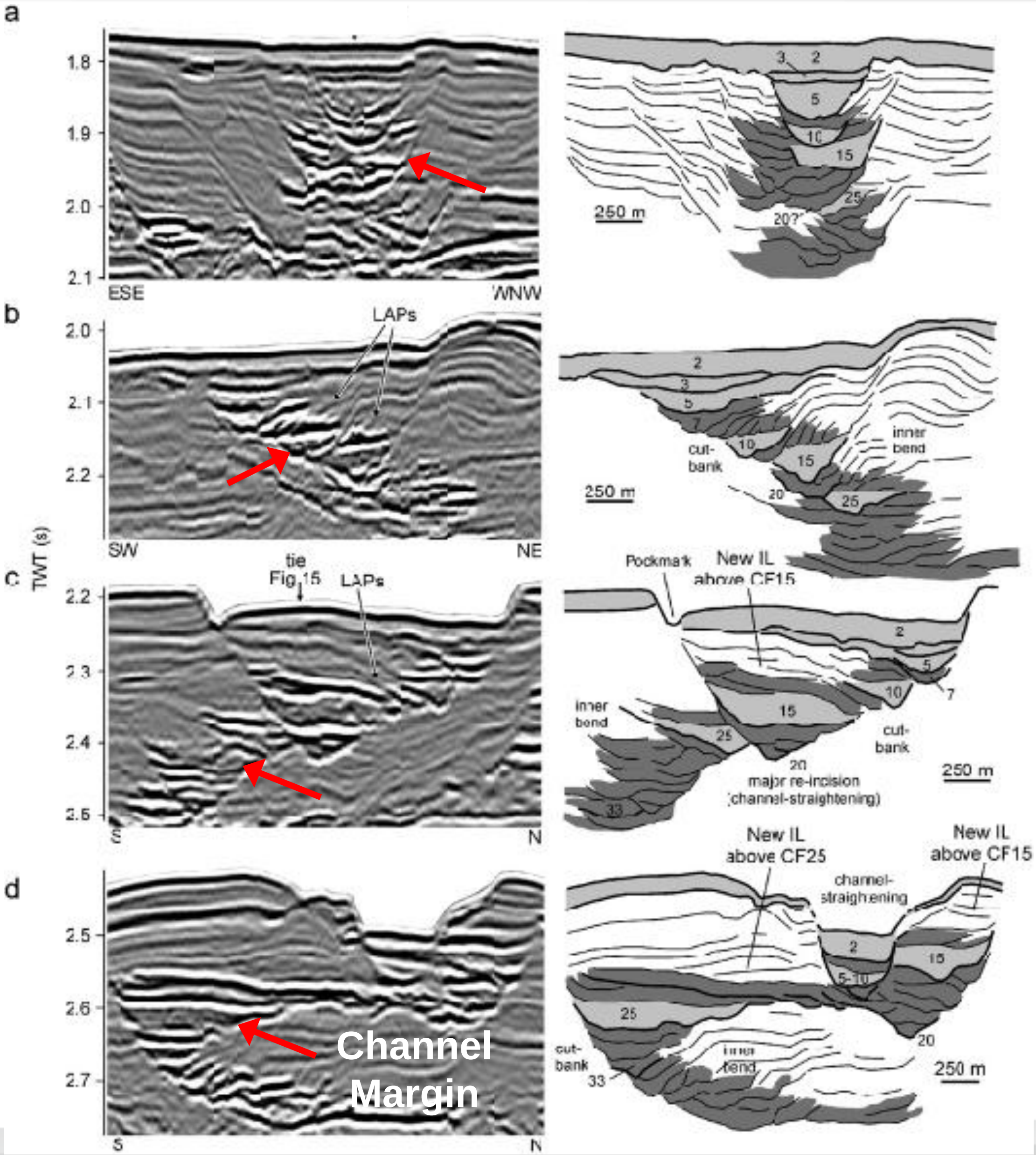


Torres del Paine, Patagonia


Benin Channel, Nigeria
Sediment Waves
Slumps
A
B
C
D
Lifted from Deptuck et al, 2007
Meters
0
2500
5000

Benin Channel, Nigeria

Stacking



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

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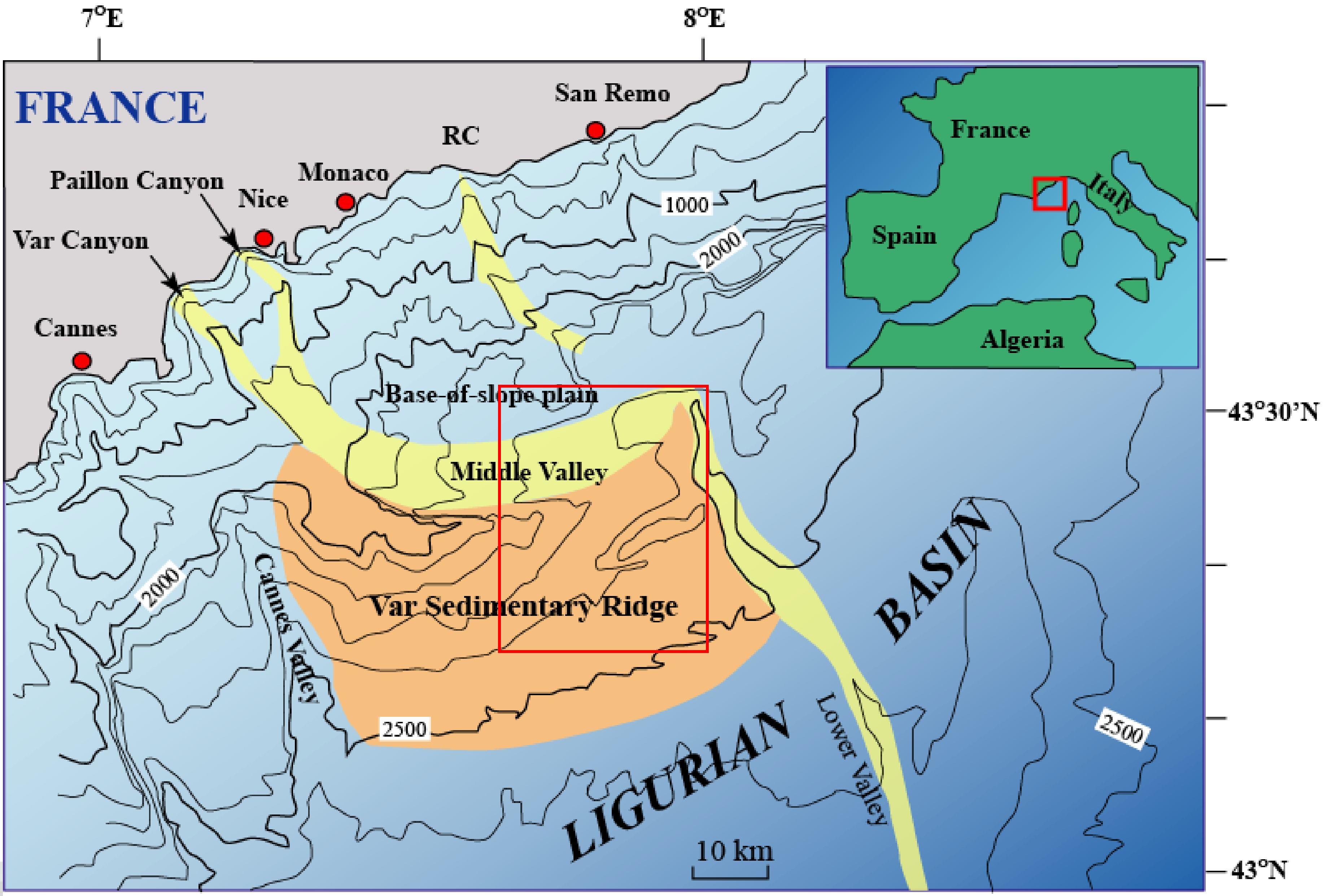
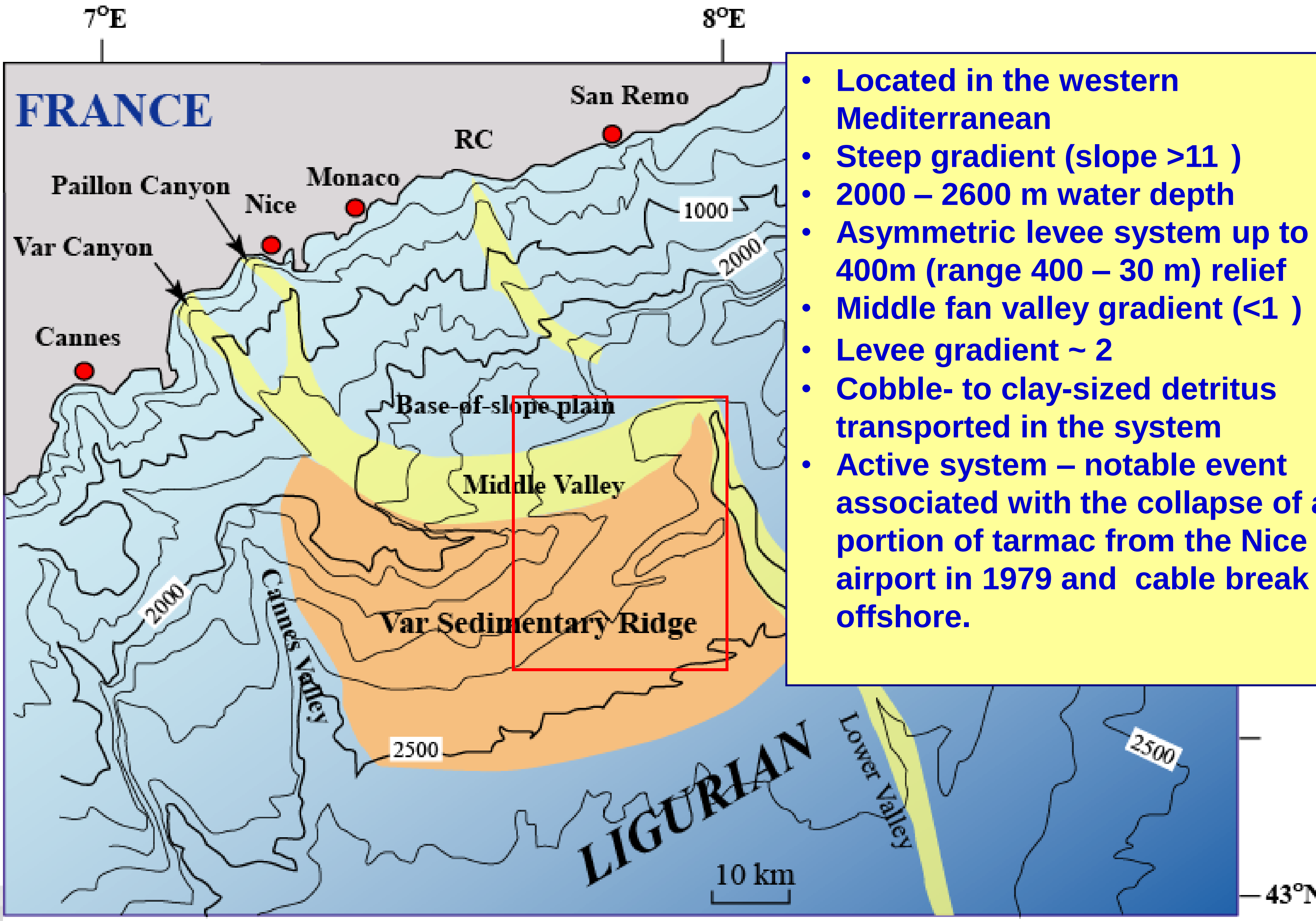
Var System

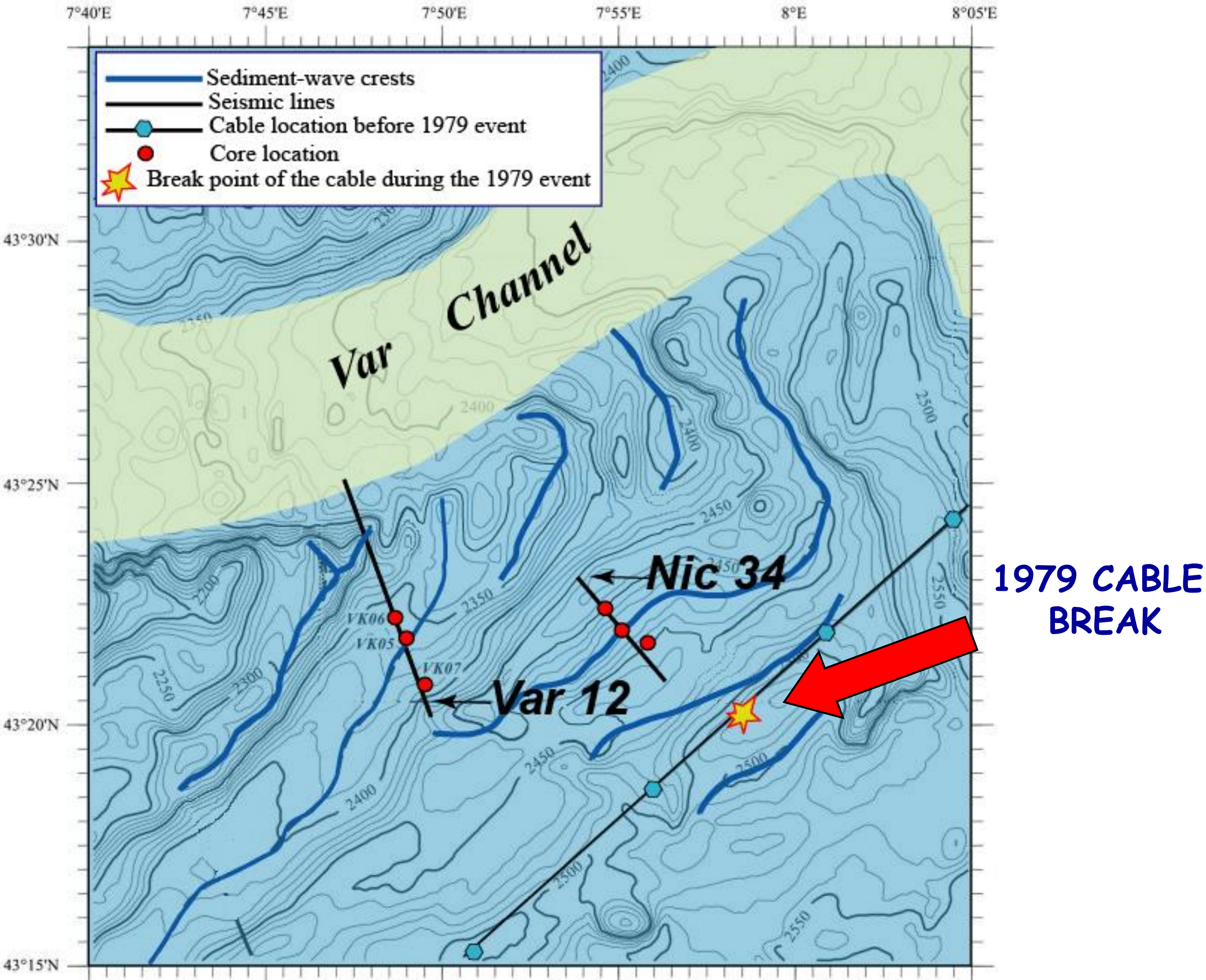
Vital Stats



Var System Vital Stats



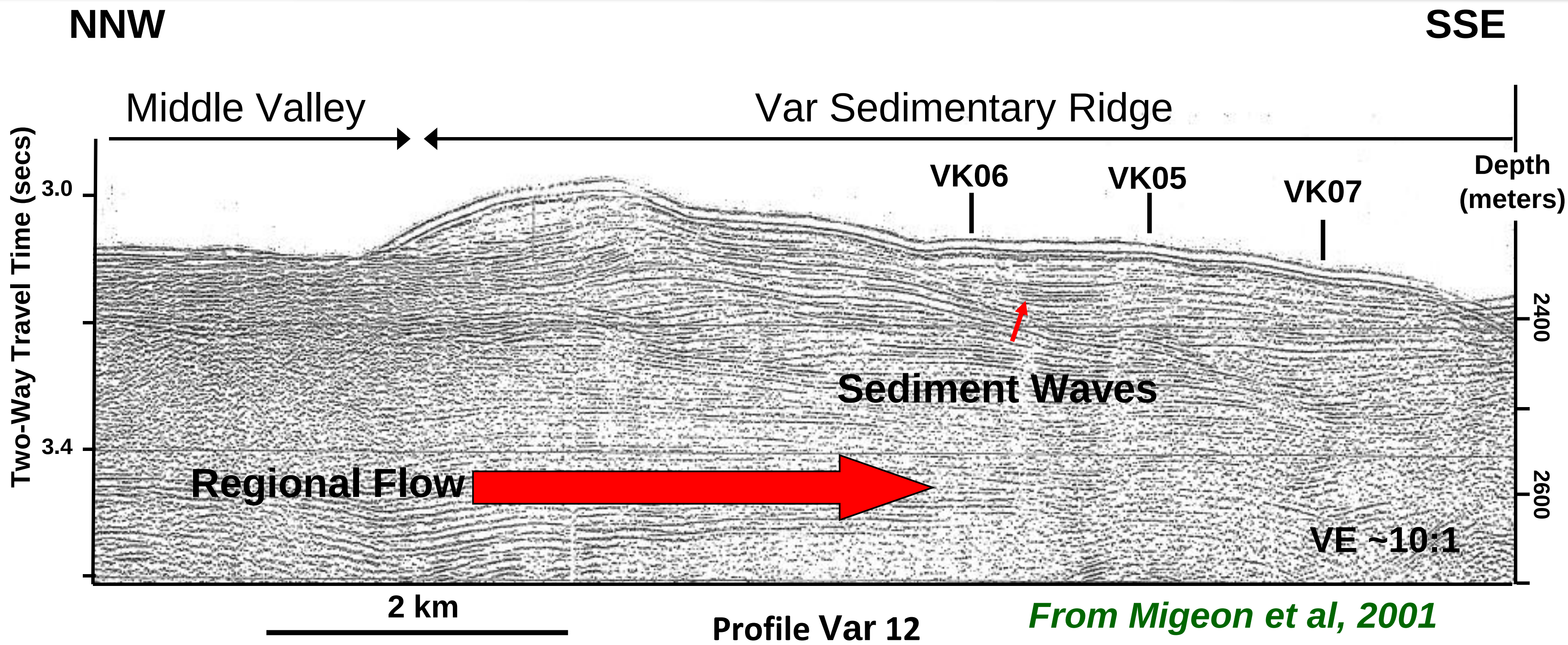
- Located in the western Mediterranean
- Steep gradient (slope >11)
- 2000 – 2600 m water depth
- Asymmetric levee system up to 400m (range 400 – 30 m) relief
- Middle fan valley gradient (<1)
- Levee gradient ~ 2
- Cobble- to clay-sized detritus transported in the system
- Active system – notable event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



Sediment-wave crests
Seismic lines
Cable location before 1979 event
Core location
Break point of the cable during the 1979 event
Var Channel
Nic 34
Var 12
VK06
VK05
VK07
1979 CABLE BREAK
7°40'E
7°45'E
7°50'E
7°55'E
8°E
8°05'E
43°30'N
43°25'N
43°20'N
43°15'N

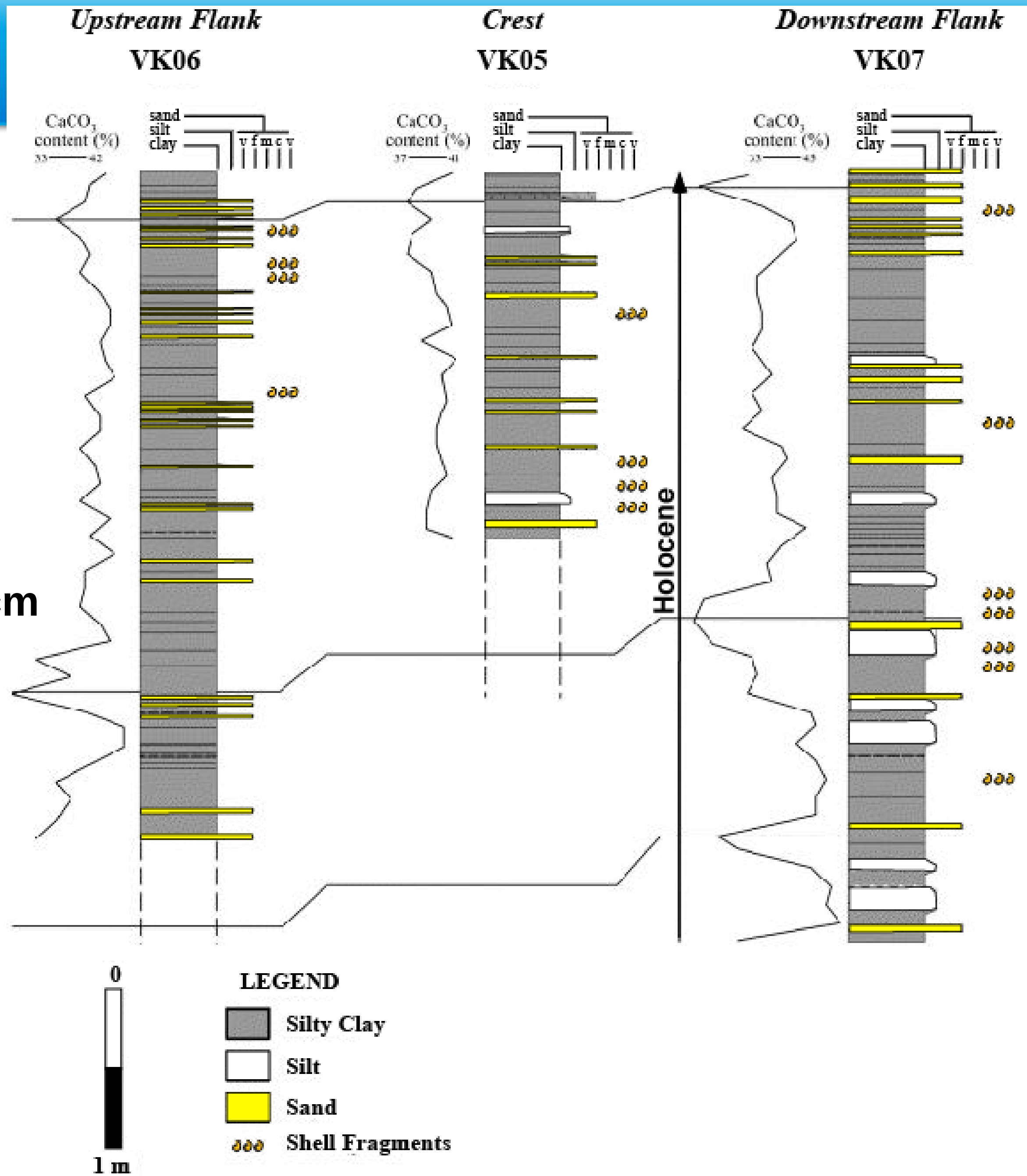
Var Seismic Characteristics

Sediment Waves



- Sediment waves are distinctive architectural features of the levee
- Sediment wave are more prominent with aggradation of channel/levee system
- Variable lithology

Core Lithofacies

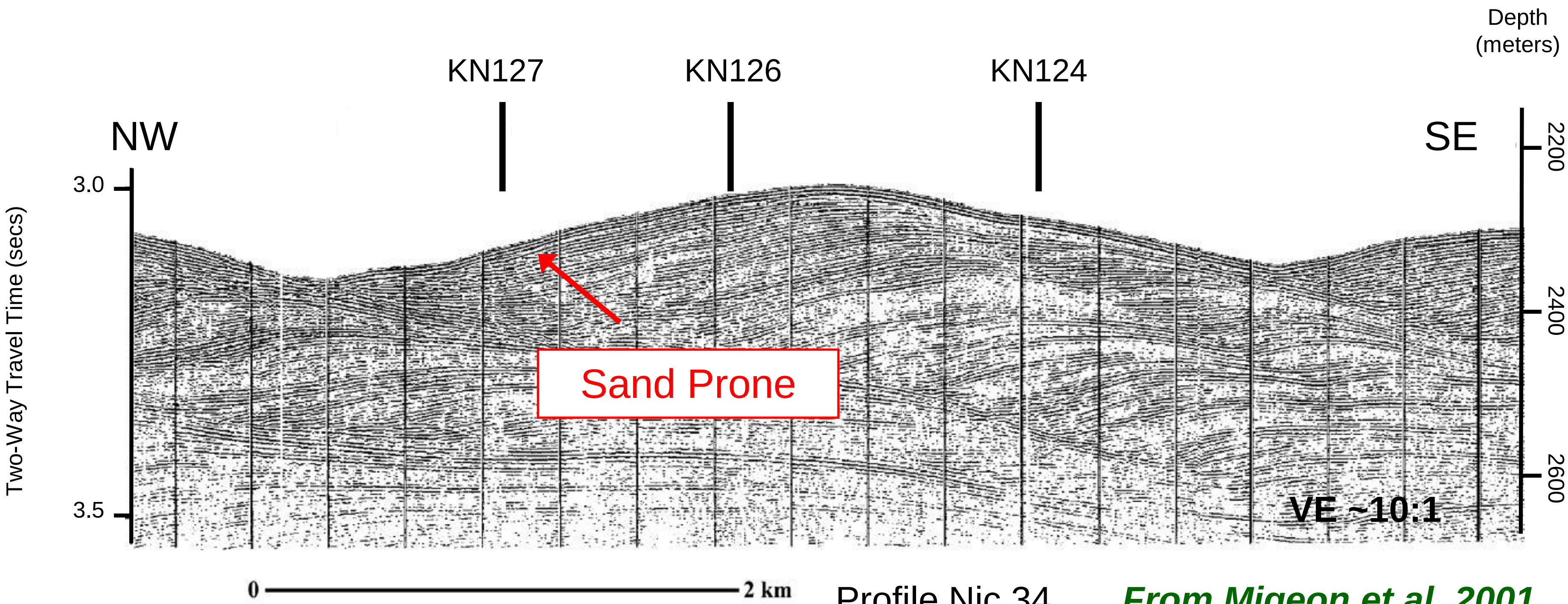


Sediment Wave Lithofacies

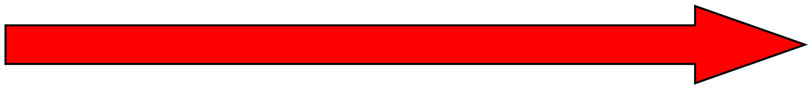
- Symmetrical waves are mud-prone
- Beds are relatively thin <10 cm
- Coarsest material is fine-grained (.012 mm)

From Migeon et al, 2001

Var Seismic Characteristics Sediment Waves



Profile Nic 34 *From Migeon et al, 2001*



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

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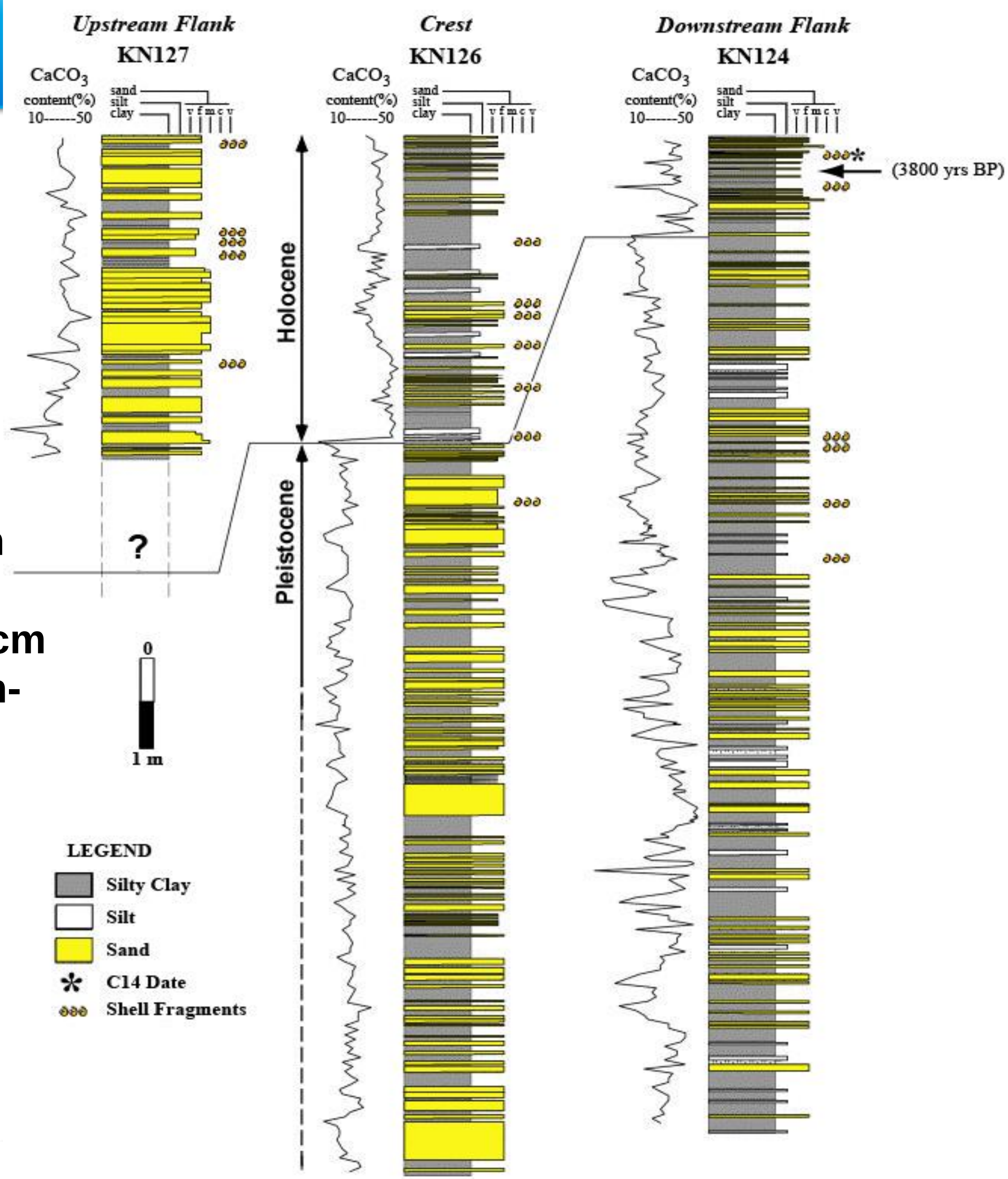
Core Lithofacies

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

Silla Syncline, Patagonia, Chile

Magallenes Basin Stratigraphy

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

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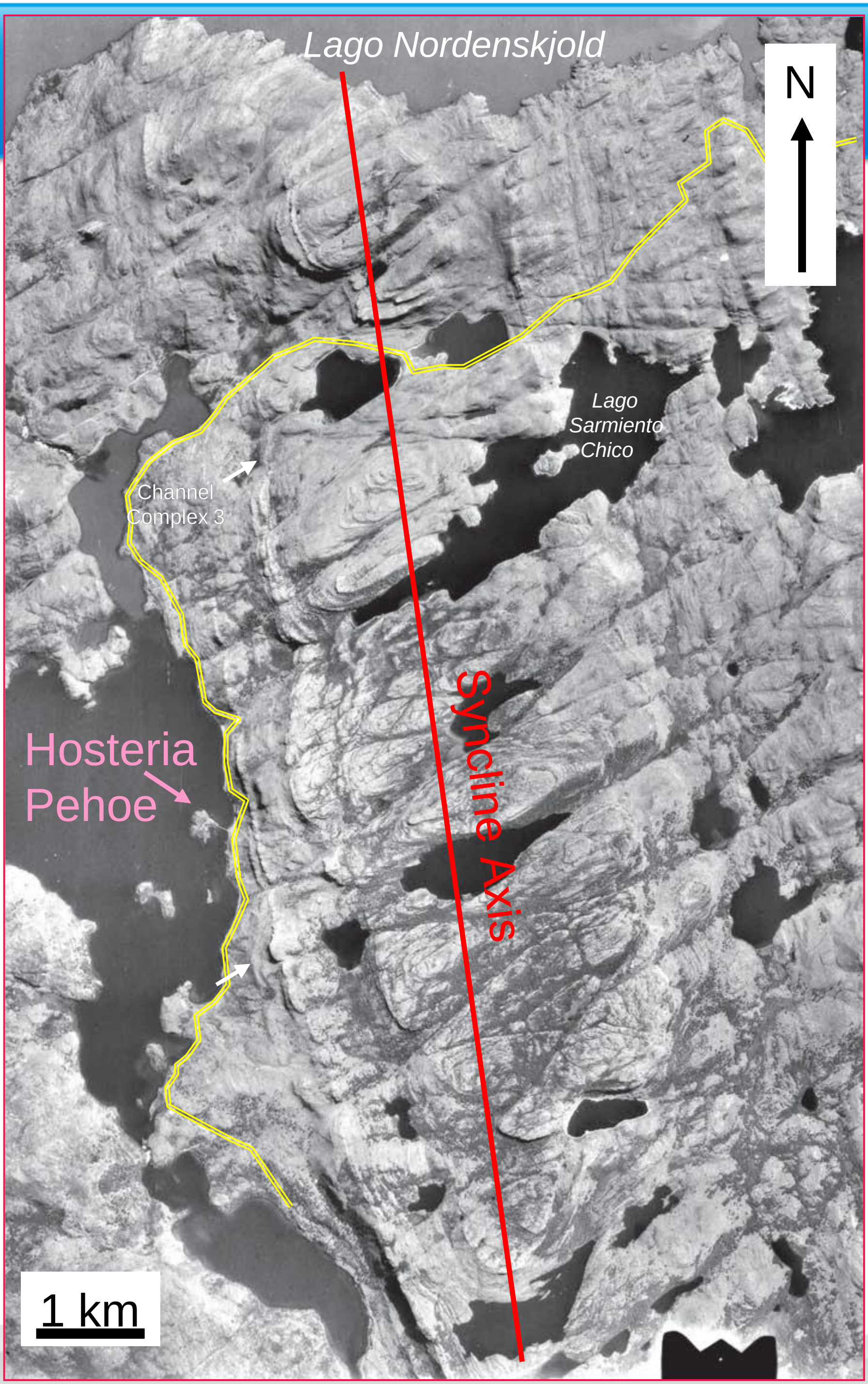
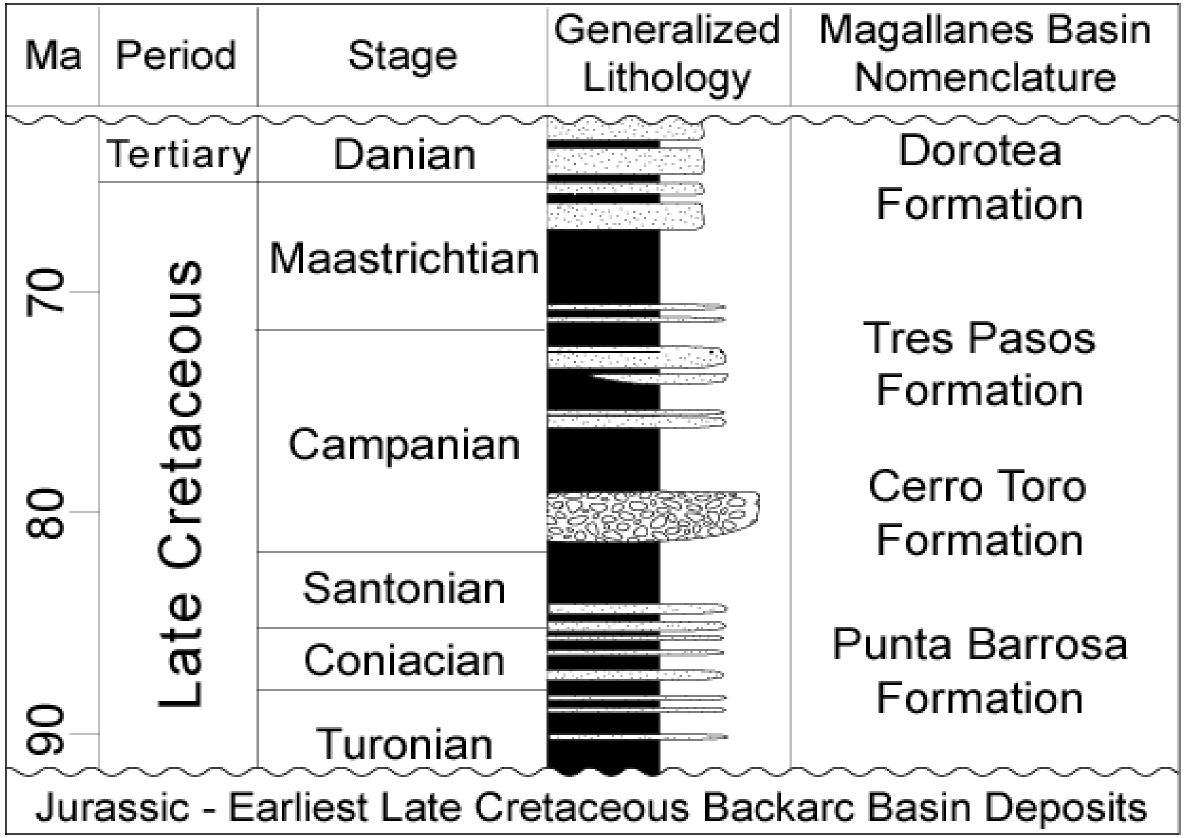


Magallenes Basin

Stratigraphy



(adapted from Natland et al., 1974; Wilson, 1991; and Fildani et al., 2003)

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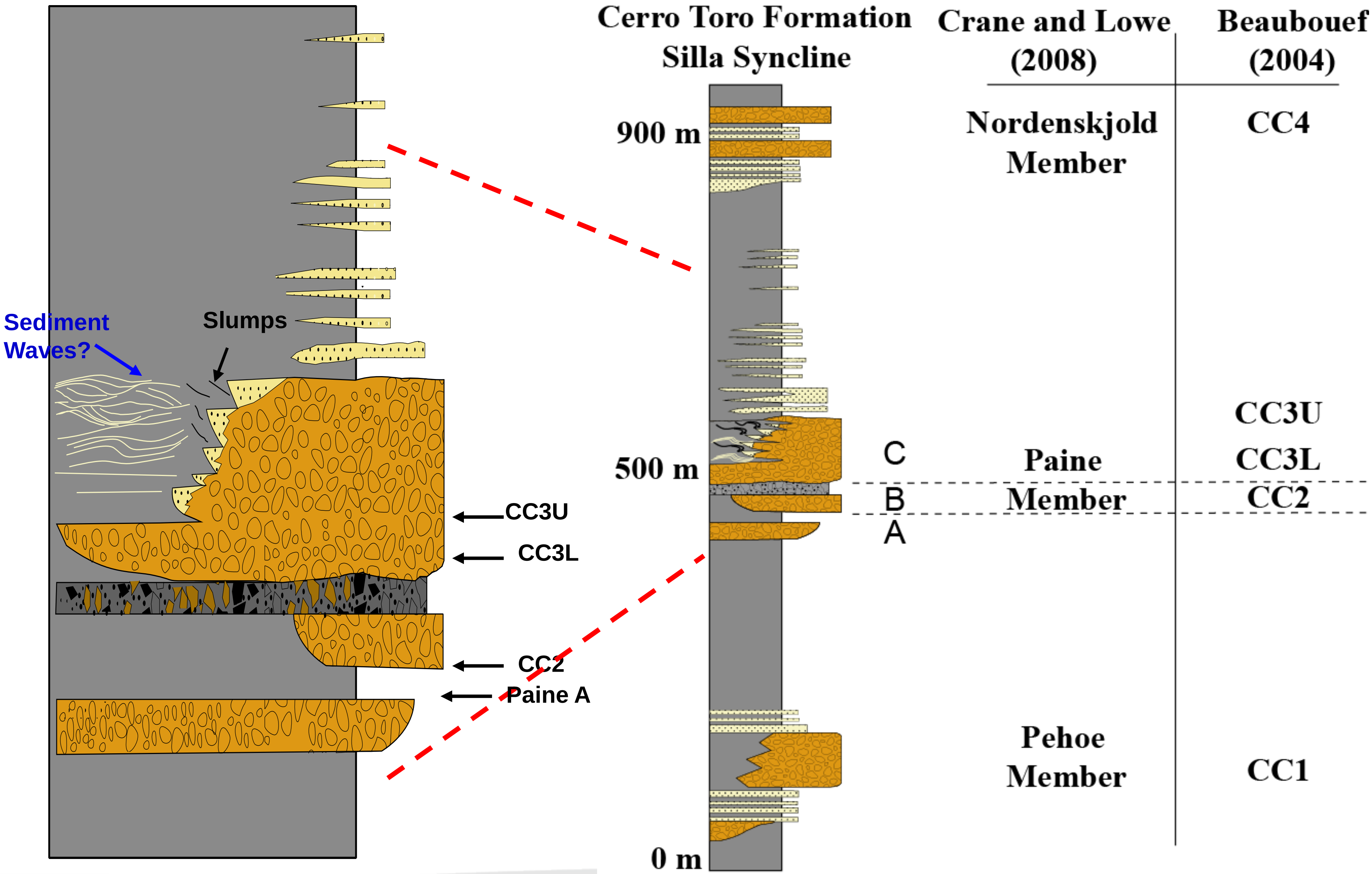
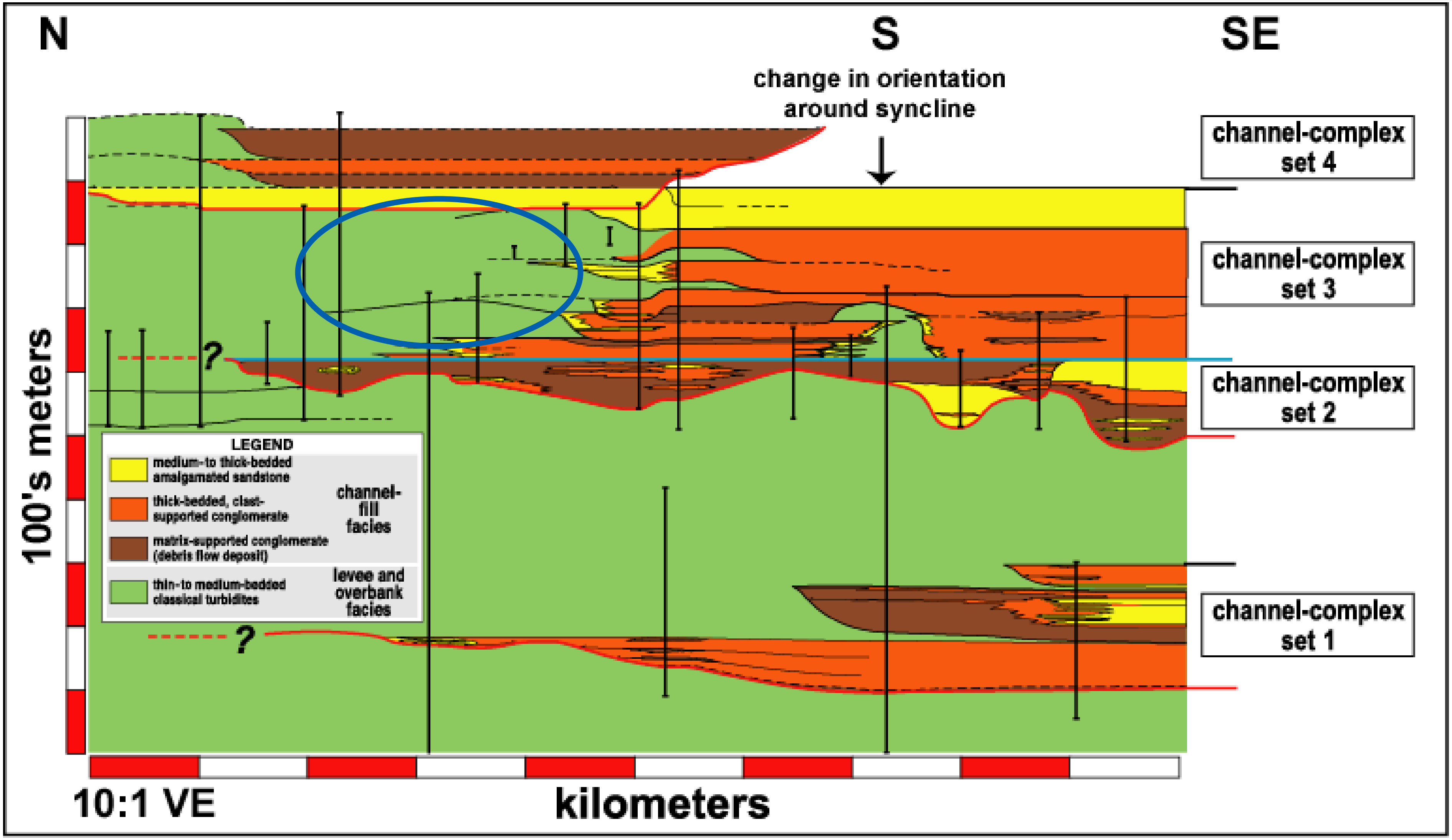
Cerro Toro Lithostratigraphy



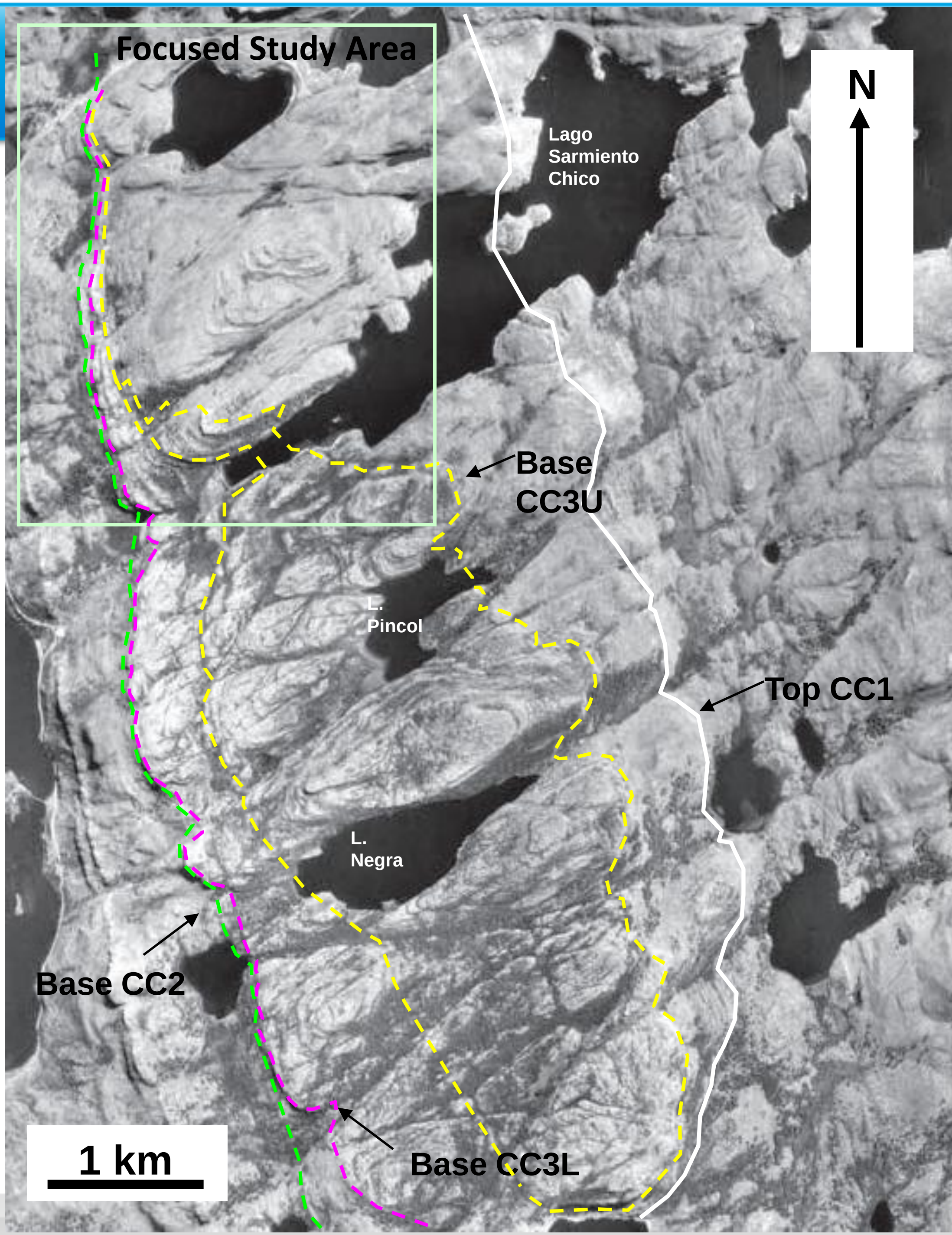
Modified from Crane and Lowe (2008)

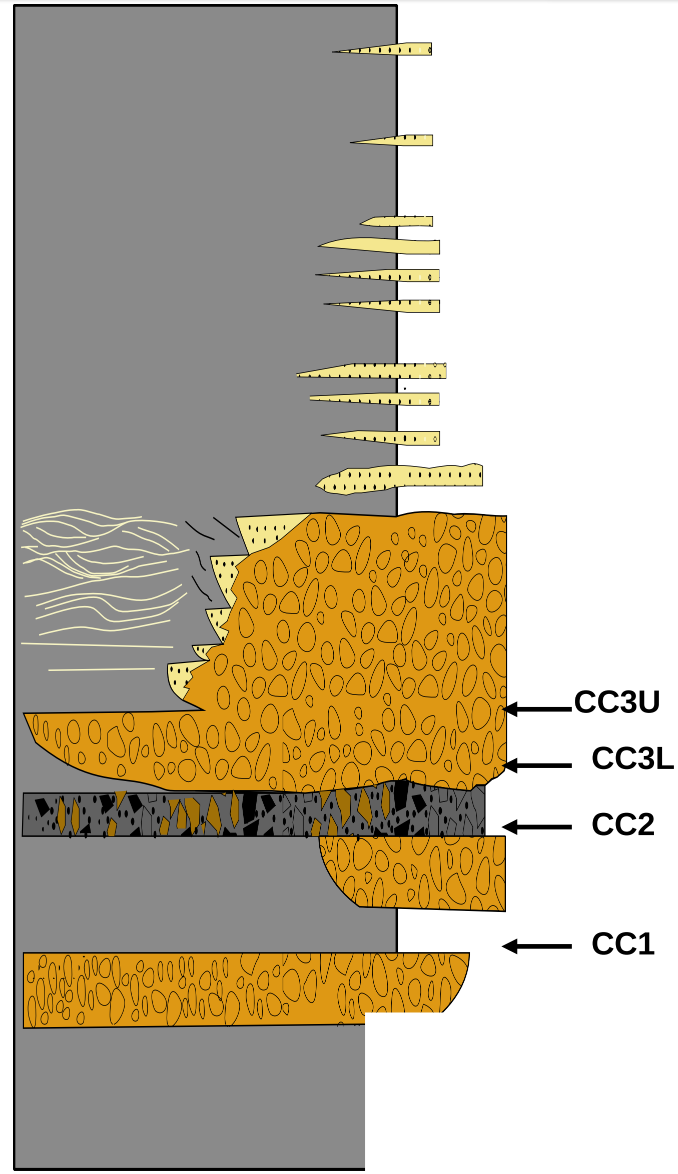
Facies and Architectural Variance



Beaubouef (2004)

Stratigraphy





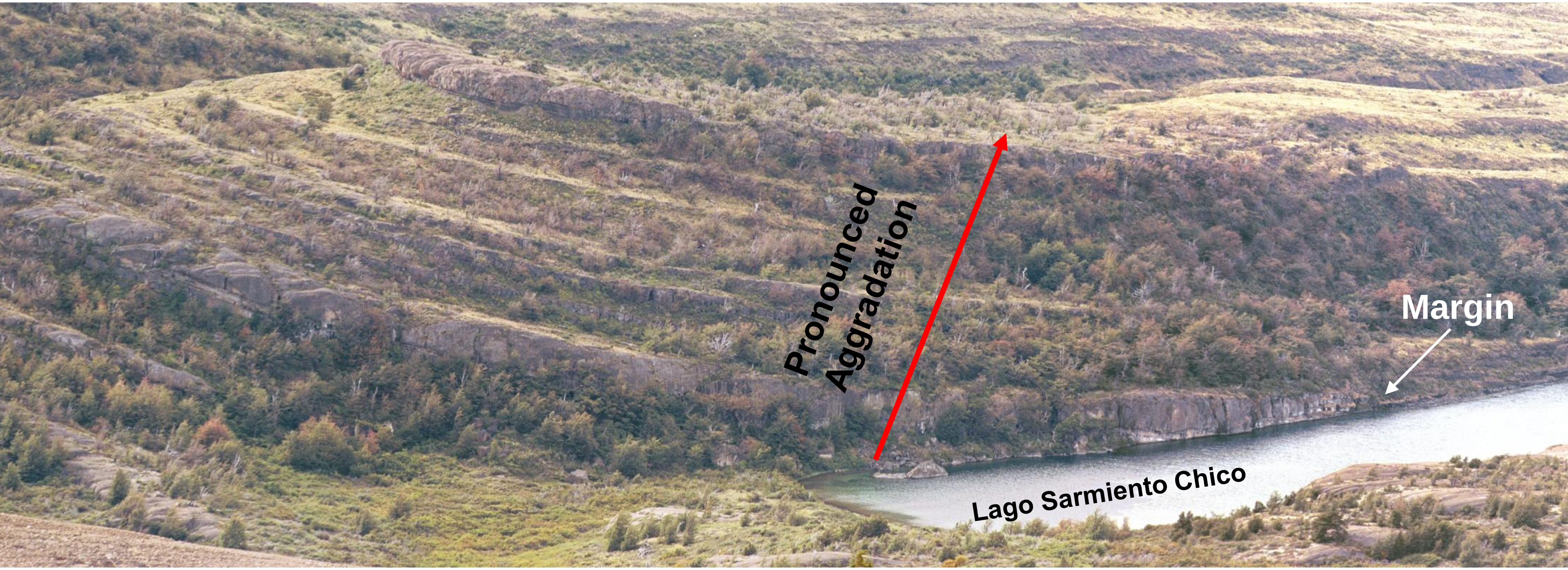
Modified from Crane and Lowe (2008)

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)

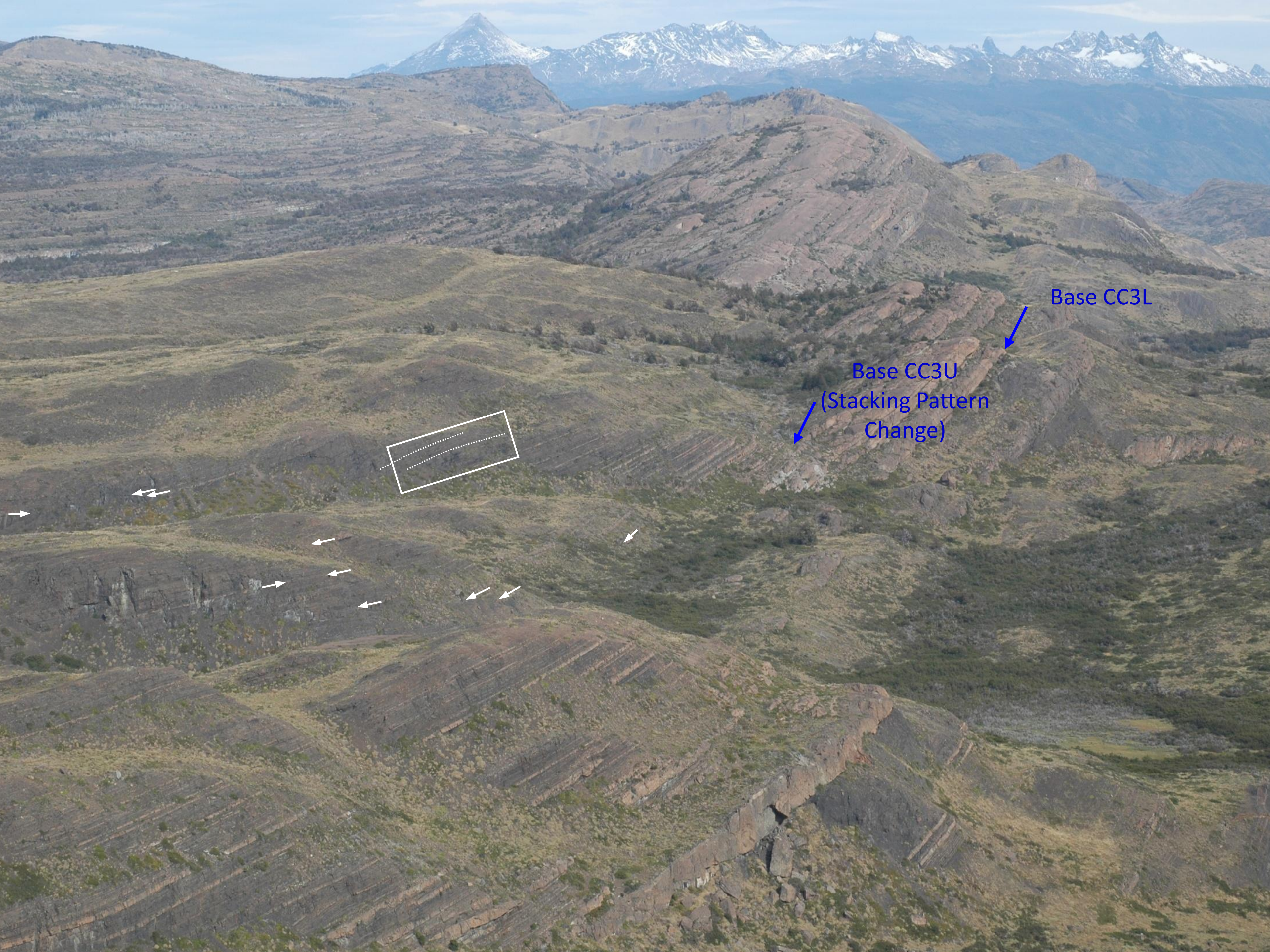
- Pinch out along the north/south shore of Lago Sarmiento Chico
- Channels stacking is aggradational
- Channel margins are localized
- Channel aggradation associated with aggradation of adjacent mudstone facies

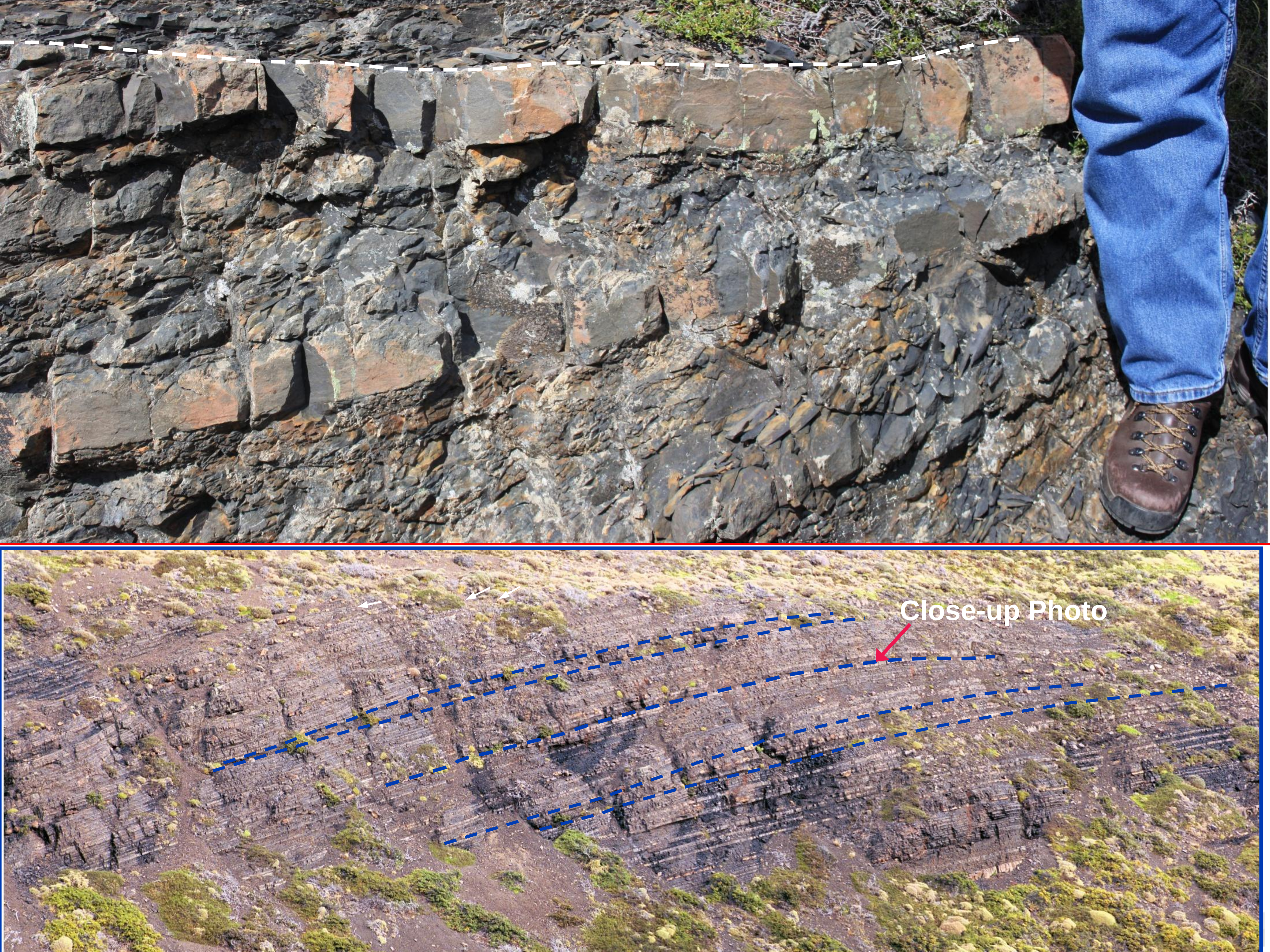


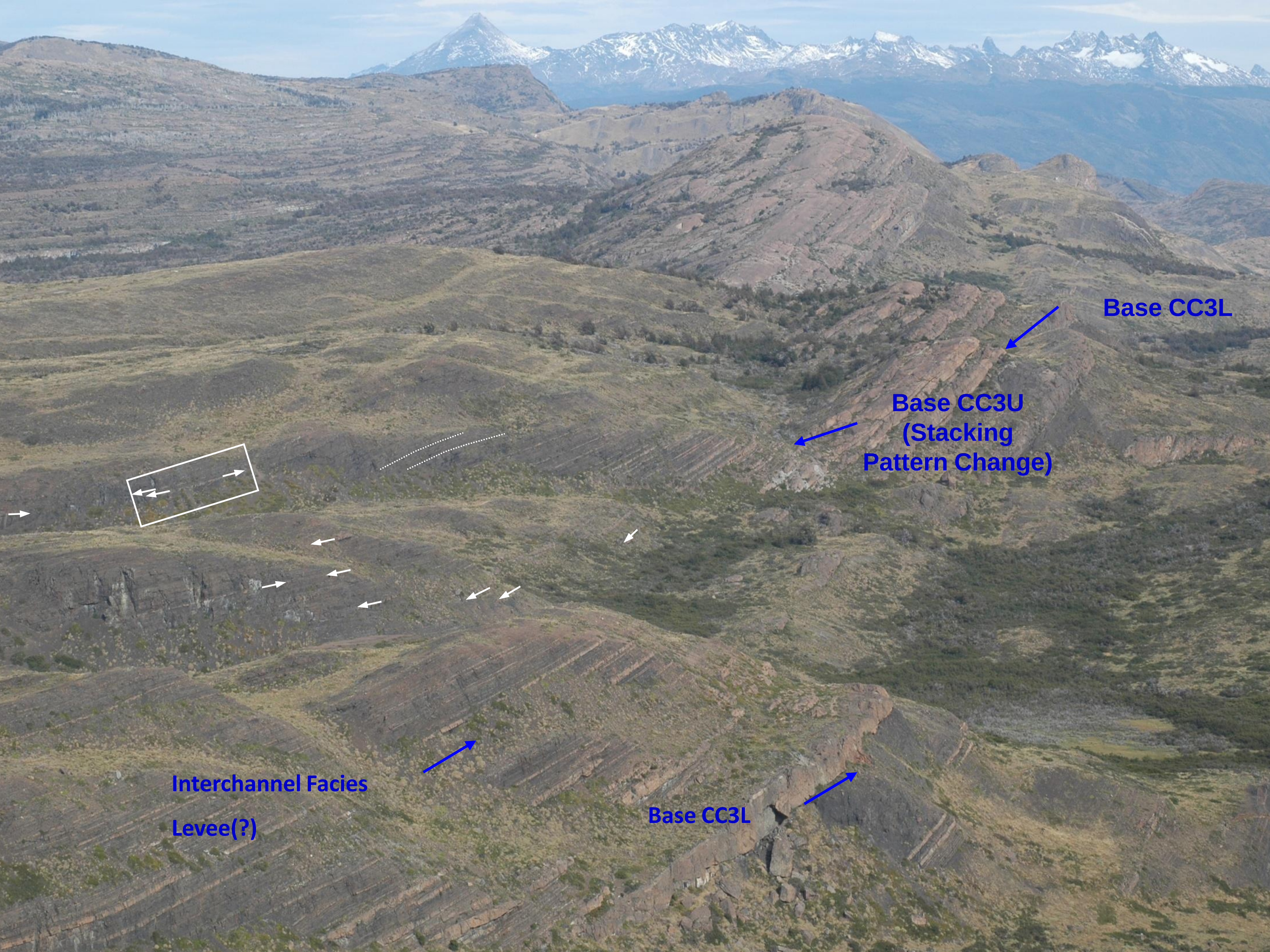
Cerro Toro

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)


Close-up Photo


Base CC3L
Base CC3U
(Stacking
Pattern Change)
Interchannel Facies
Levee(?)
Base CC3L

Cerro Toro

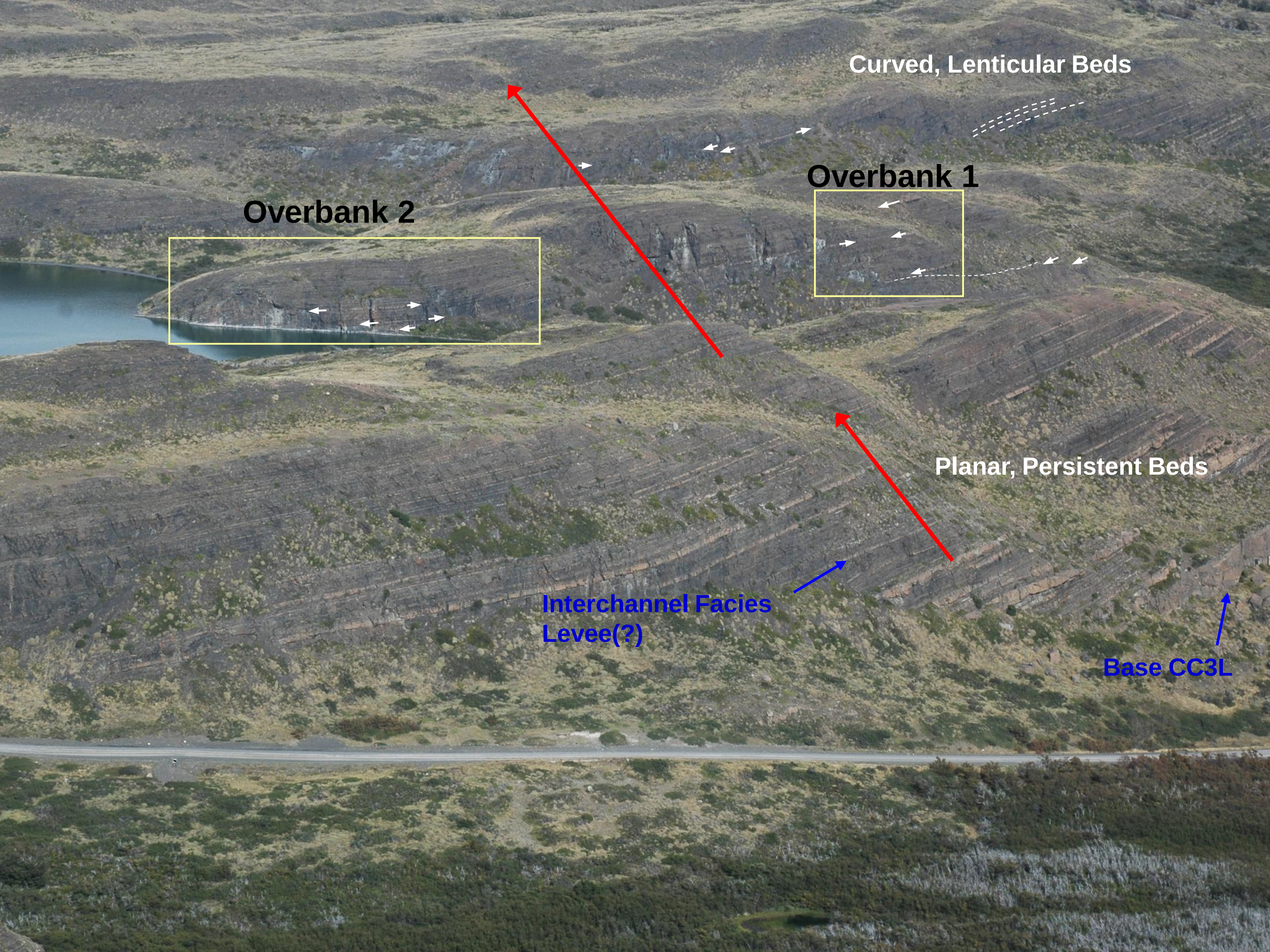
Lithofacies

Thin-bedded siltstone (Tde)

Lenticular Sandstone
- **Medium grained**
- **Abundant rip up clasts**
- **Inclined lamination**

Cerro Toro

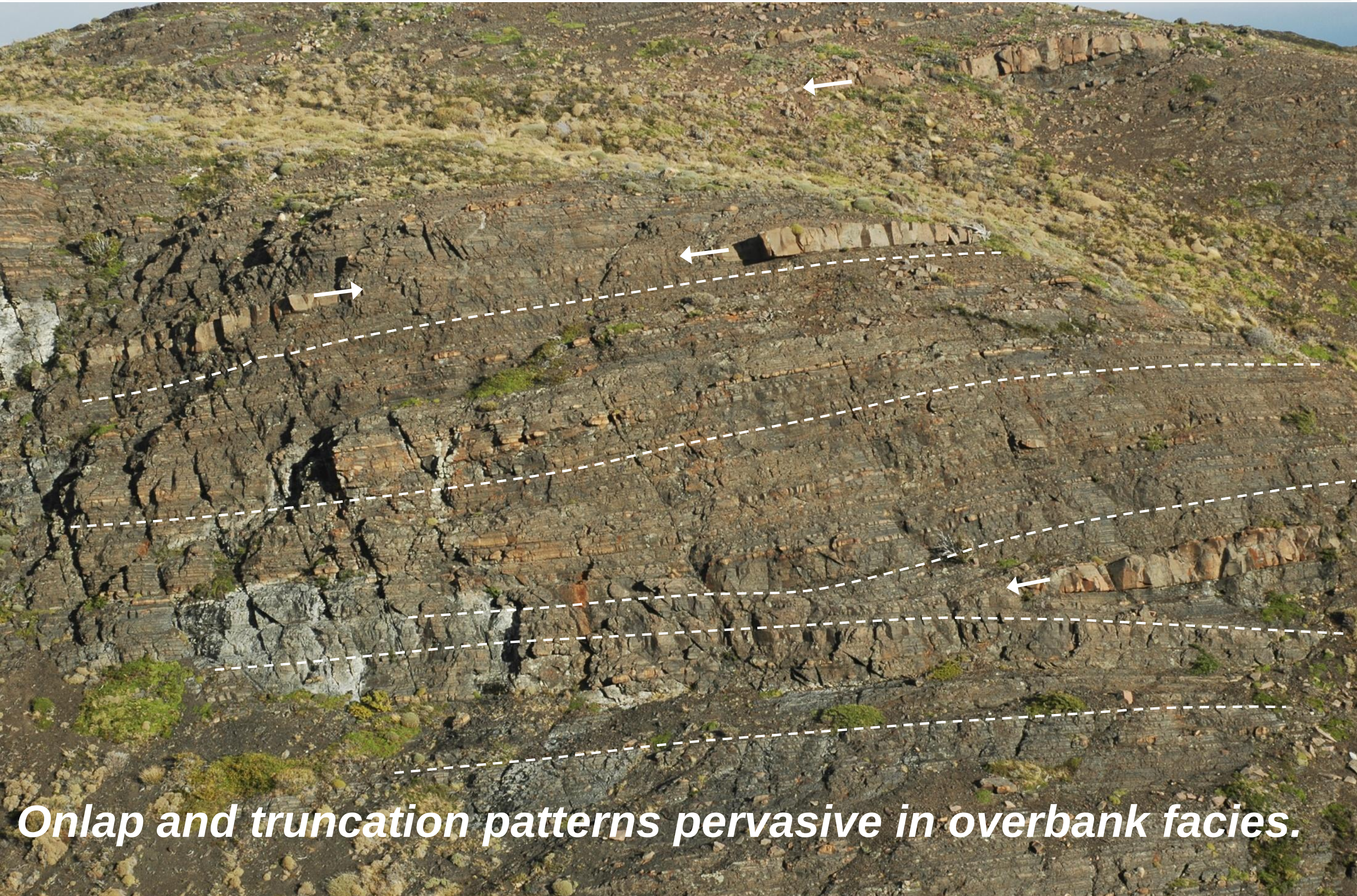
Lithofacies



Curved, Lenticular Beds
Overbank 1
Overbank 2
Planar, Persistent Beds
Interchannel Facies
Levee(?)
Base CC3L

Overbank Facies - 1

Stratal Patterns

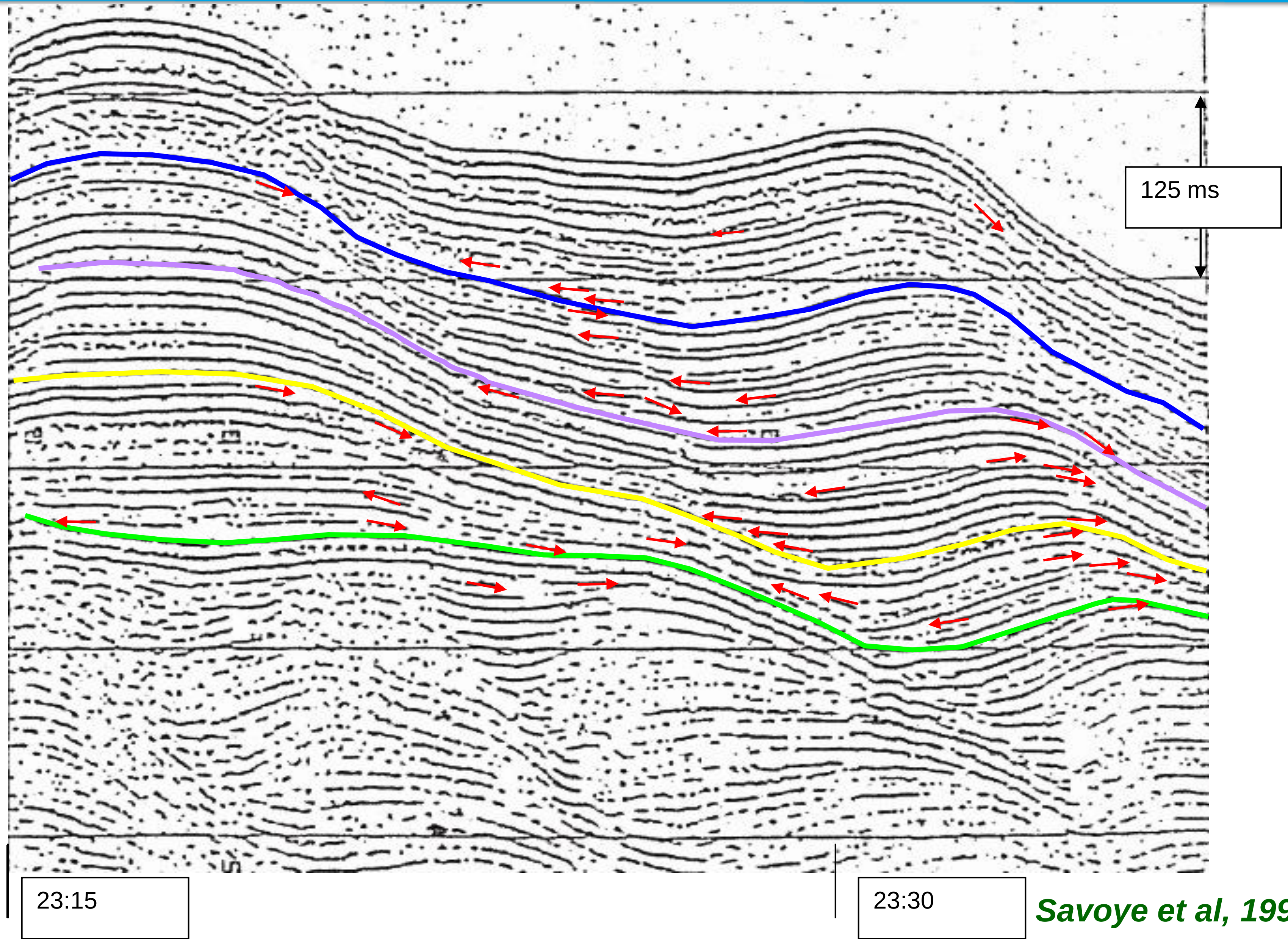


Onlap and truncation patterns pervasive in overbank facies.

Overbank Facies - 2

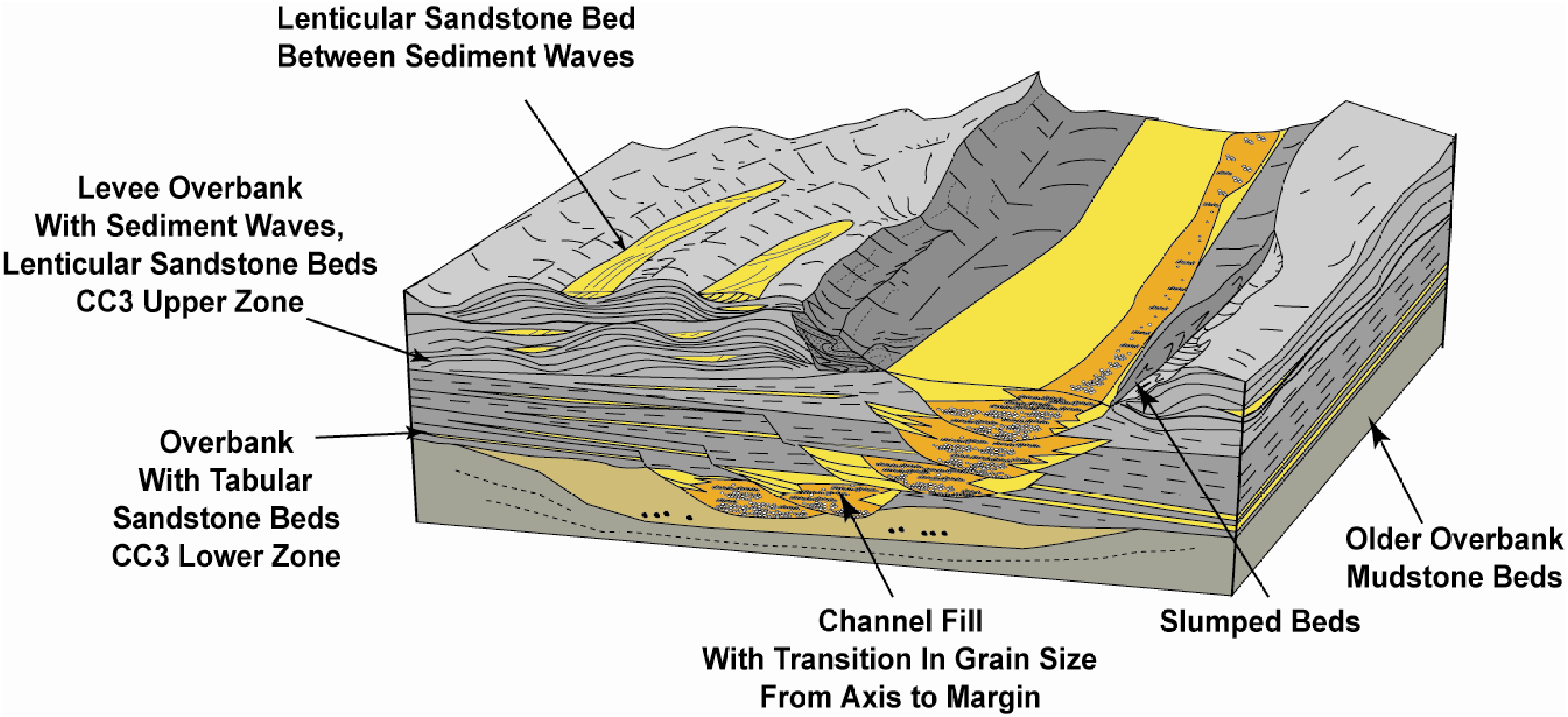

1m

Var Ridge Levee Architecture



Savoye et al, 1993

Cerro Toro Model Channel/Levee System



- ***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)*

Silla Syncline, Patagonia, Chile