Offshore Hikurangi Margin: Tectonic deformation - sedimentation - climate interactions

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NIWA
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Outline

1. Summarise Hikurangi Margin geomorphology and tectonic structure

2. Relative roles of control parameters on active forearc basins

3. Role of submarine canyons

4. Input sequence: Hikurangi plateau and trough

Subduction margin sedimentary basins and tectonic geomorphology

Climate
* Precipitation rate to catchment (rainfall, snow)
* Extreme events

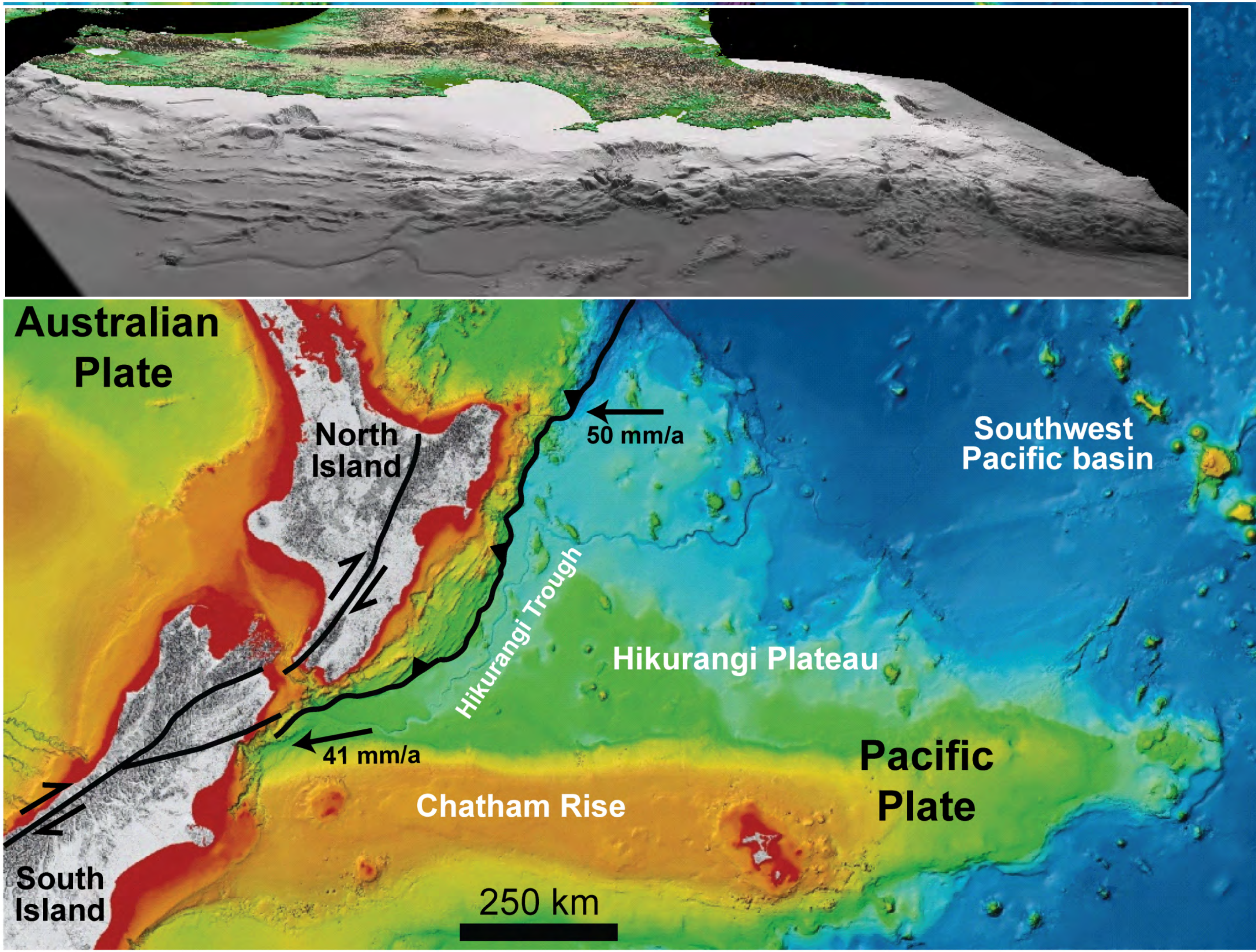
Sedimentary Responses to Climate & Sea-level Changes
* Sediment supply & dispersal / bypassing
* Sequence architecture

Terrestrial Sediment Supply
* Uplift rate
* Catchment lithology
* Erosion rate and sediment yield
* Oceanography / wave climate/ sediment dispersal
* Arc volcanism
* Earthquake ground shaking

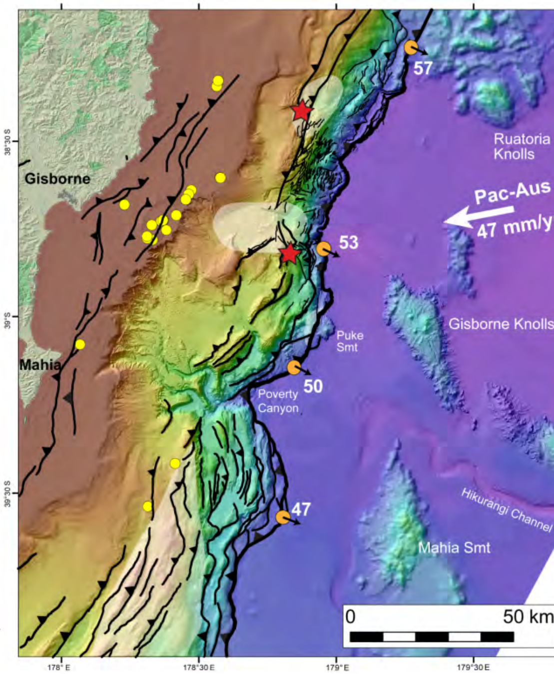
Upper Plate Wedge
* Frontal accretion
* Underplating
* Tectonic erosion (frontal / basal)
* Uplift / subsidence
* Structural inheritance
* Structural evolution
* Taper / tectonic stability
* Slope stability

Tectonic parameters
* Plate convergence rate
* Plate convergence obliquity
* Interplate coupling
* Seismicity (frequency / magnitude)
* Geological strain partitioning

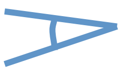
Subducting Plate
* Thickness, age, strength
* Surface roughness / relief (grabens, horst, seamounts, ridges)
* Pelagic sediment cover
* Thickness of Trench-fill turbidites


Australian Plate
North Island
South Island
50 mm/a
41 mm/a
Southwest Pacific basin
Hikurangi Trough
Hikurangi Plateau
Chatham Rise
Pacific Plate
250 km

Steep northern margin with subducting seamounts

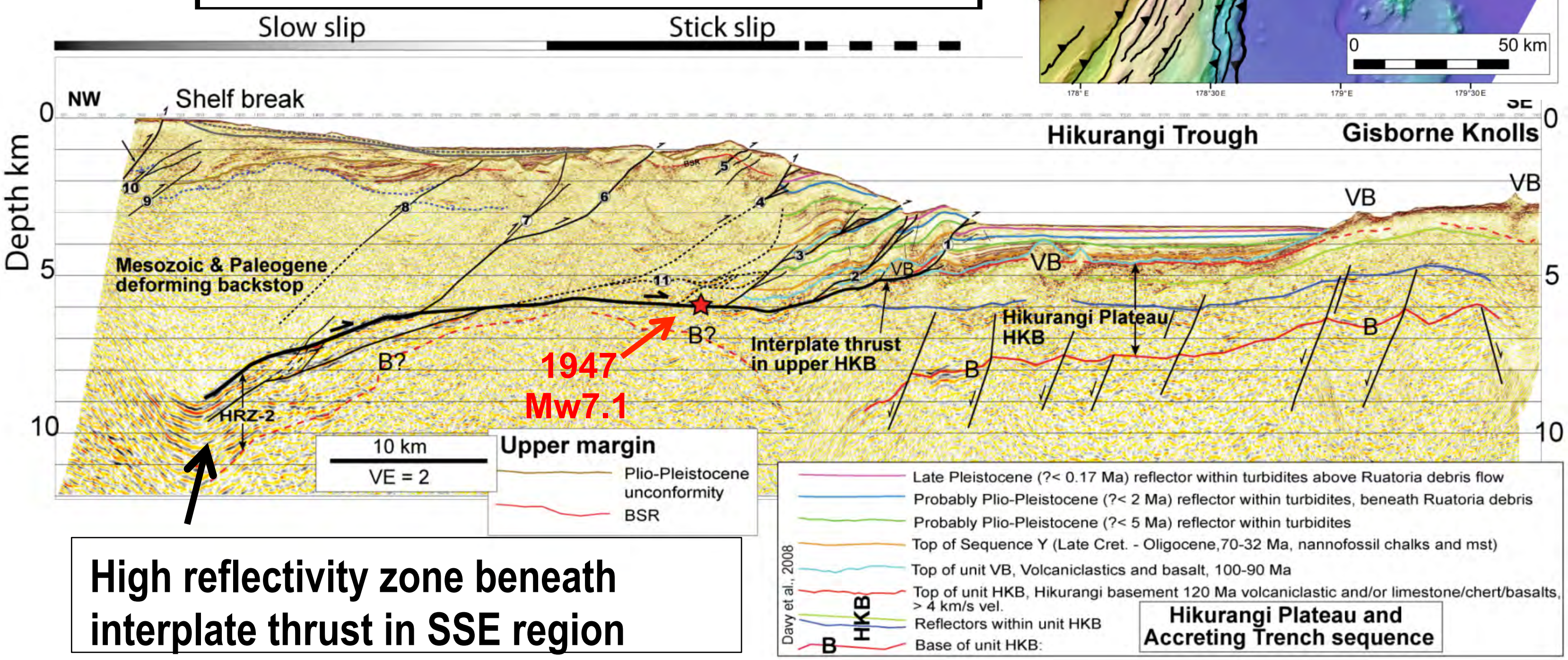


Wedge taper



Ramp-flat-ramp interface geometry

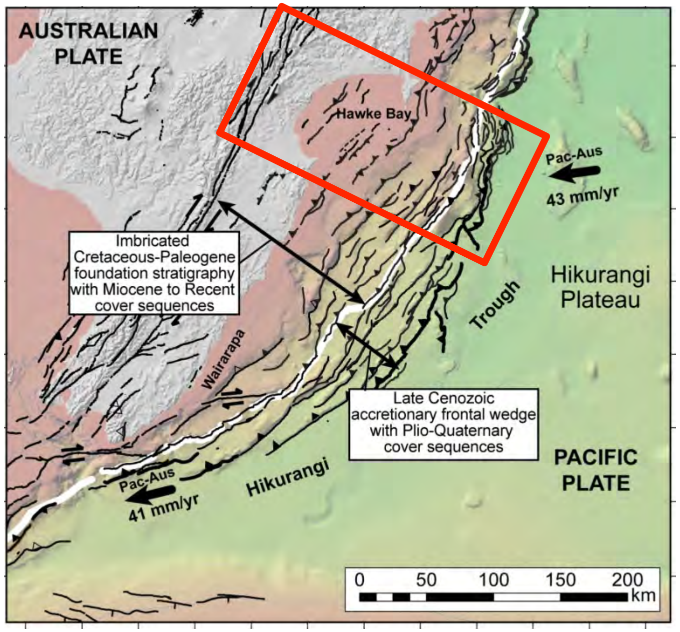
~9-10° → | ← ~0-3° → ← ~15° →

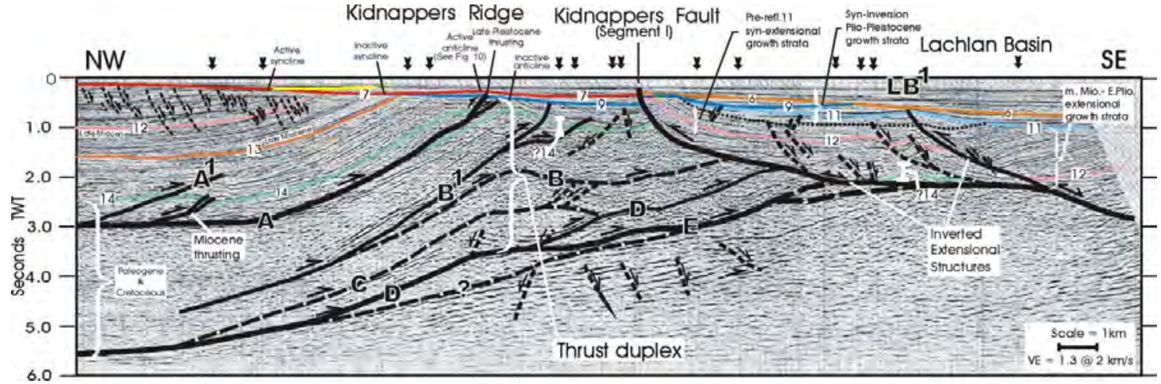


High reflectivity zone beneath interplate thrust in SSE region

MCS line CM05 # 4

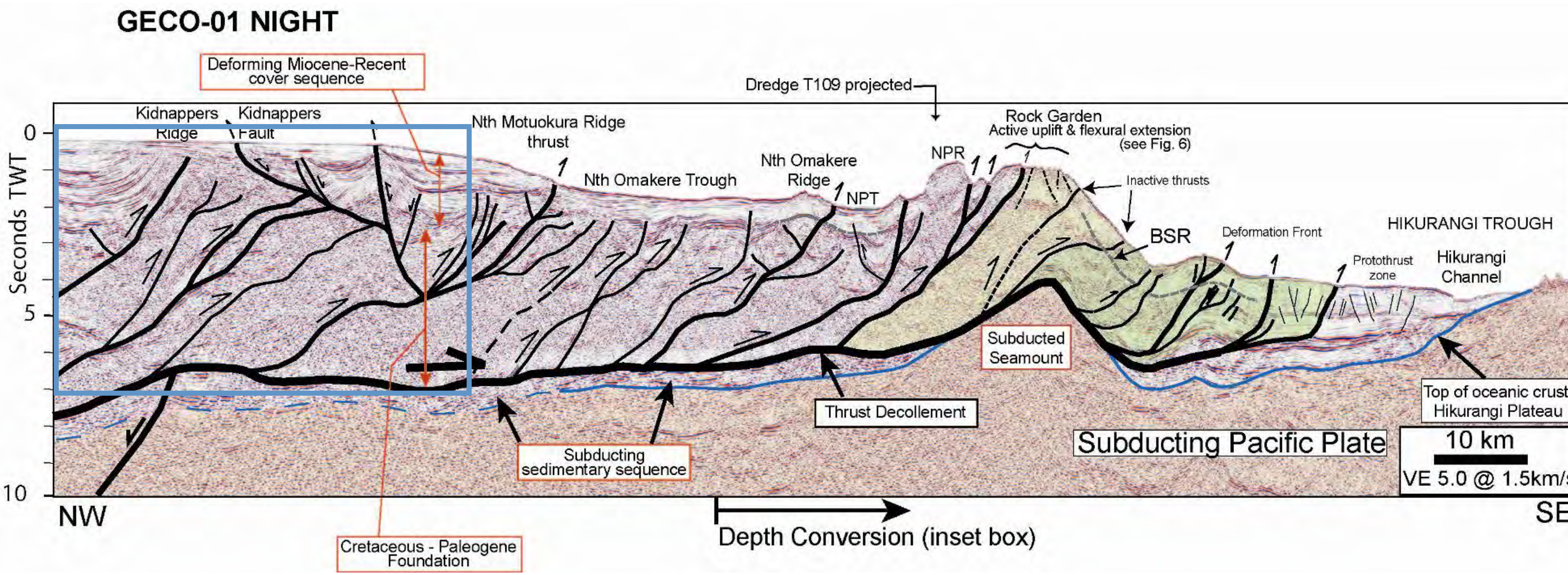
Barnes et al, unpubl



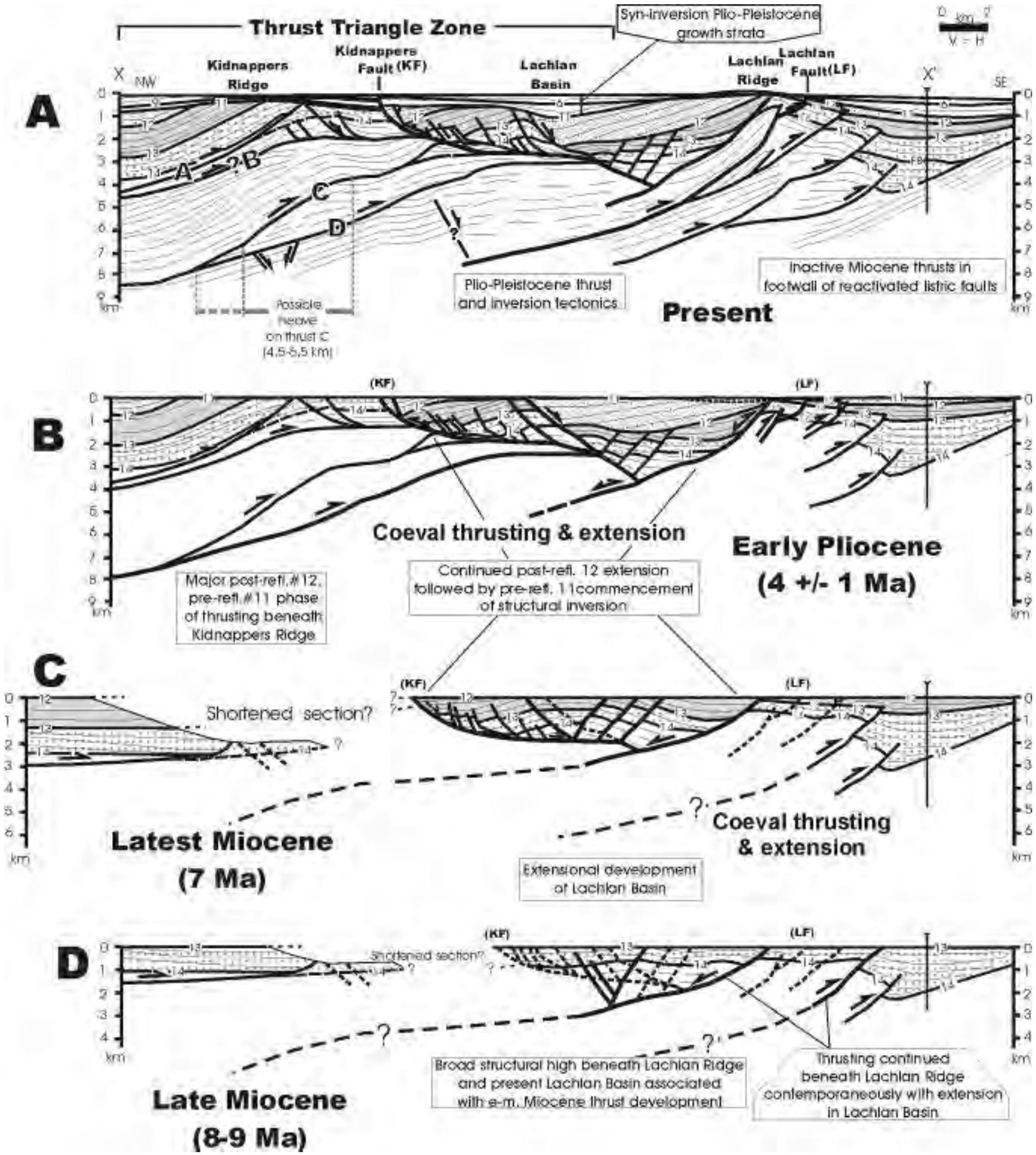


Polyphase thrust systems & Inversion tectonics

Barnes et al., 2002 Barnes & Nicol 2004

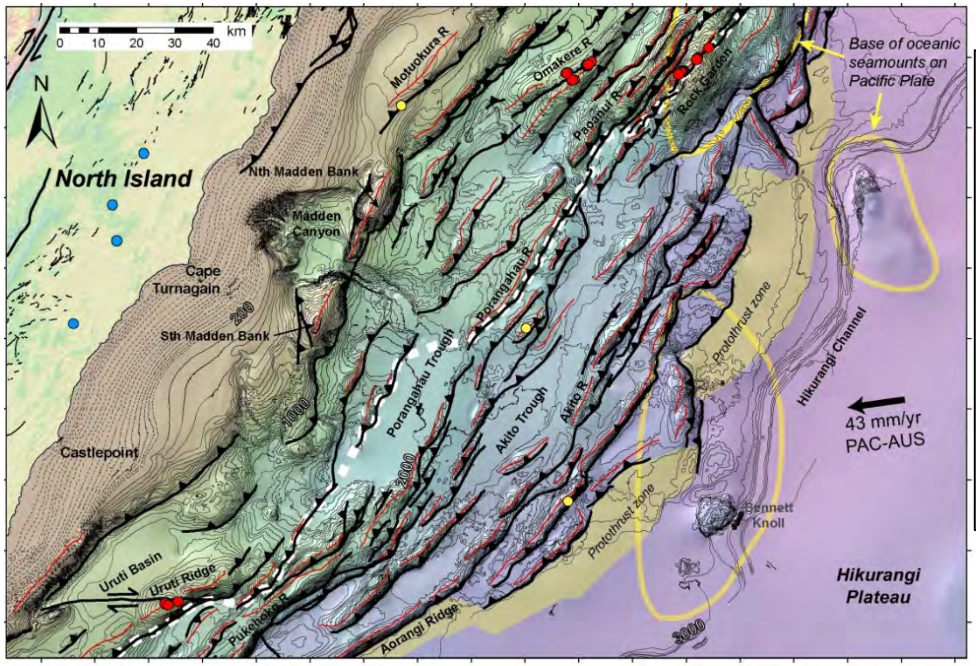


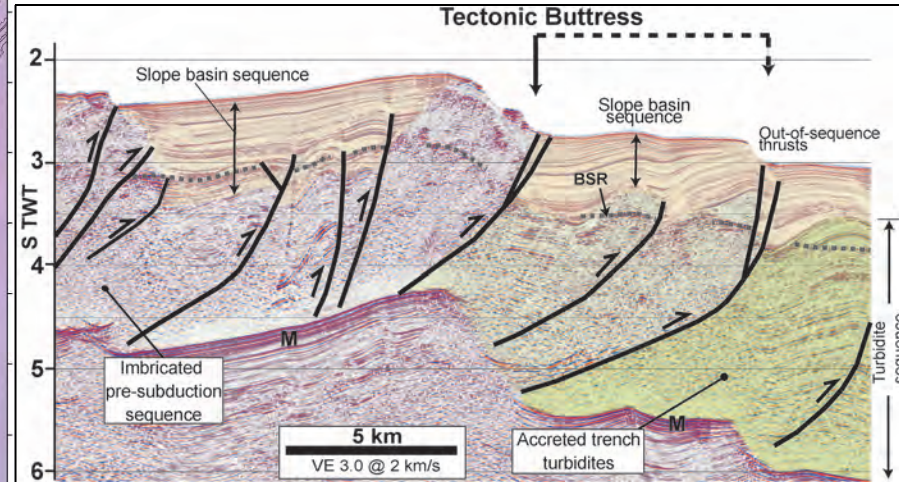
Pecher et al. 2004, 2005 Henrys et al. 2006



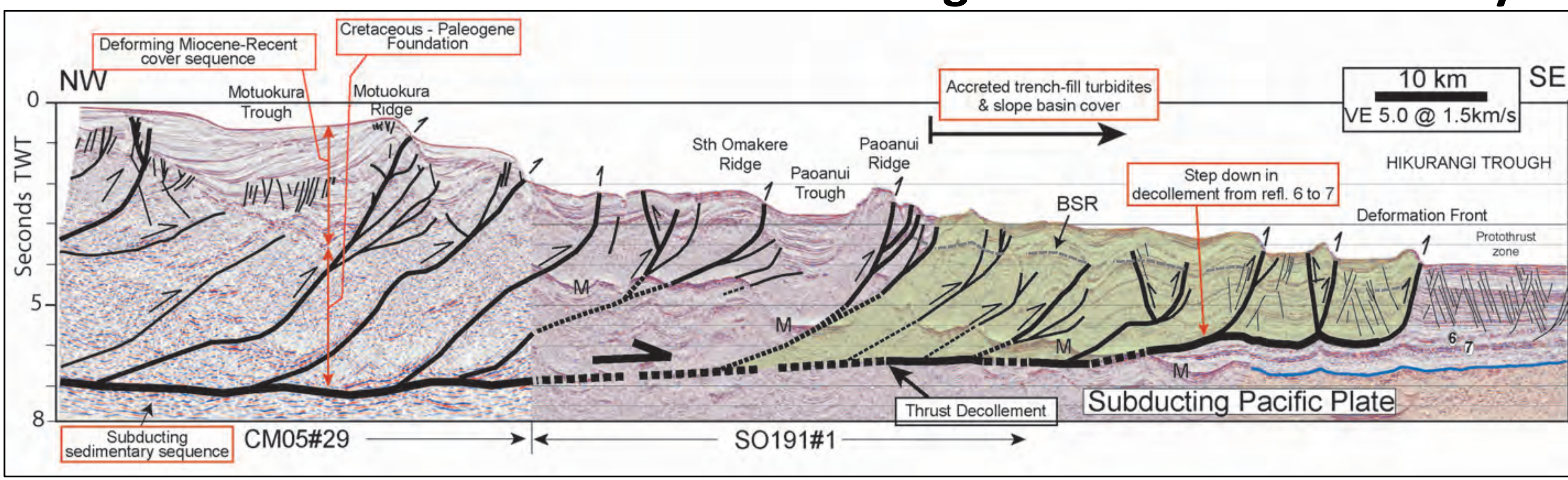
Forearc basin structure analyses indicate polyphase deformation, and reactivated faulting

Barnes et al., 2002   Barnes & Nicol 2004



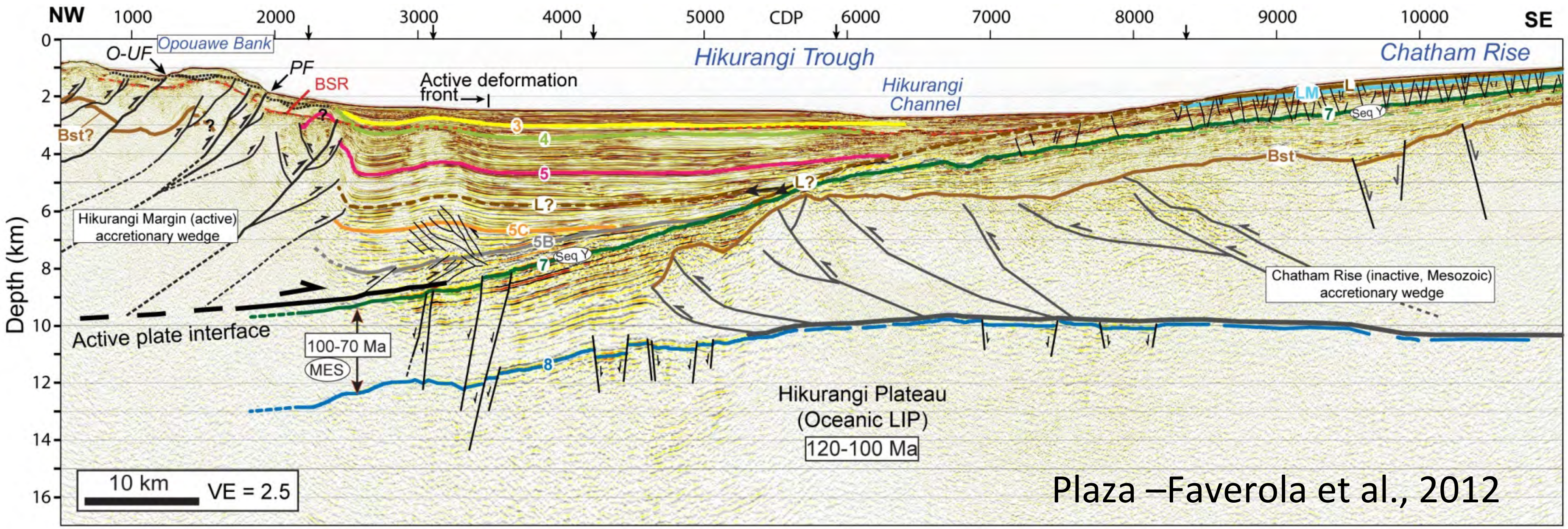


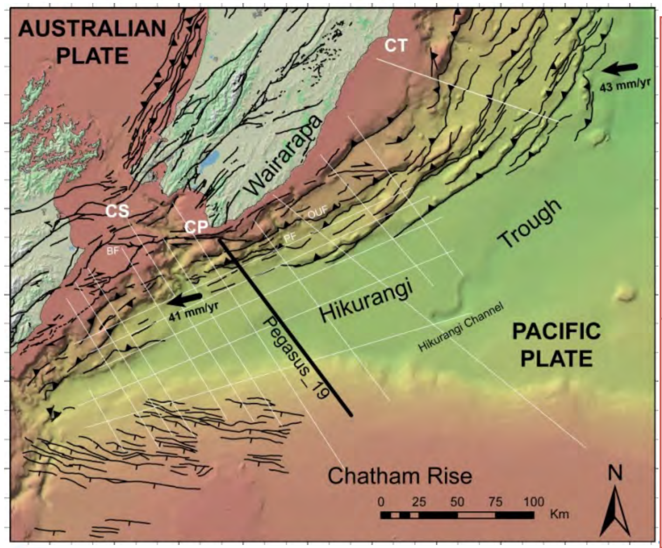
Accretion-dominated imbricated wedge: south of Hawke's Bay

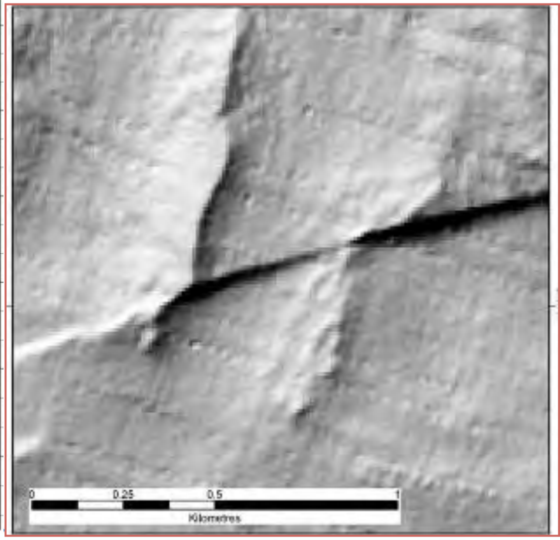


Barnes et al., 2010

Southern Hikurangi Margin







- **Narrow accretionary wedge**
- **Thickest trench-fill**
- **Subducting Chatham Rise sequences**
- **Strike-slip and thrust tectonics inboard**

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2. **Relative roles of control parameters on active forearc basins**

3. Role of submarine canyons

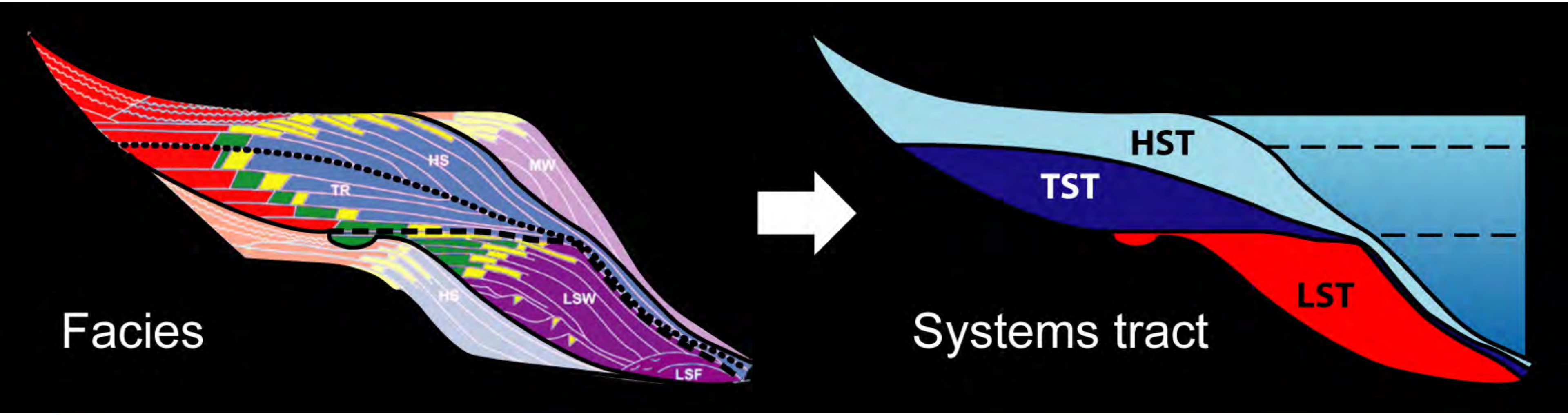
4. Input sequence: Hikurangi plateau and trough

⇨ **Stratigraphic architecture** of **sedimentary basins** at continental margins is known from a multitude of studies…

…but predominantly from **passive margin settings**

- Low rate regional subsidence
- Eustasy as a predominant driver

⇨ Studies on **active margins characterised by complex defm and uplift** have been relatively scarce...



NEED WELL CONSTRAINED STRATIGRAPHIC MODELS FOR ACTIVE SUBDUCTION MARGINS

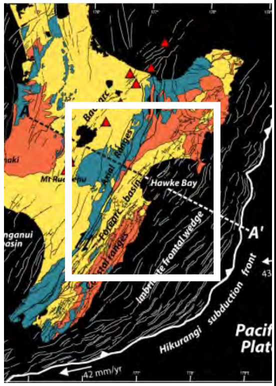
-

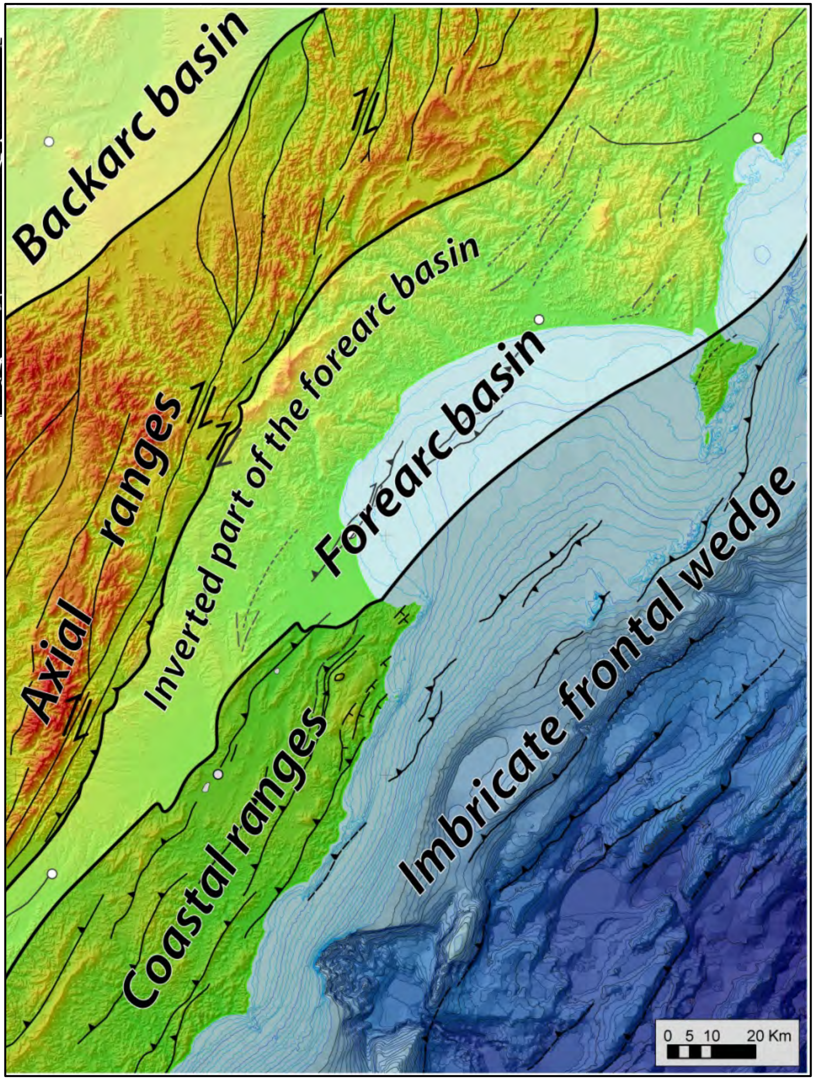
TO UNDERSTAND & QUANTIFY THE INFLUENCE OF CONTROL PARAMETERS – *TECTONICS, EUSTASY & CLIMATE* – ON THE STRATIGRAPHIC ARCHITECTURE

Example from the active Hawke Bay forearc basin

Paquet et al. 2009, 2011

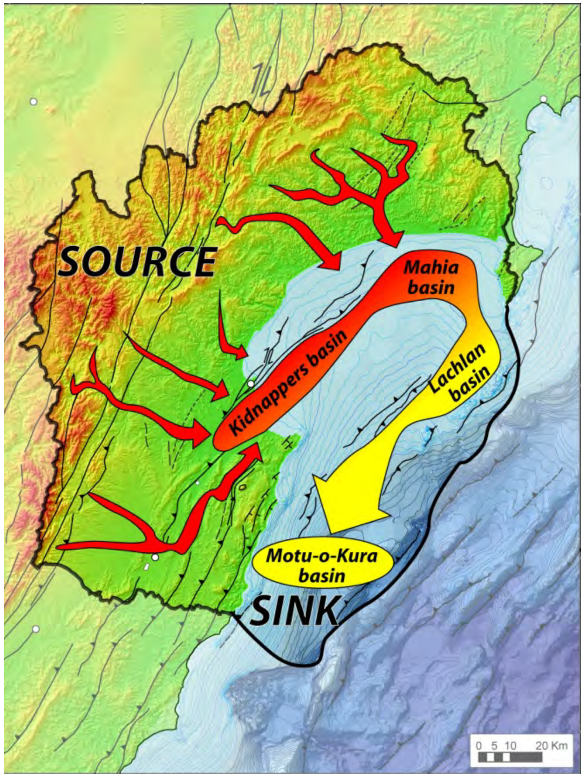
Morphostructural evolution of active forearc basins





Fabien Paquet

The example of the Hawke Bay forearc basin



Source to sink approach

Paquet et al. 2009, 2011

Methodology :

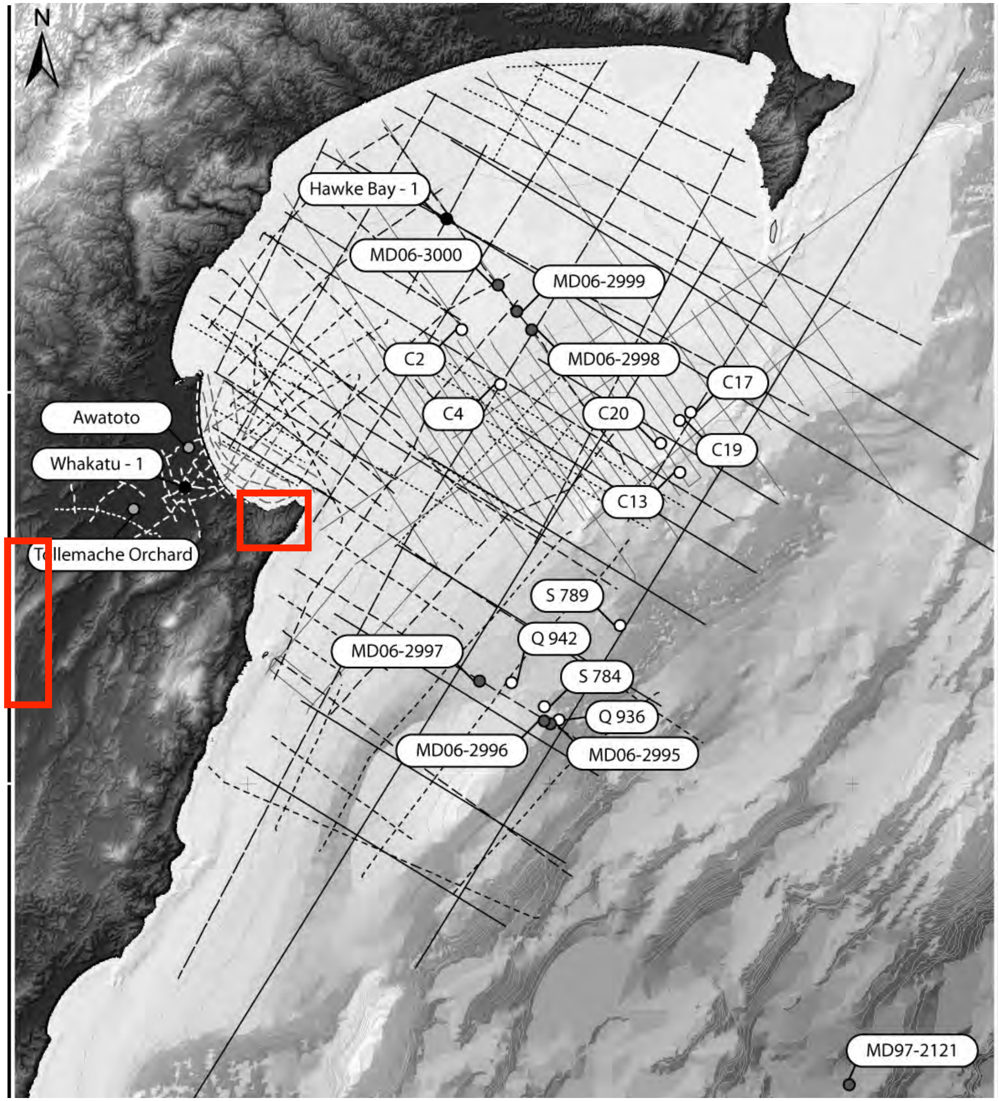
⇨ Identifying the last depositional sequence (140 ka) in order to produce a reliable stratigraphic model

⇨ Using this model to describe the stacking pattern of depositional sequences of the last c. 1 Ma

⇨ Quantifying preserved volumes of sediments in the Hawke Bay forearc domain

⇨ Evaluate the role of each control parameter on the stratigraphic architecture at different time scales

Morphostructural Evolution of Active Forearc Basins

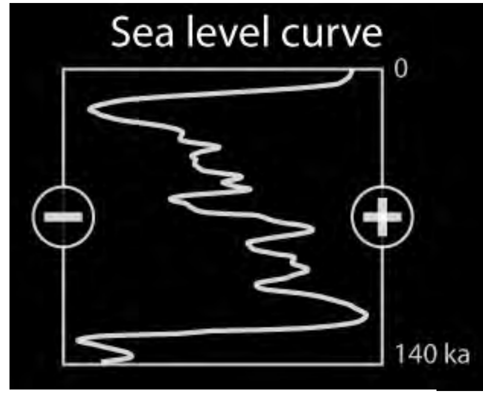


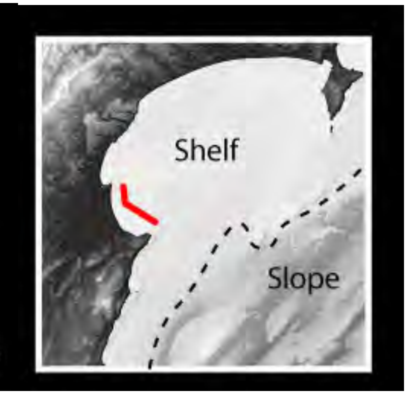
An extensive dataset:

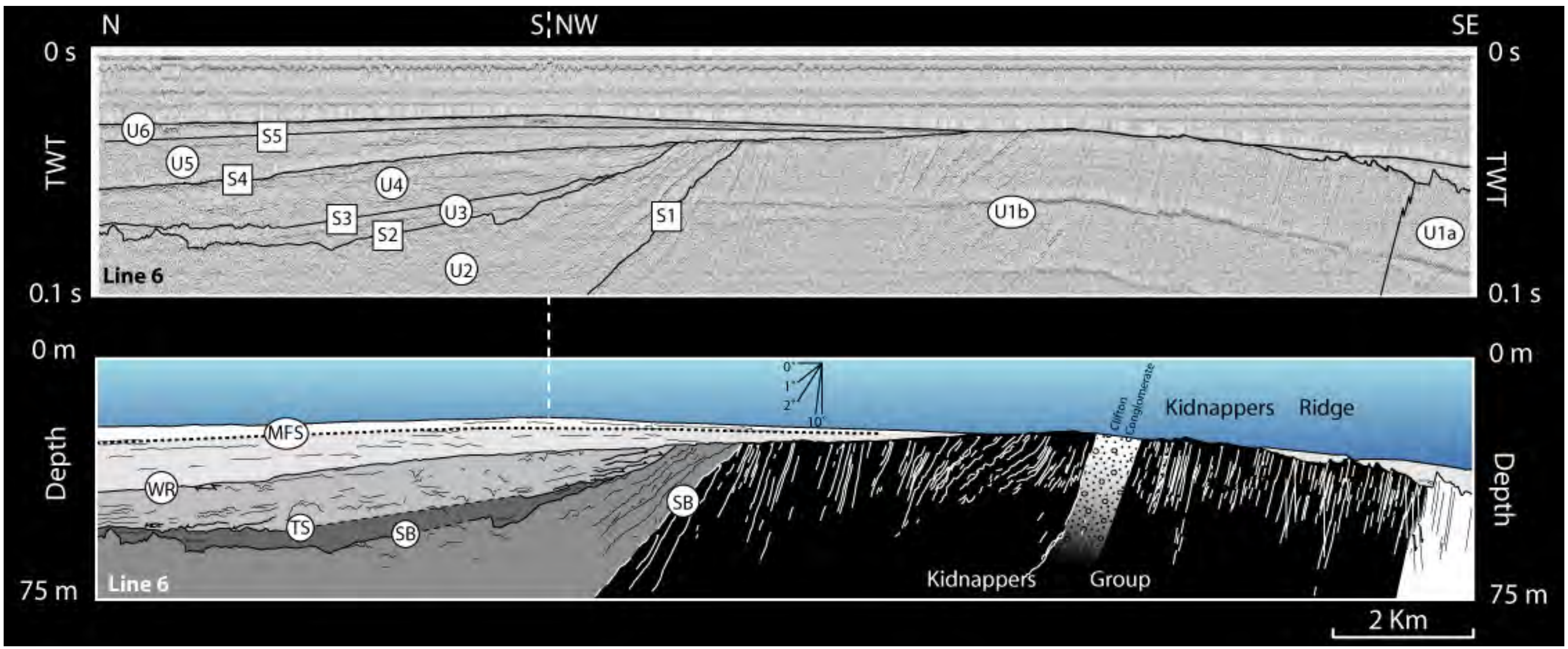
- marine MCS
- 3.5 KHz
- Boomer
- Cores
- Oil exploration wells
- Field mapping

Paquet et al. 2009, 2011

Boomer seismic surveys – Hawke Bay

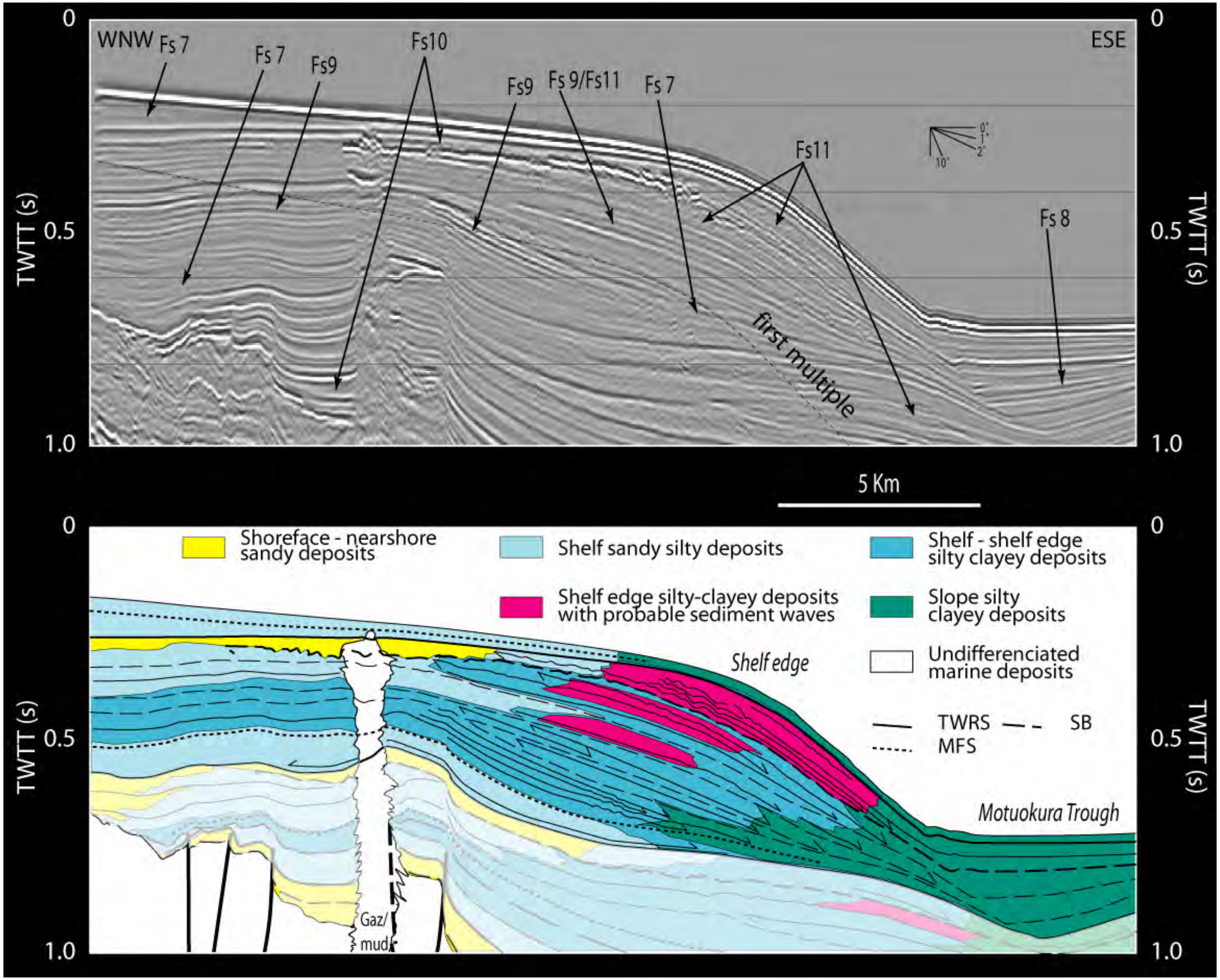






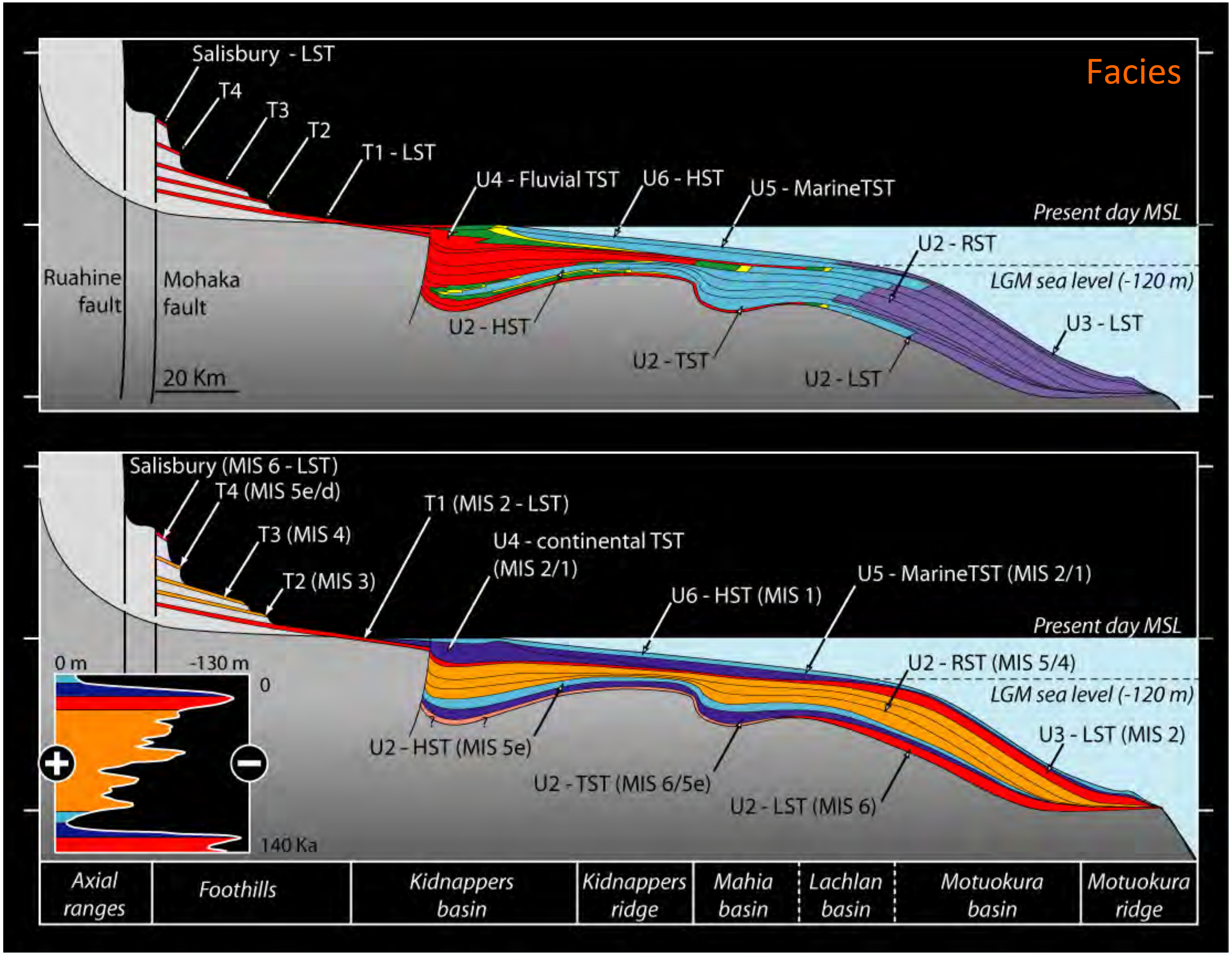
Paquet et al. 2009

Hi-fold multichannel seismic data – 0ffshore Hawke Bay



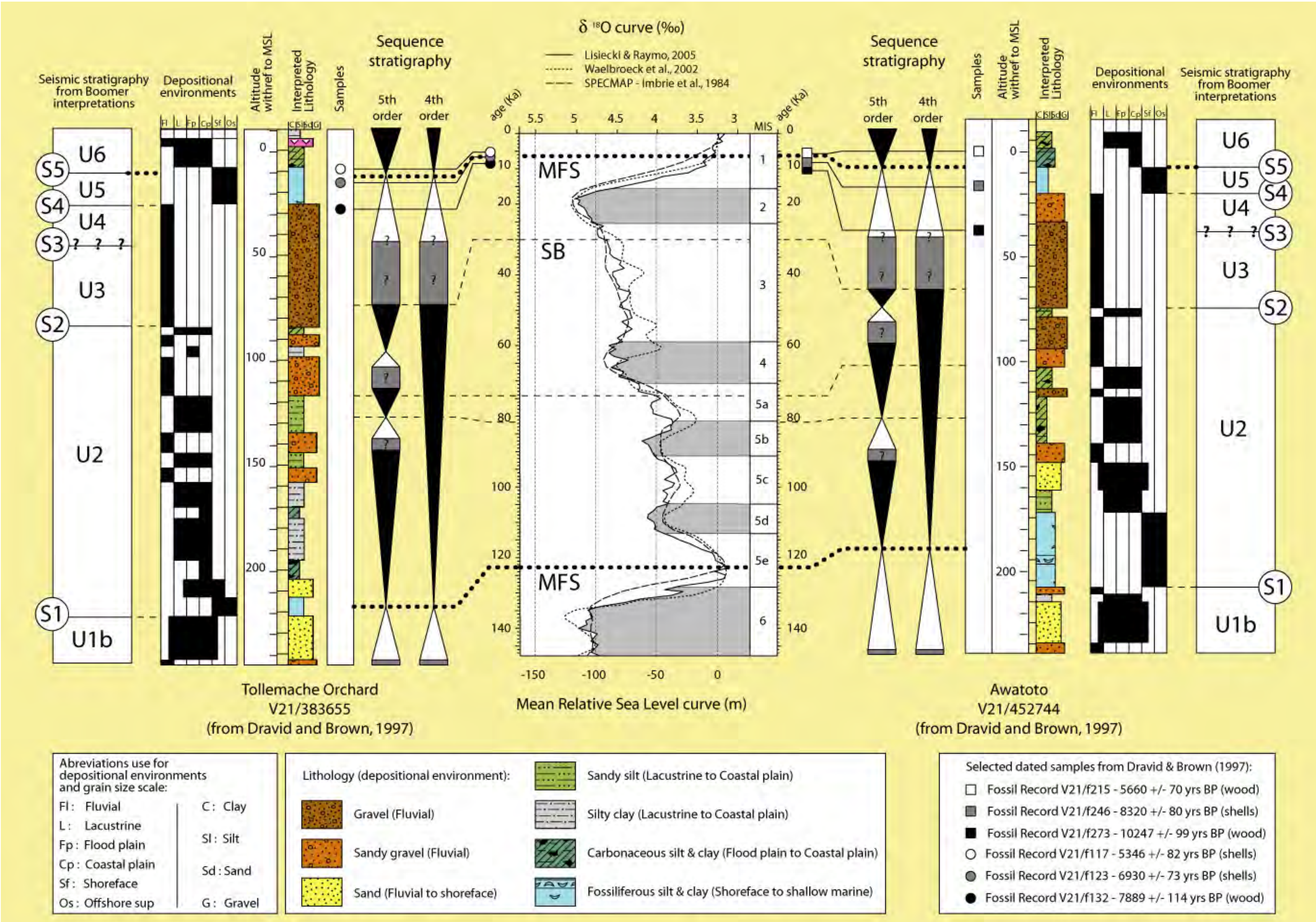
Paquet et al. 2009

Construct facies and depositional model for last sealevel cycle sequence



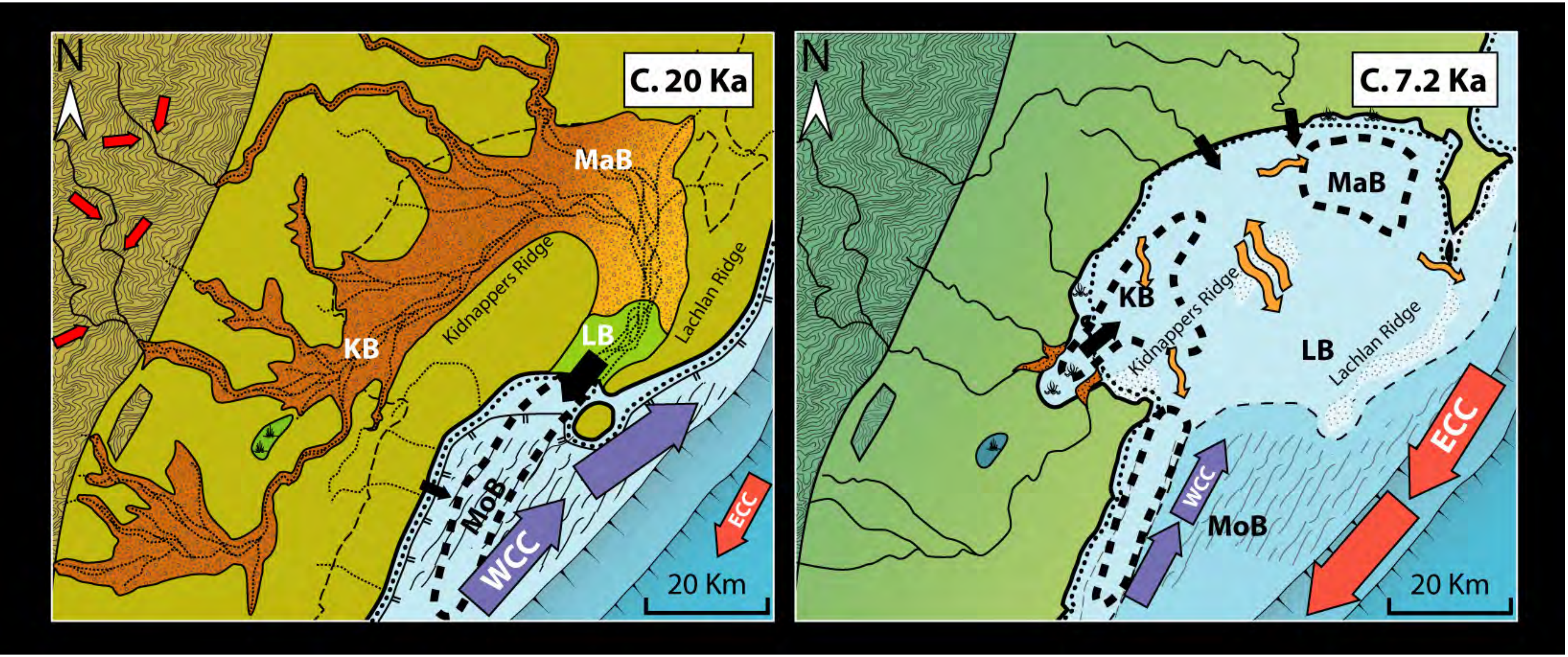
Paquet et al. 2009

Offshore seismic stratigraphy correlated to coastal plain wells



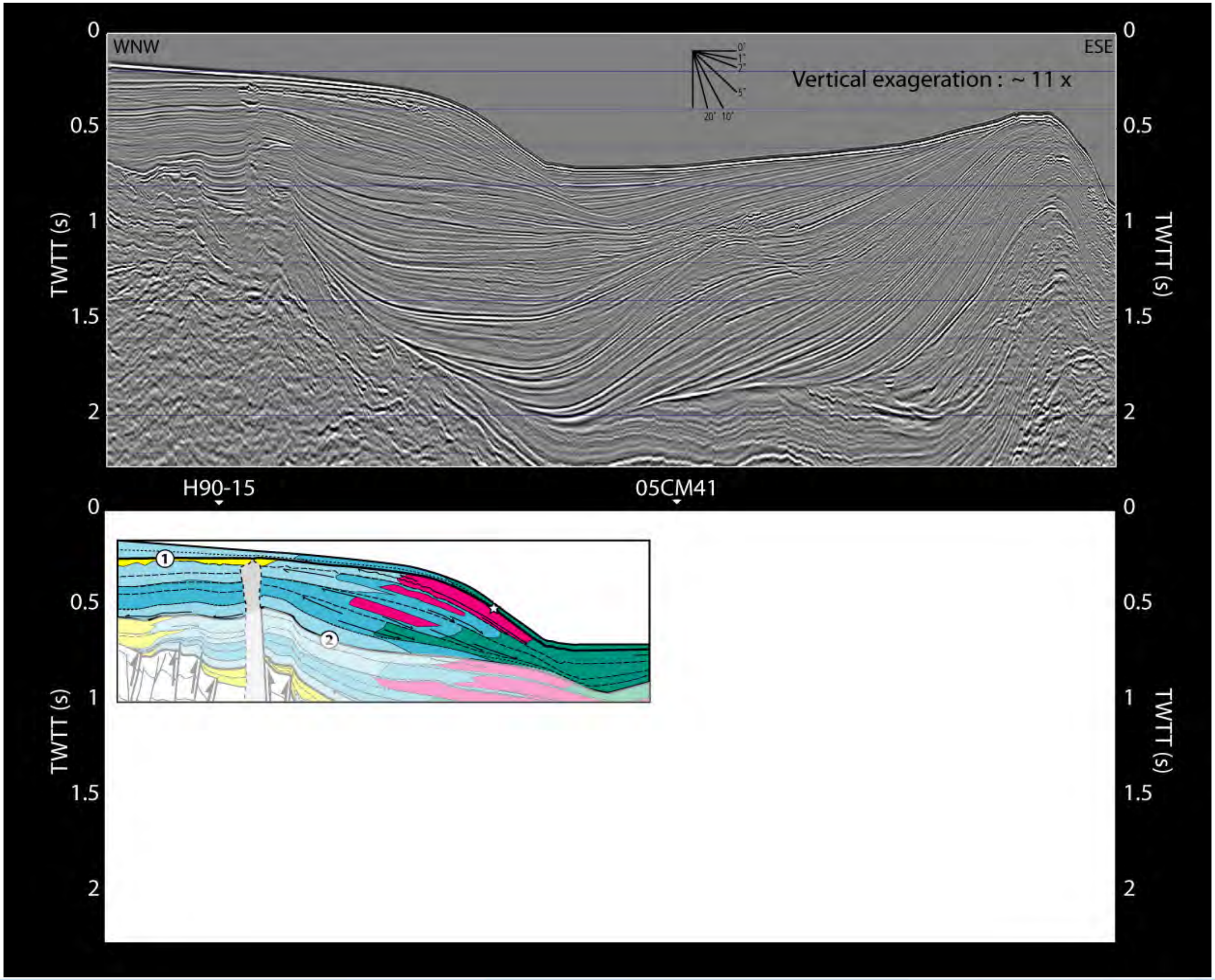
Paquet et al. 2009

Develop end-member paleogeographic interpretations



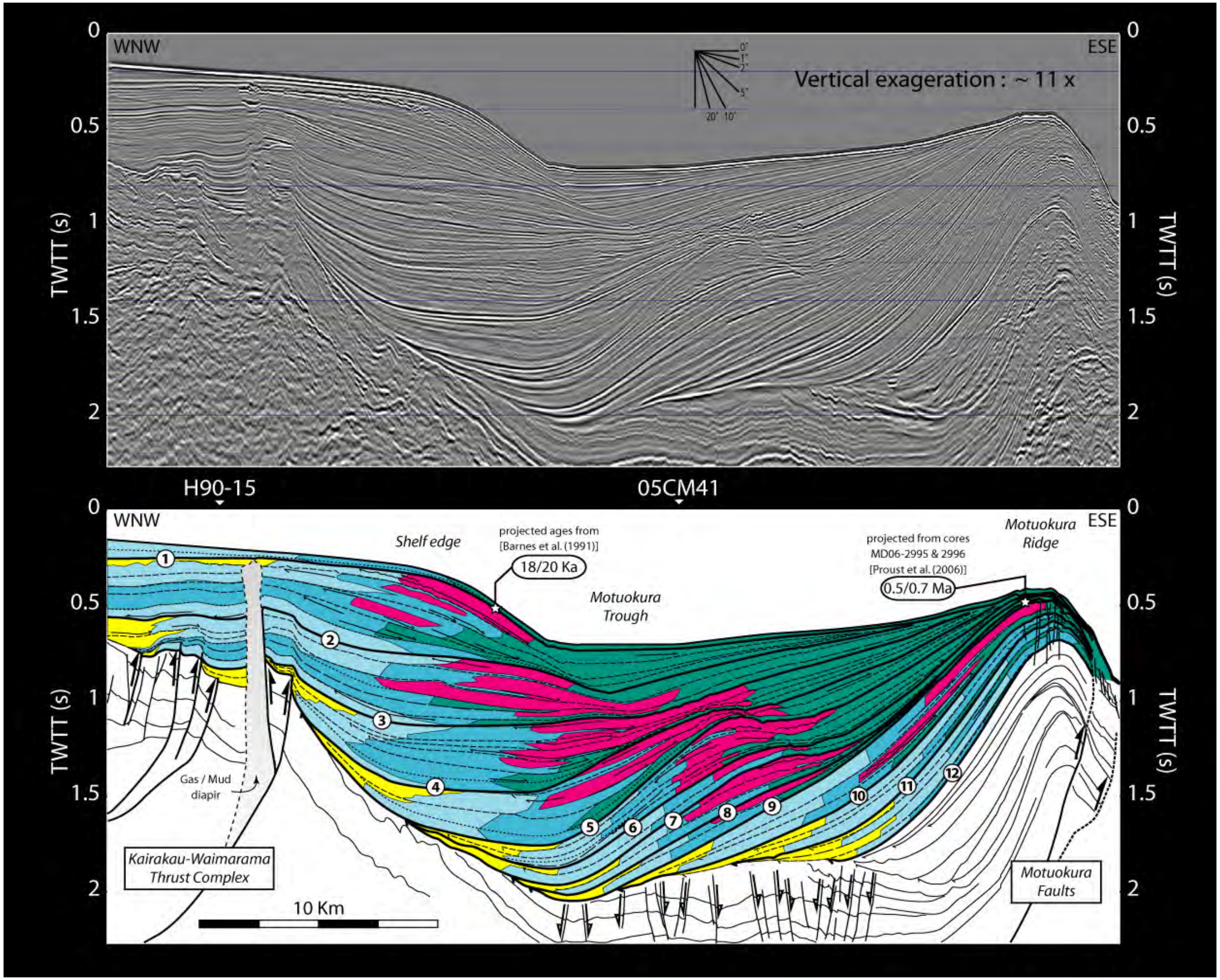
Paquet et al. 2009,

With one well constrained sealevel cycle sequence……



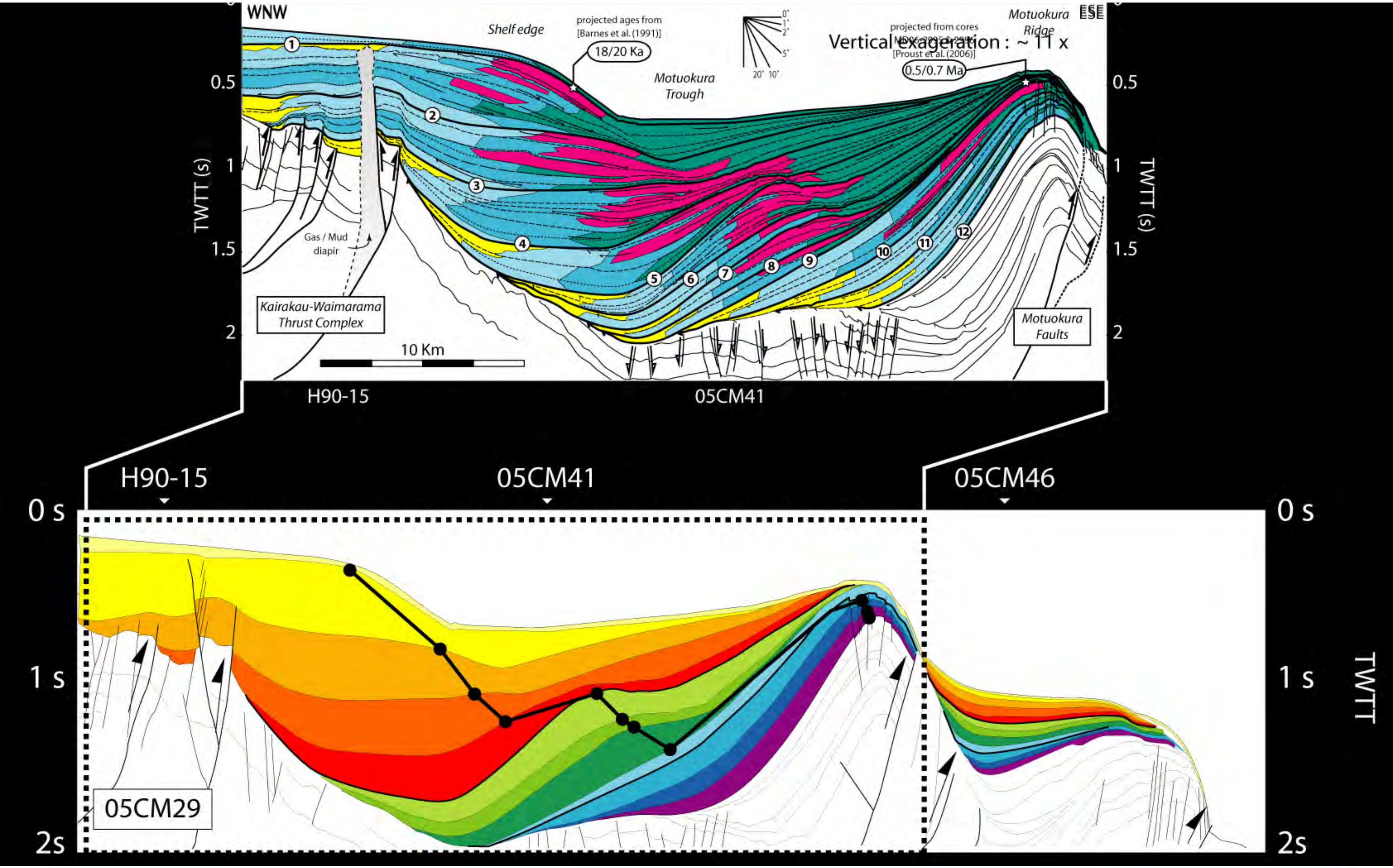
Paquet et al. 2009, 2011

….interpret older stratigraphic successions over 1 Ma timescale



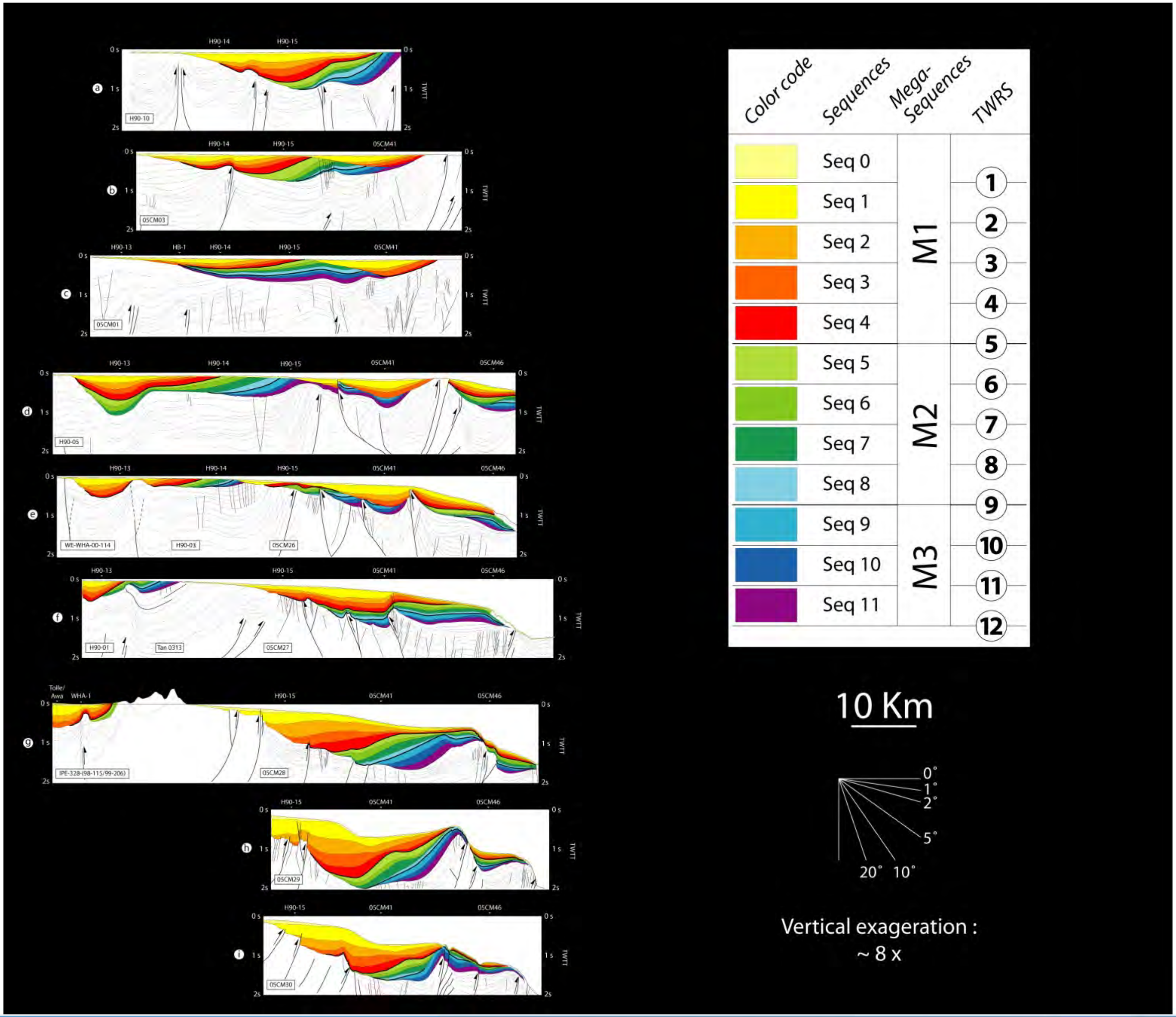
Paquet et al. 2011

....and identify multiple sealevel cycle sequences



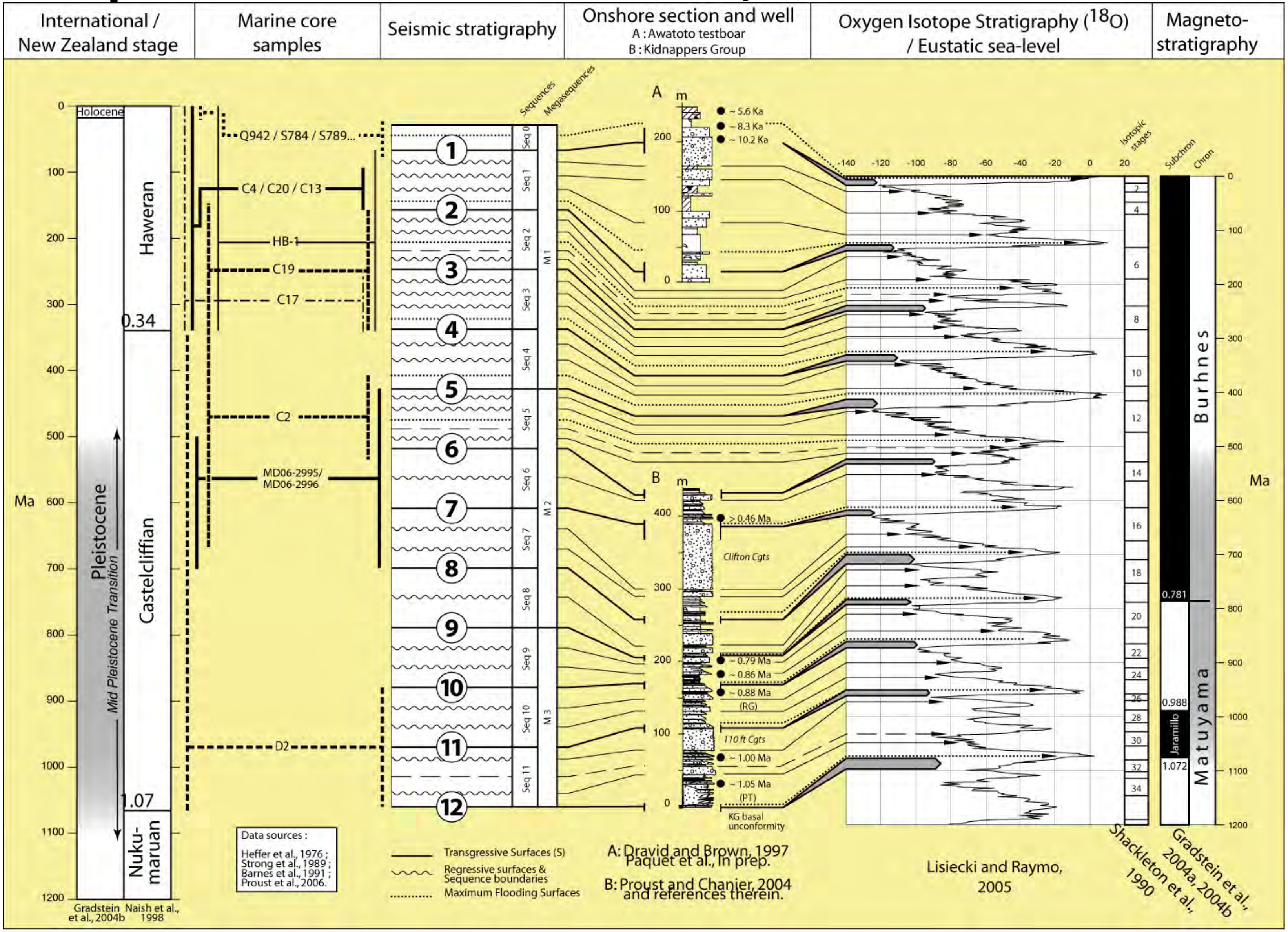
Paquet et al. 2011

11 sequences correlated throughout Hawke Bay



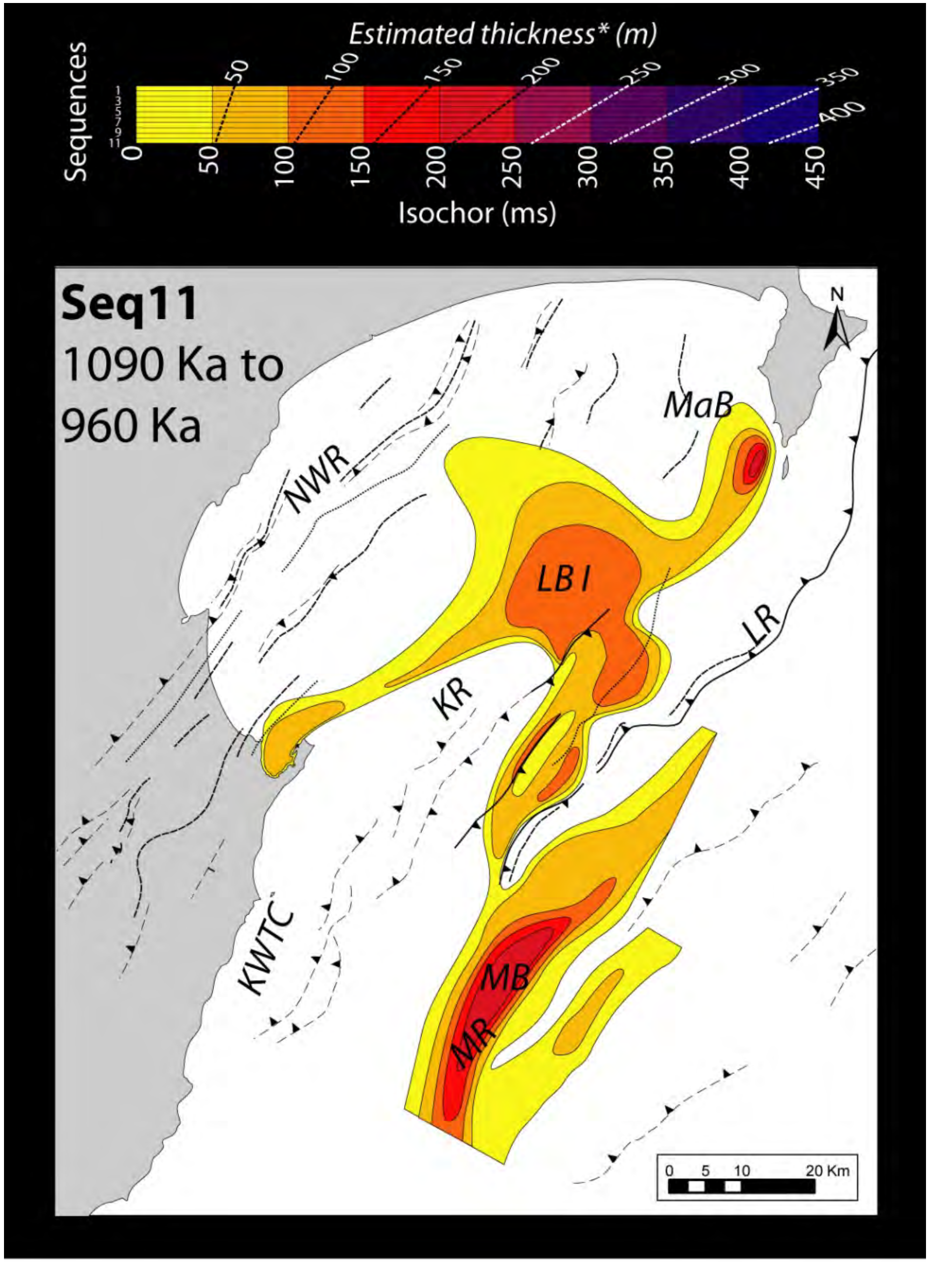
Paquet et al. 2011

All sequences correlated to MIS/Eustatic sealevel curves

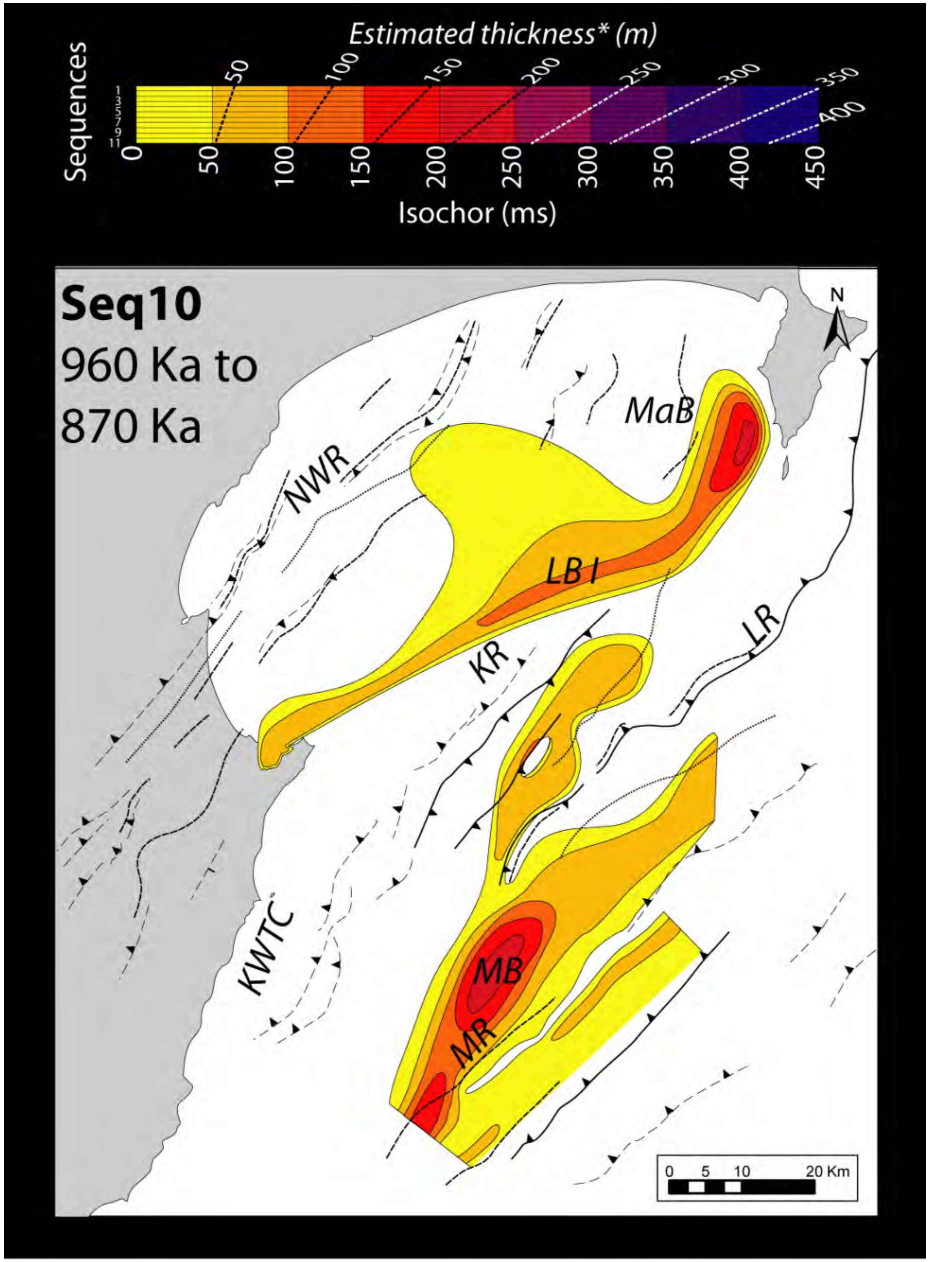


Paquet et al. 2011

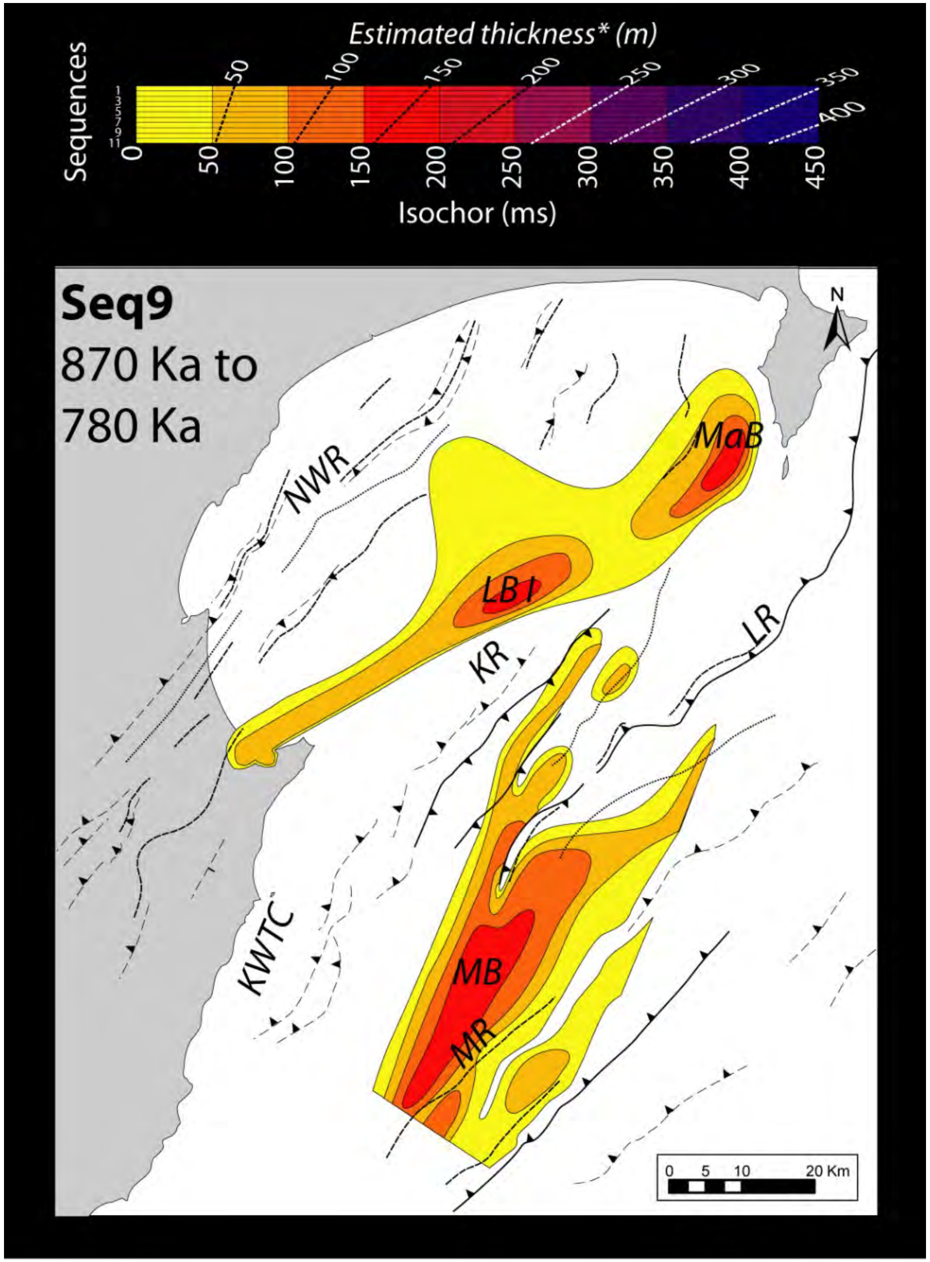
Isopach mapping of each depositional sequence



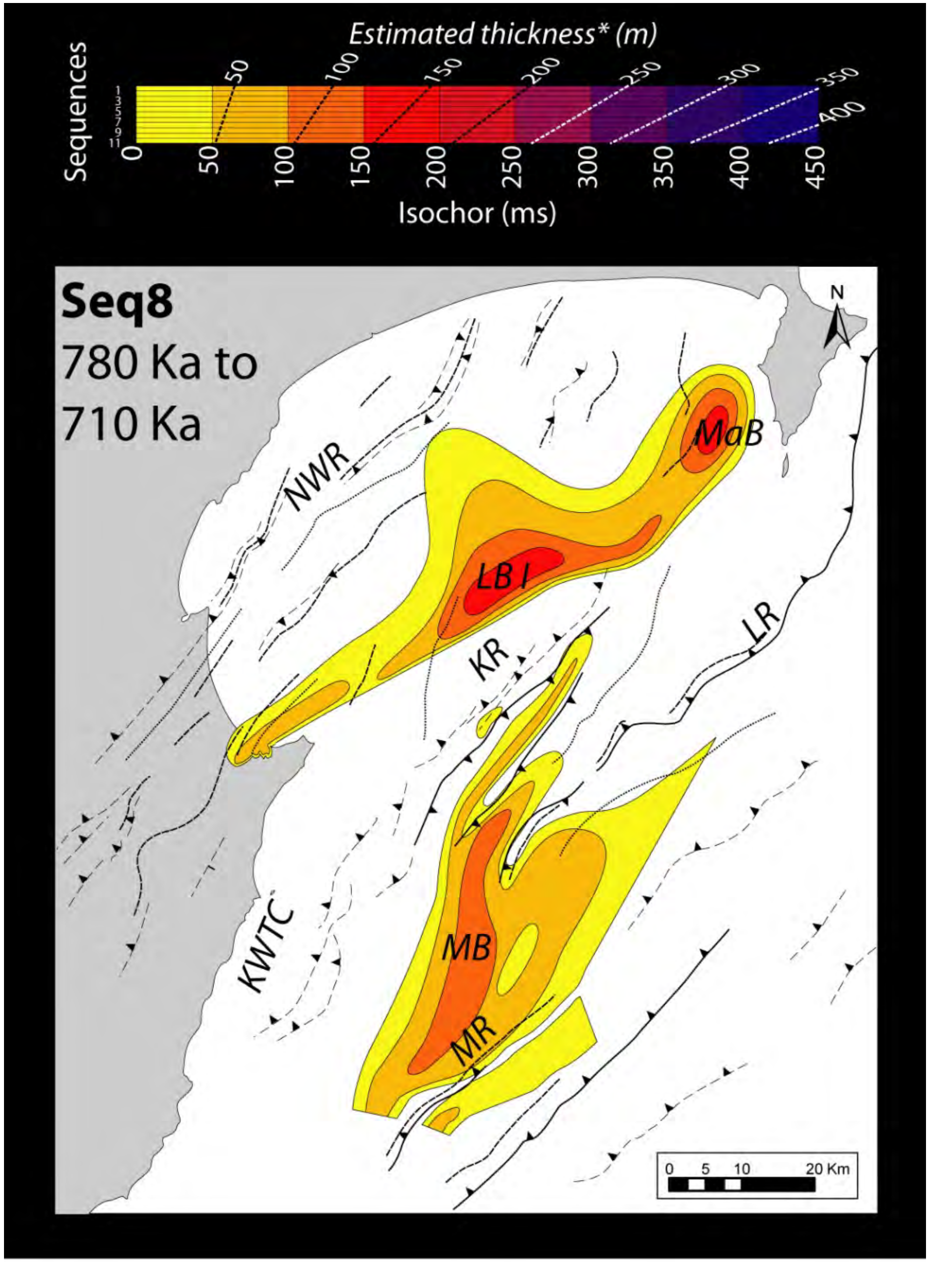
Paquet et al. 2011



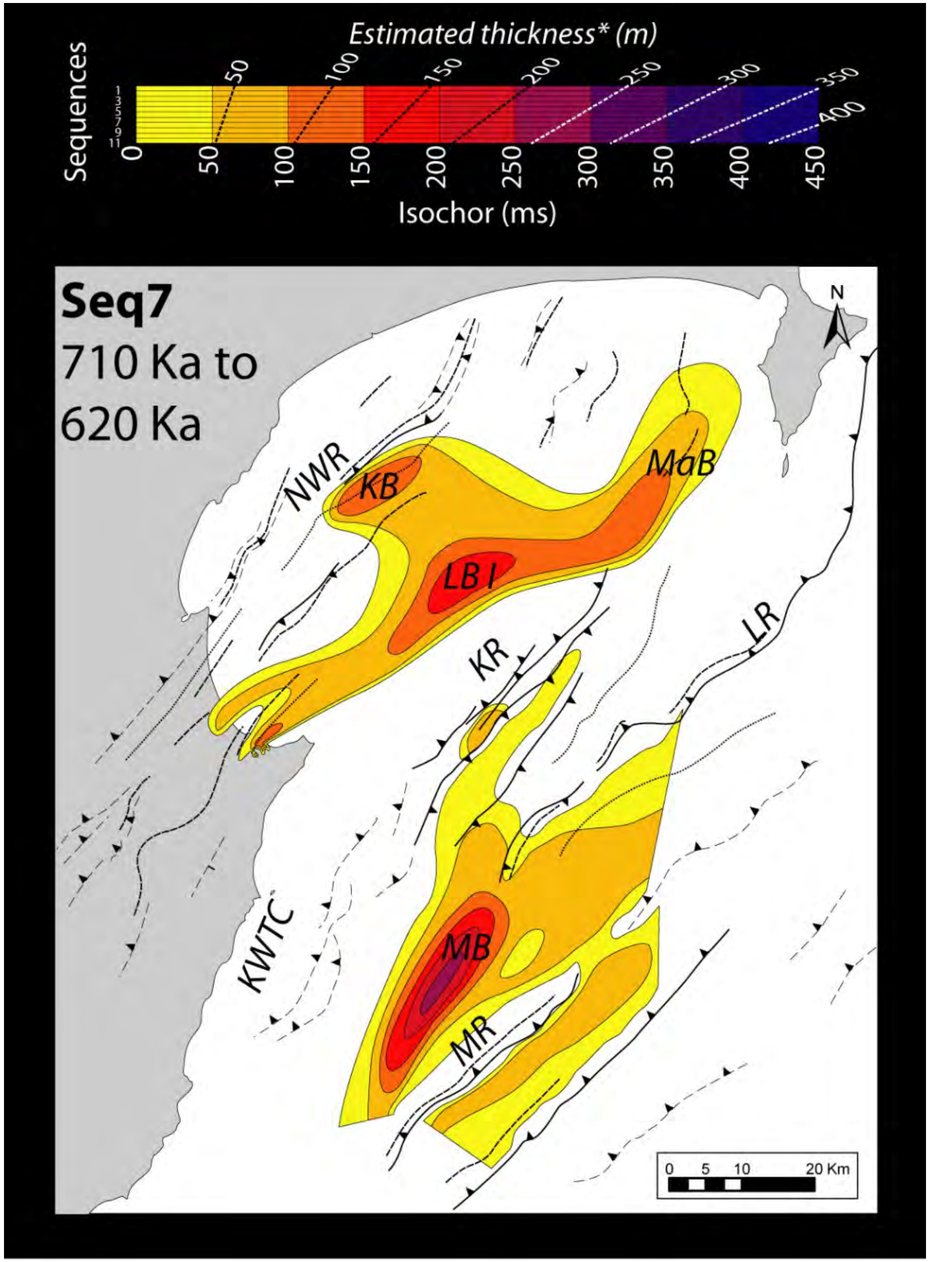
Paquet et al. 2011



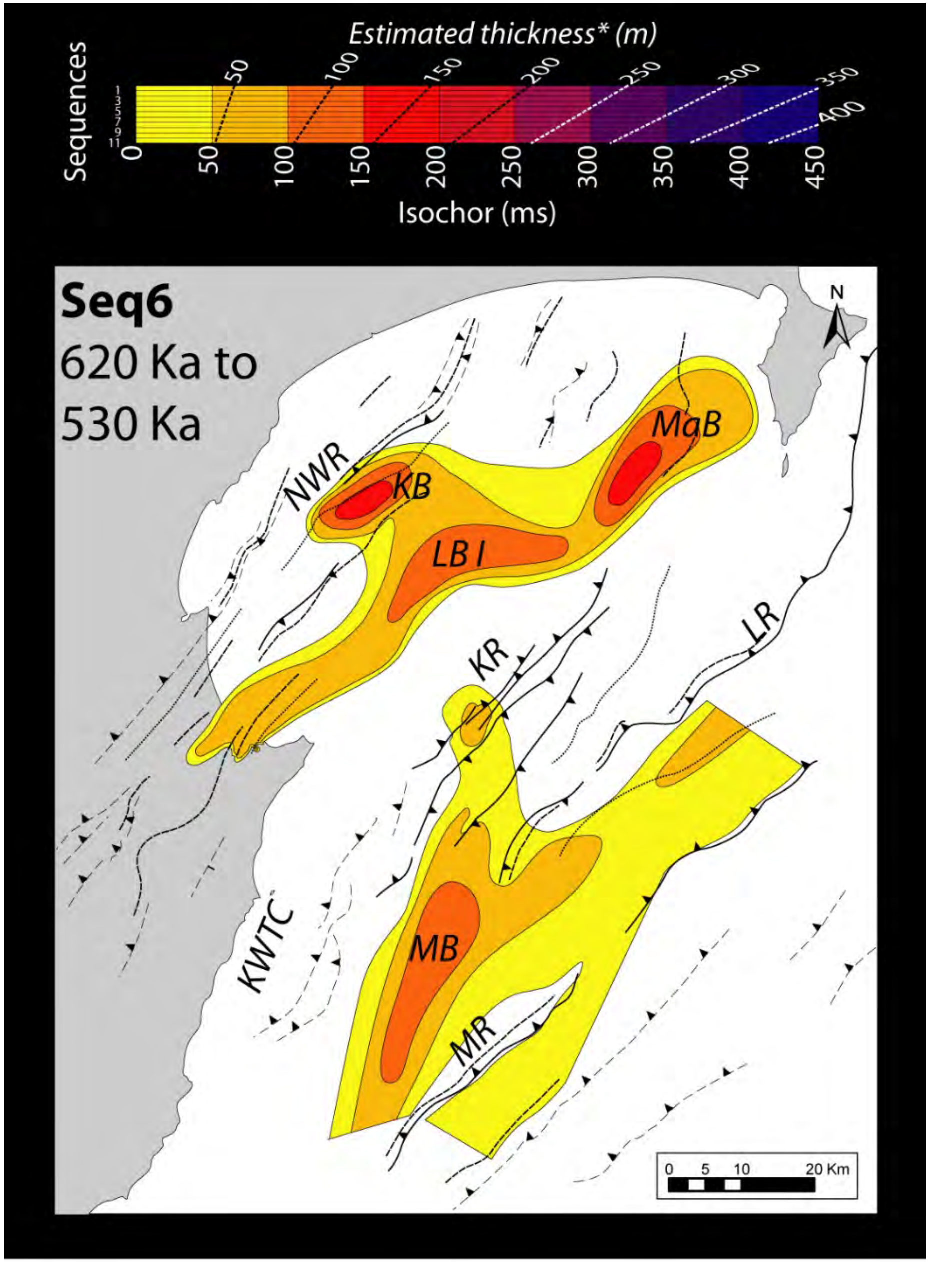
Paquet et al. 2011



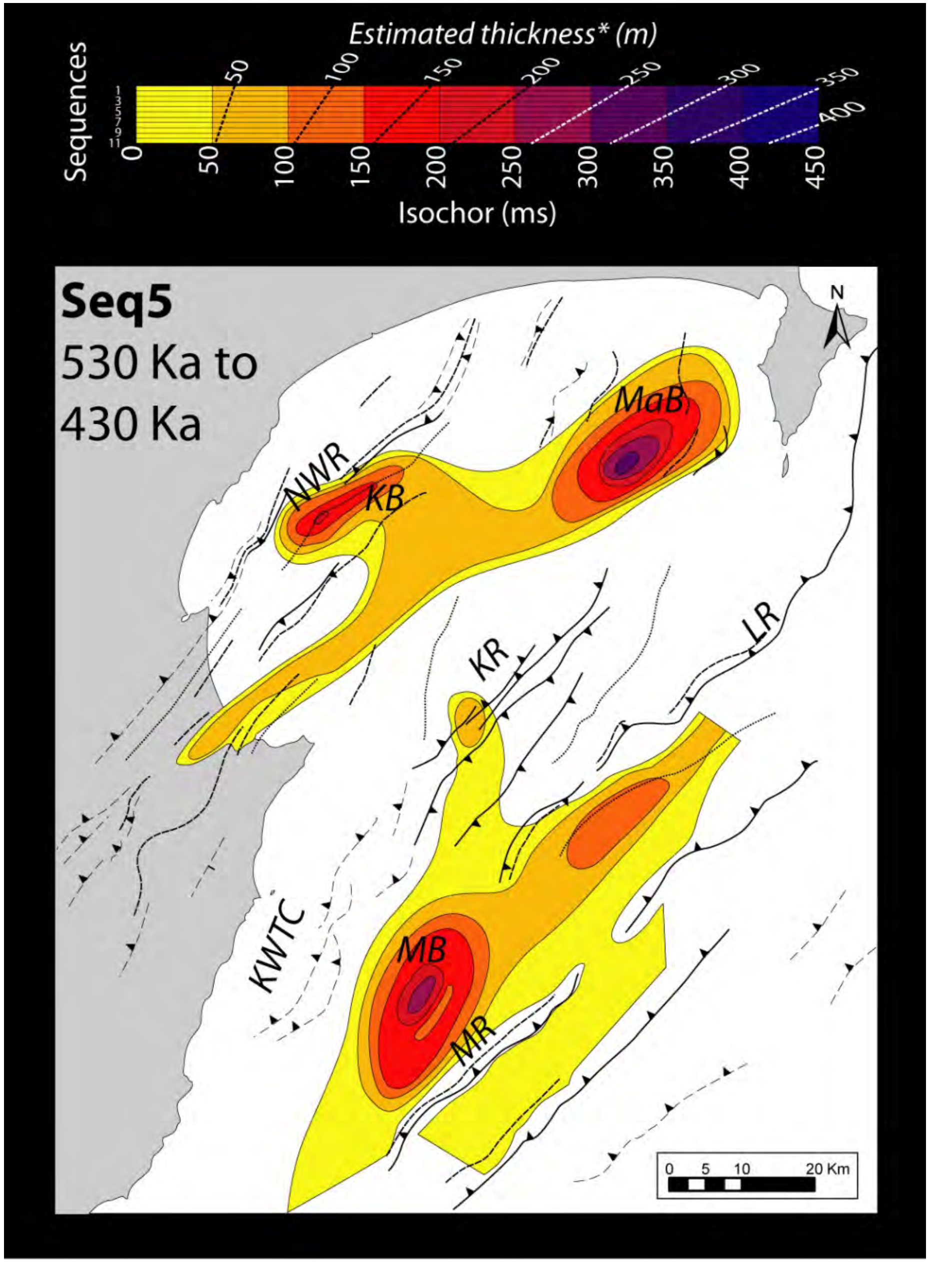
Paquet et al. 2011



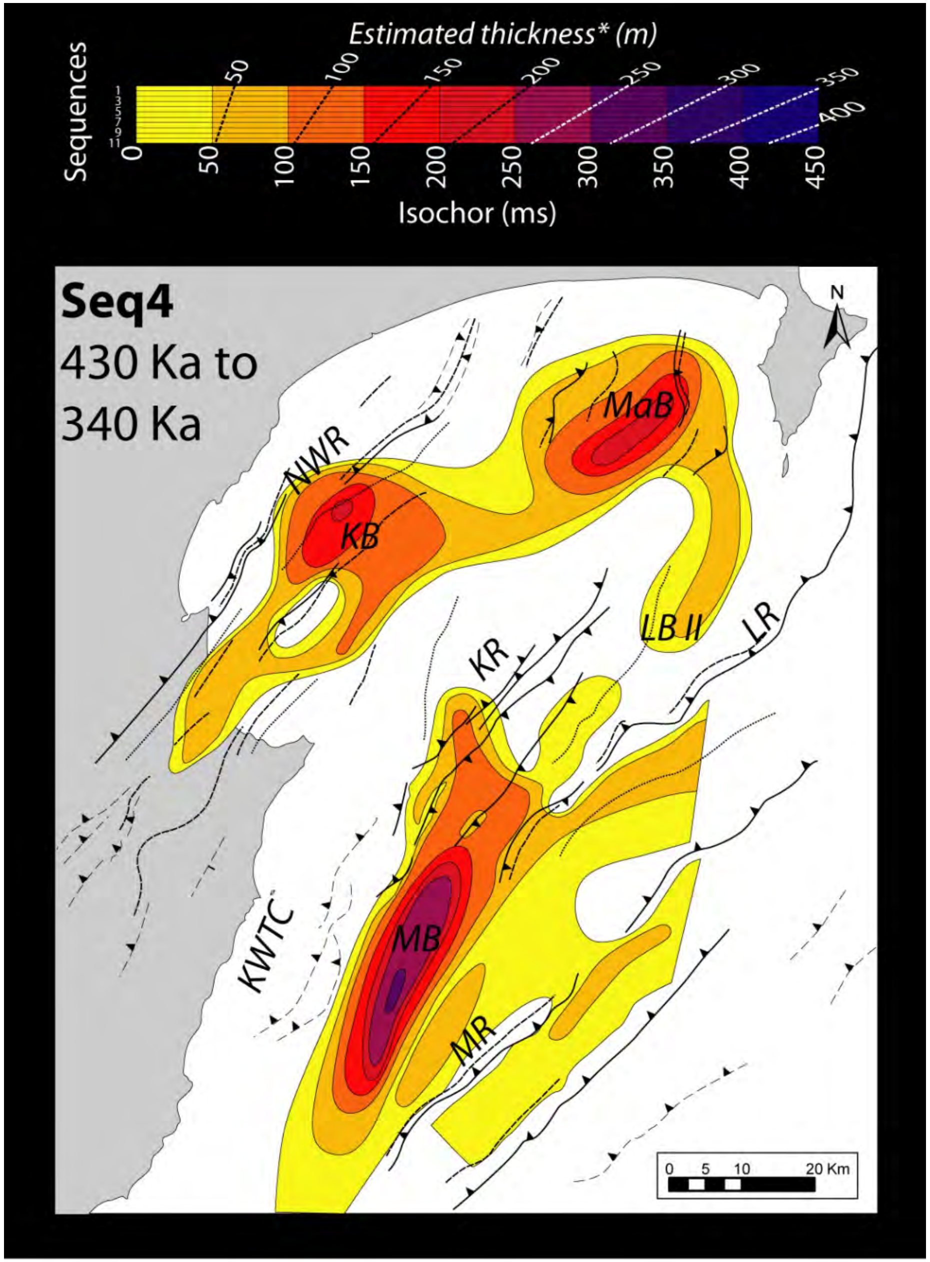
Paquet et al. 2011



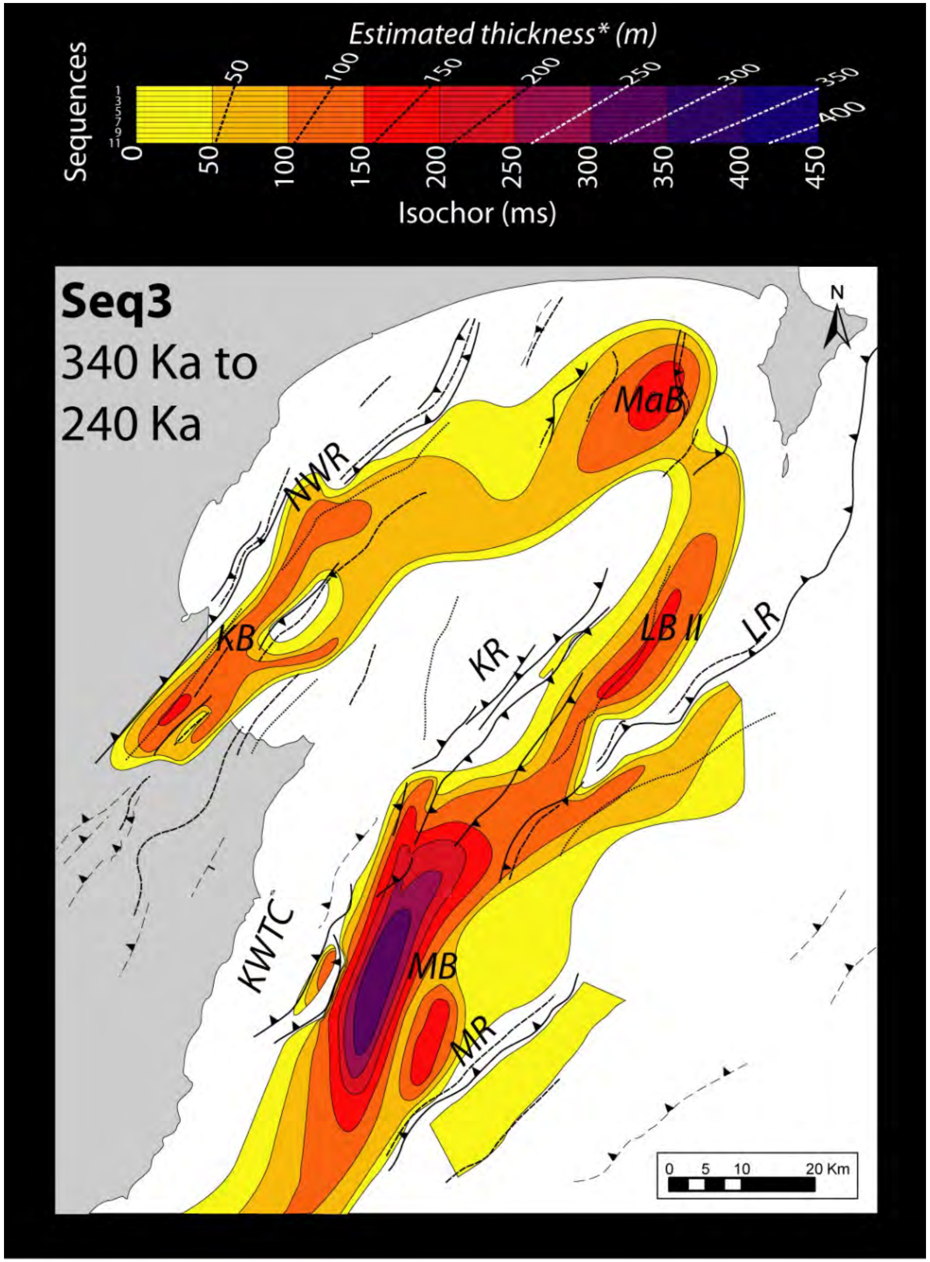
Paquet et al. 2011



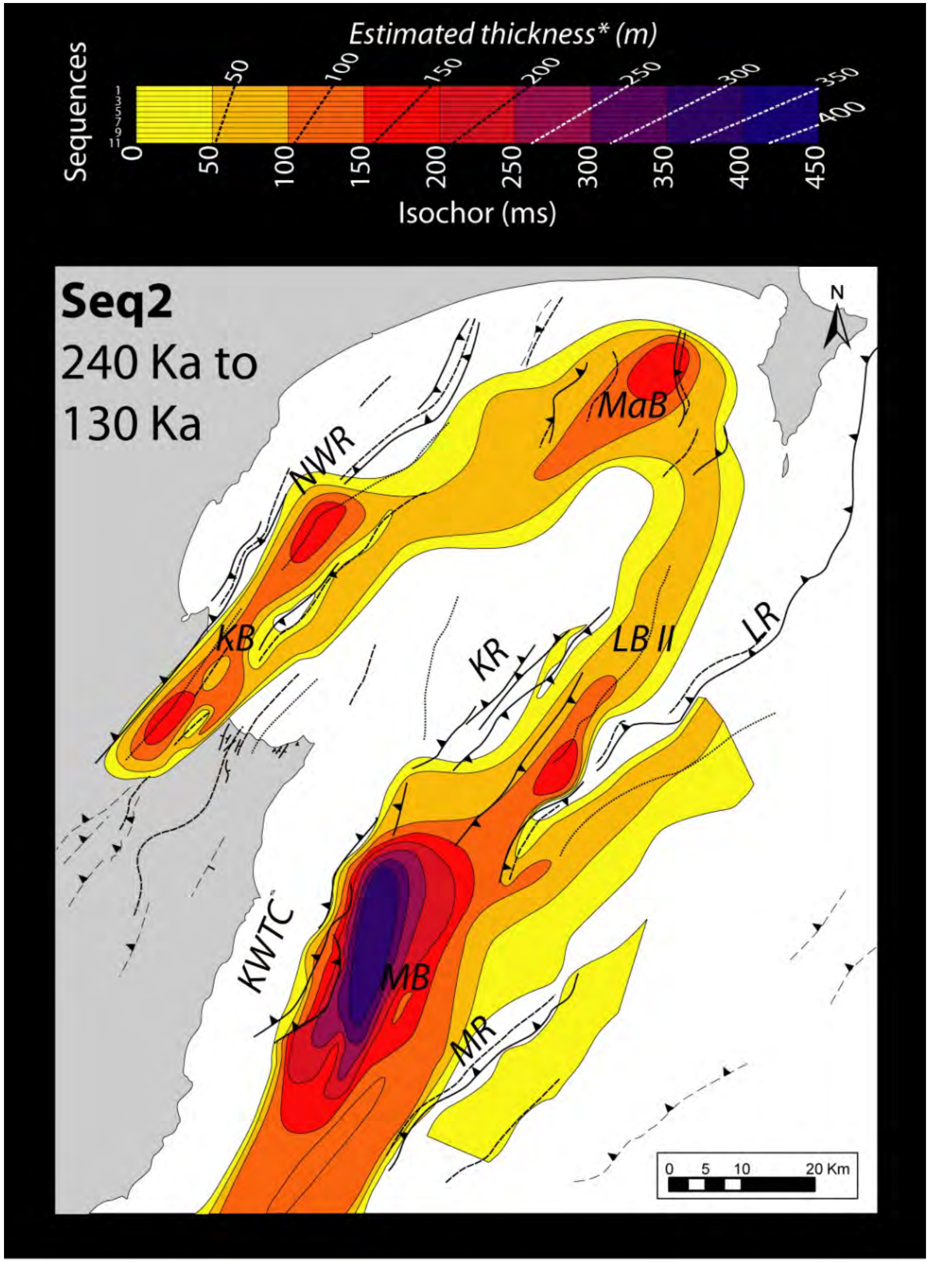
Paquet et al. 2011



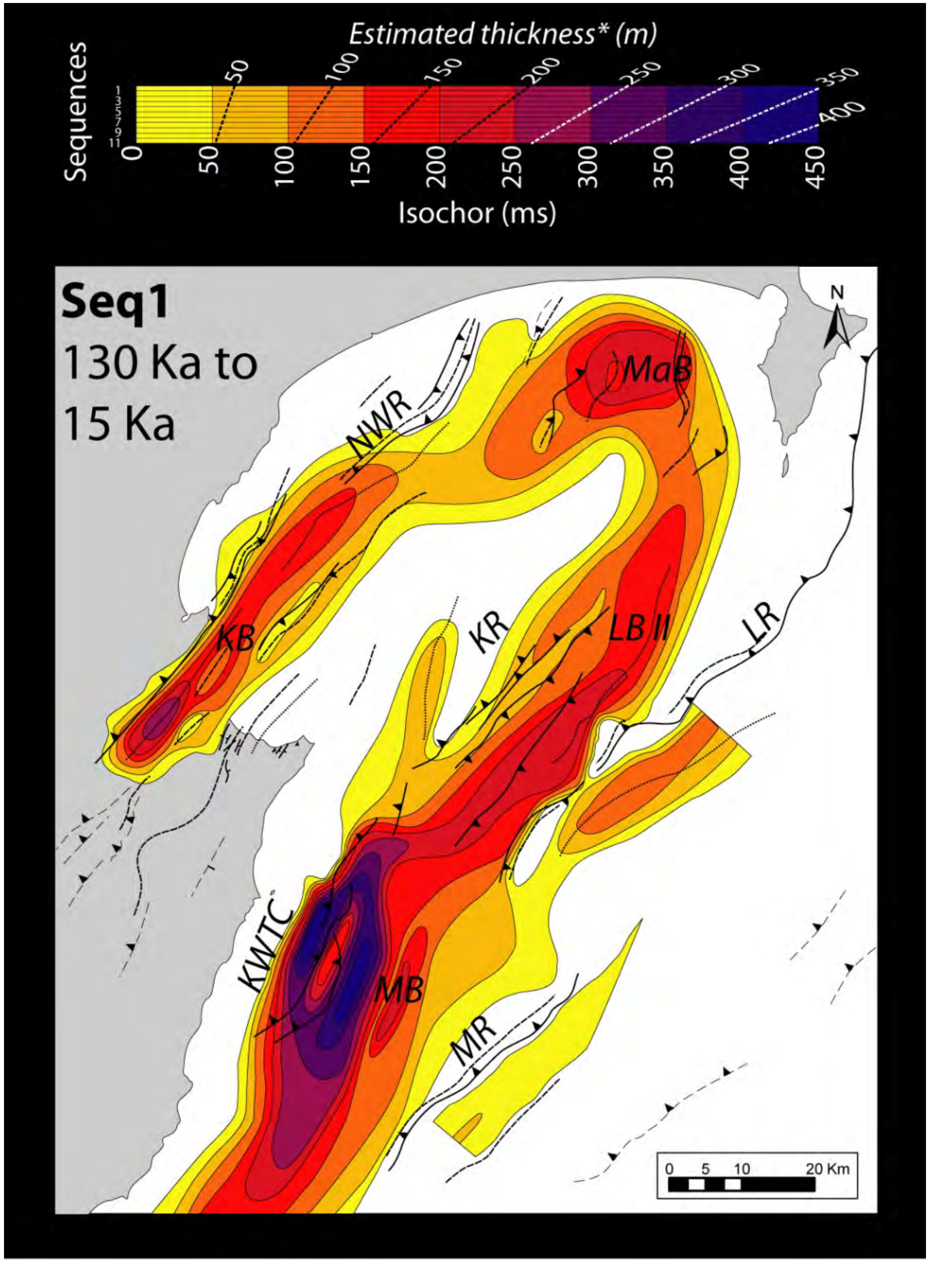
Paquet et al. 2011



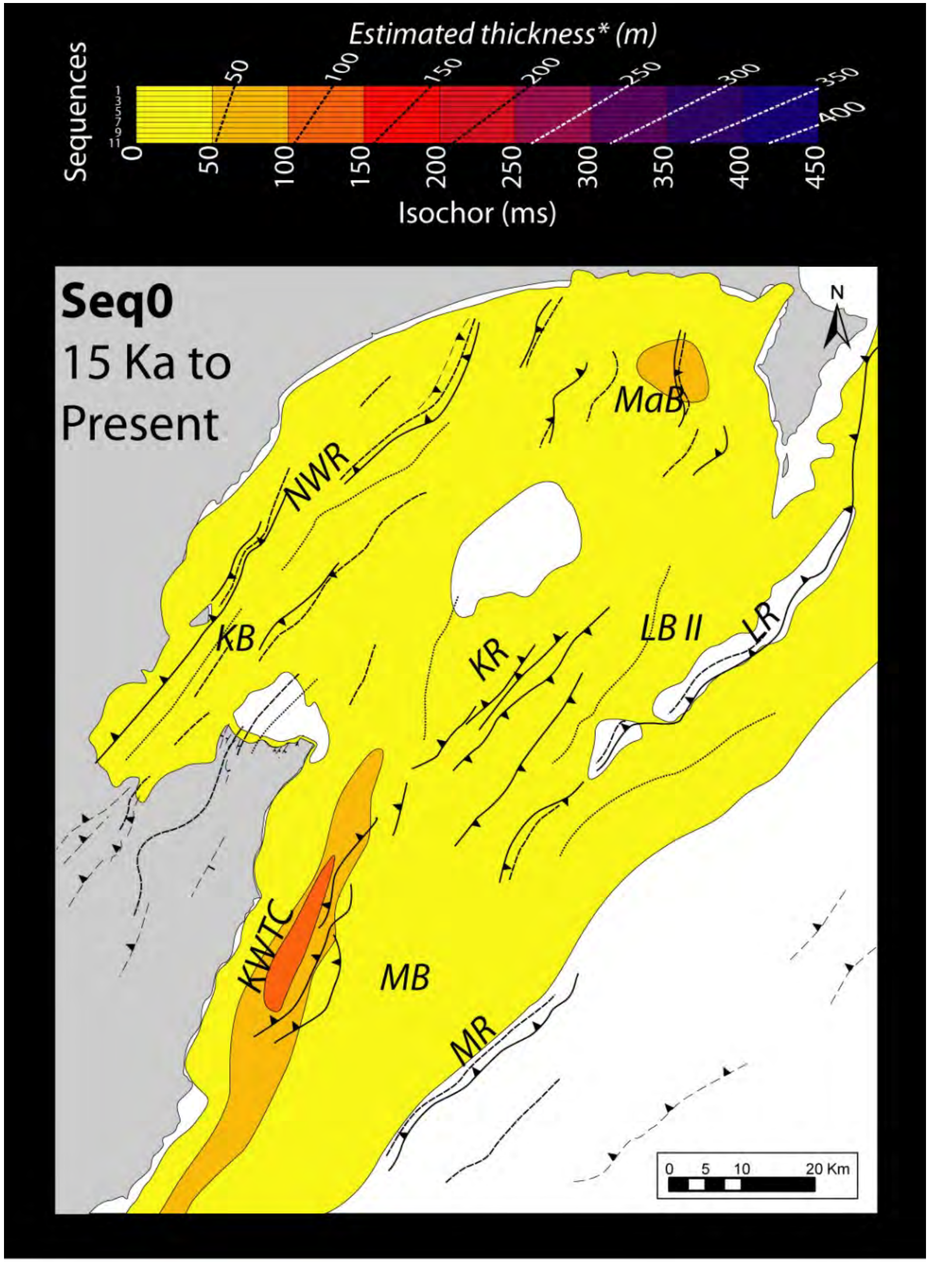
Paquet et al. 2011



Paquet et al. 2011



Paquet et al. 2011



Paquet et al. 2011

Quantitative methodology to determine preserved sediment fluxes

Isopach maps

⇩

Volume estimations

⇩

Volume compaction

⇩

Mass conversion

⇩

Mass / sequence duration

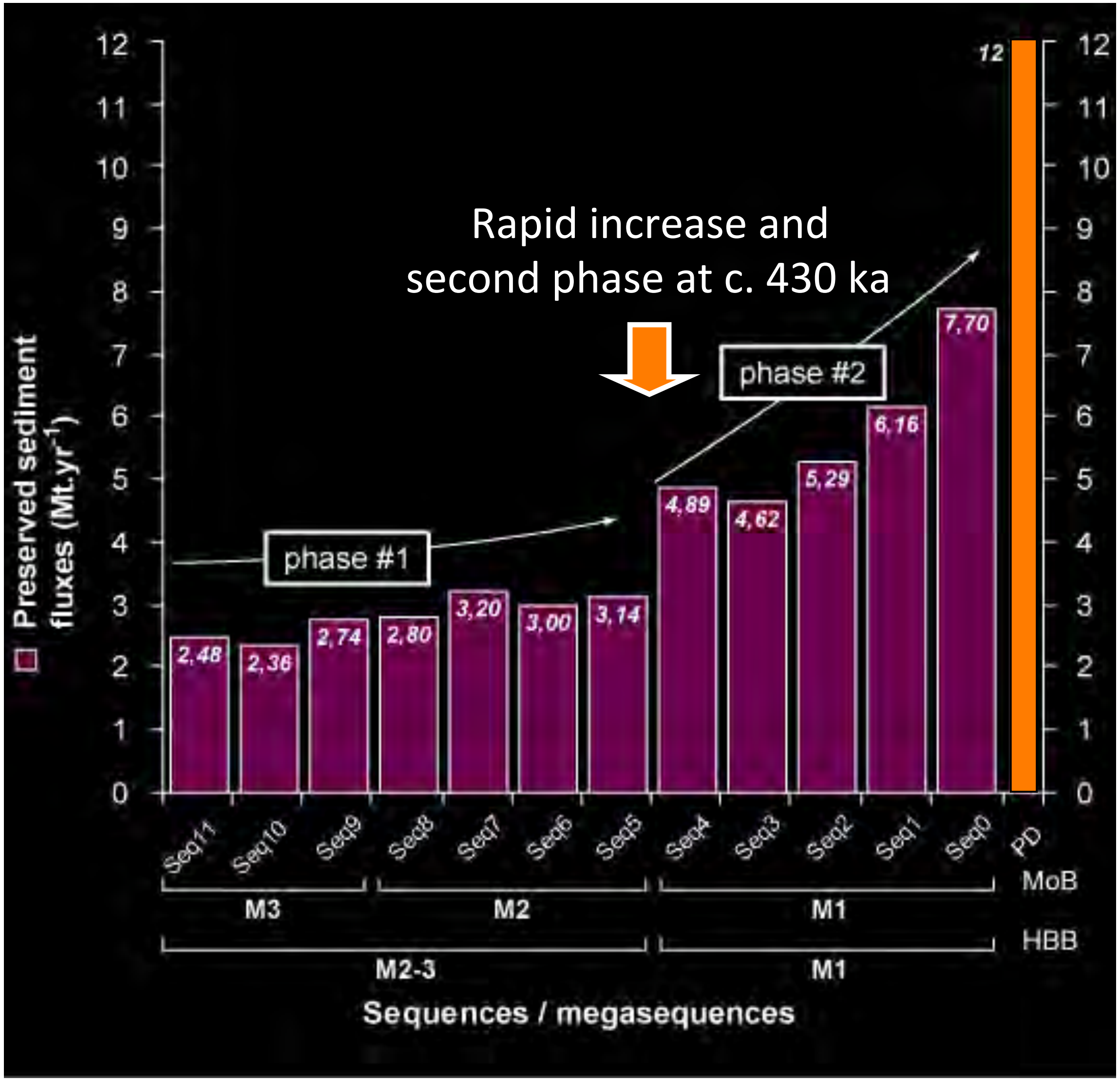
=

Sediment flux estimation

Significant errors at each stage

Paquet et al. 2011

Preserved sediment fluxes during the last 1.1 Ma :



Change in basin configuration at 430Ka: Tectonic influence on preservation potential?

Possible result of:

- Cannibalism?
- Change in pres'n potential?

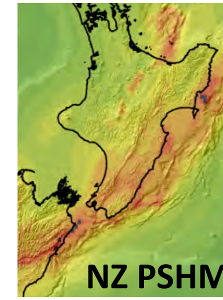
Significant increase entering Last glacial : Seq 1-0 transition

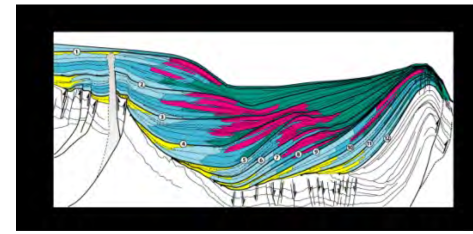
V. High present day sediment flux:

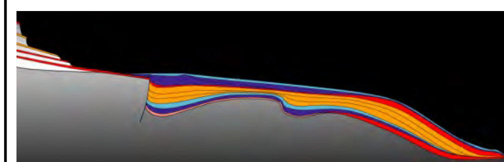
- Anthropogenic effect (deforestation, land use)

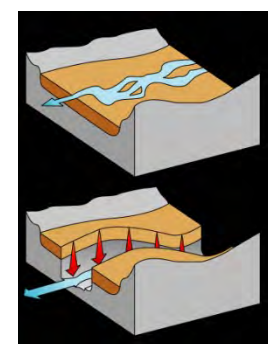
Paquet et al. 2011

Control parameters	Time scale: 1 ka	20 ka	100 ka	1 Ma
Tectonic deformation	★★★	★	★	★★★
Eustasy	★	★★★	★★★	★
Climate	★★★	★★★	★★★	★









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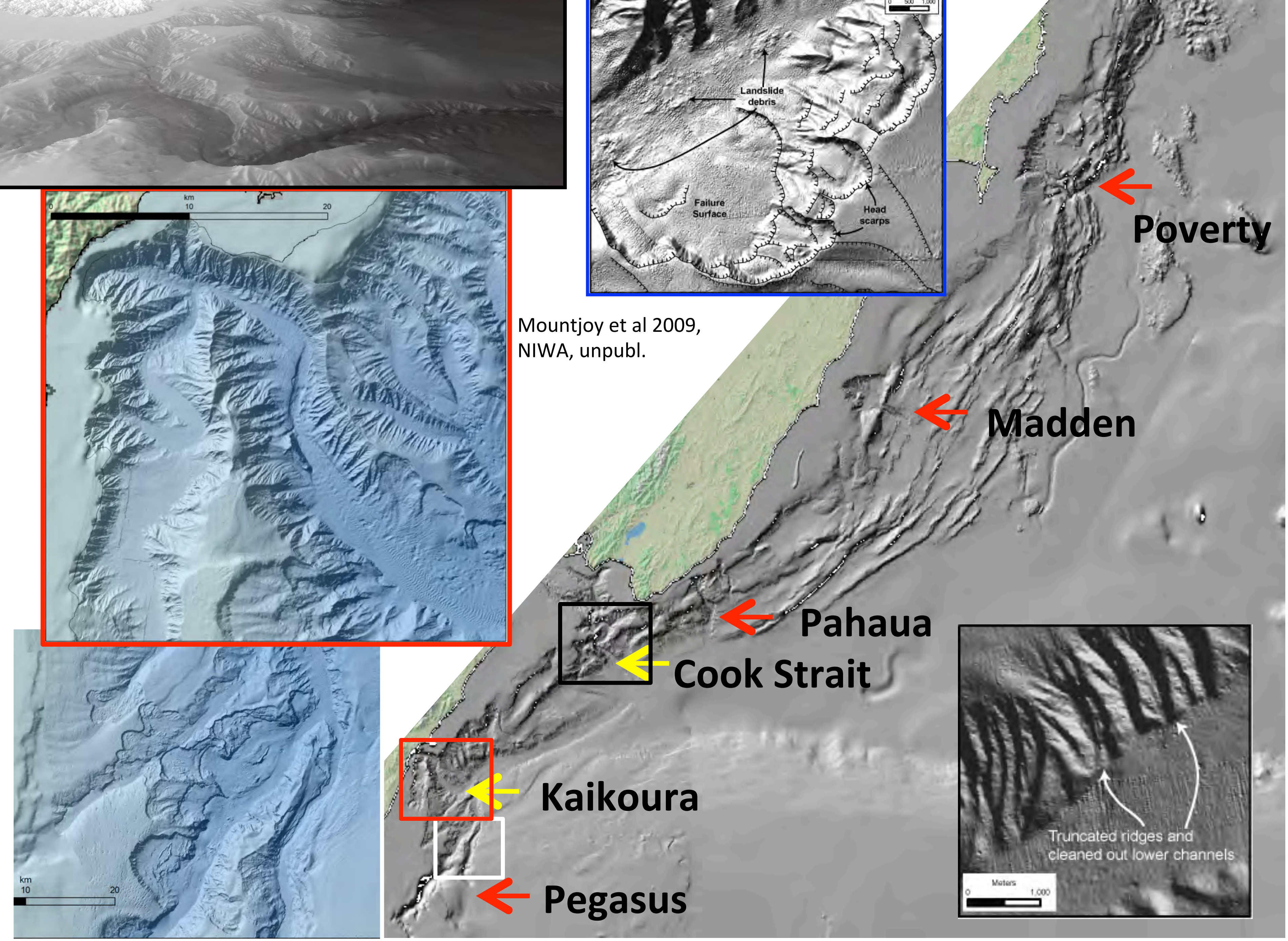
3. **Role of submarine canyons**
4. Input sequence: Hikurangi plateau and trough



Mountjoy et al 2009, NIWA, unpubl.

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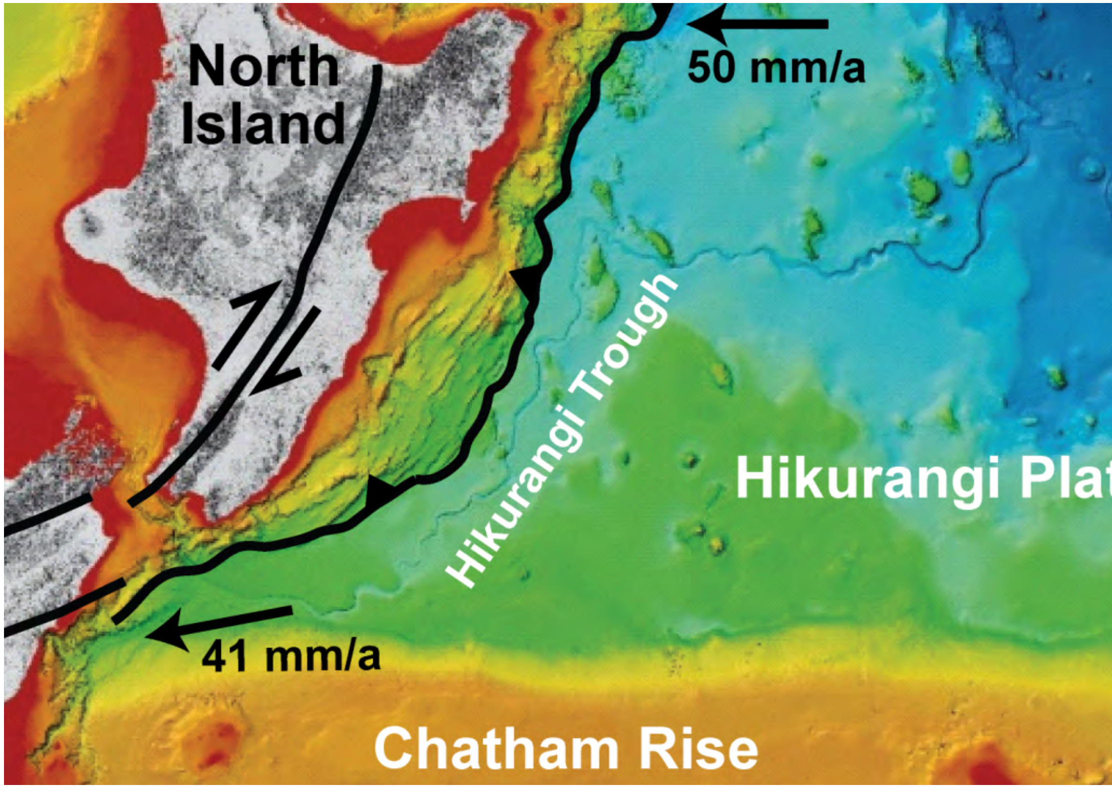
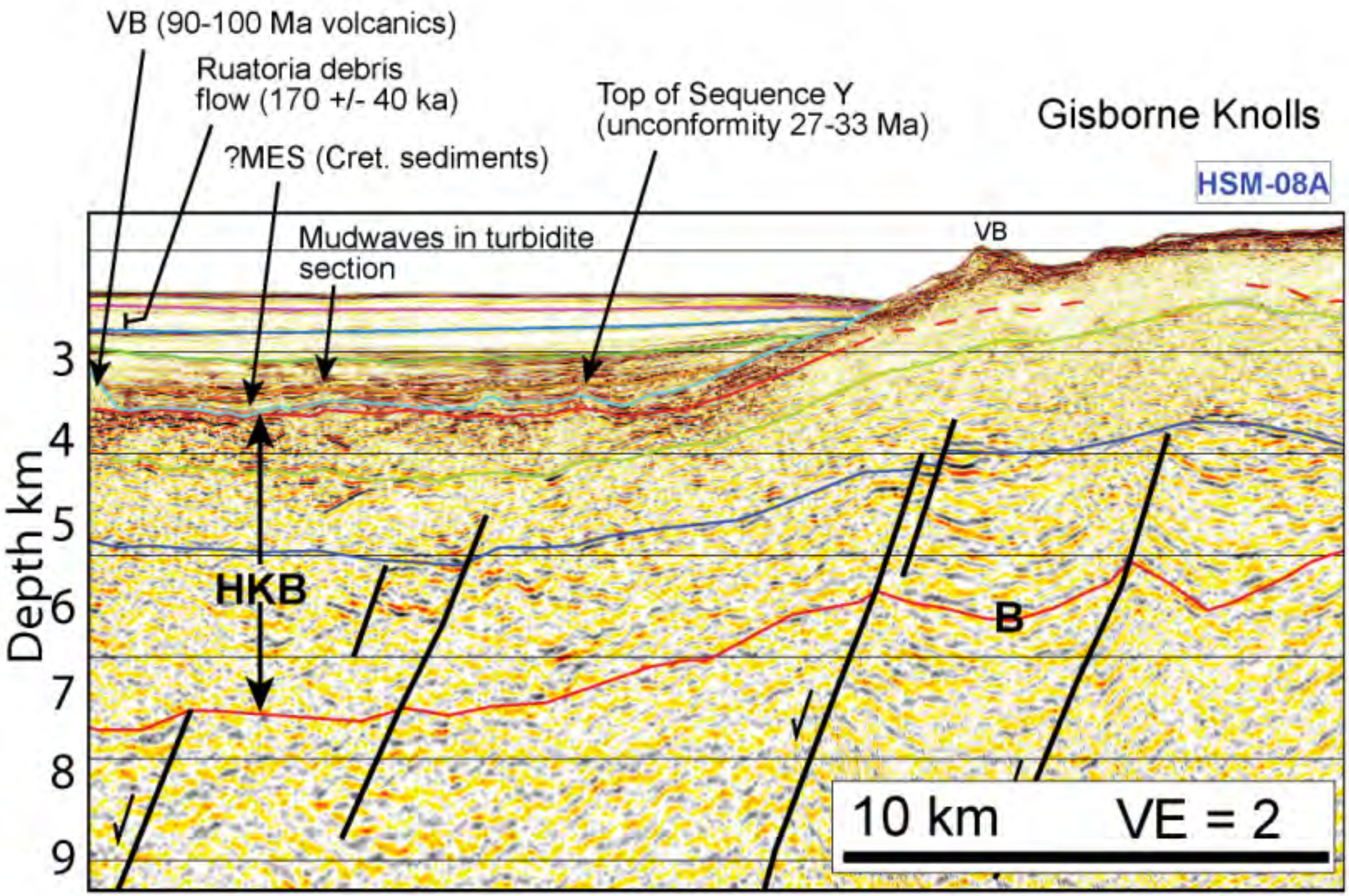
Input Sequence: Hikurangi trough and plateau



Lewis et al 1998

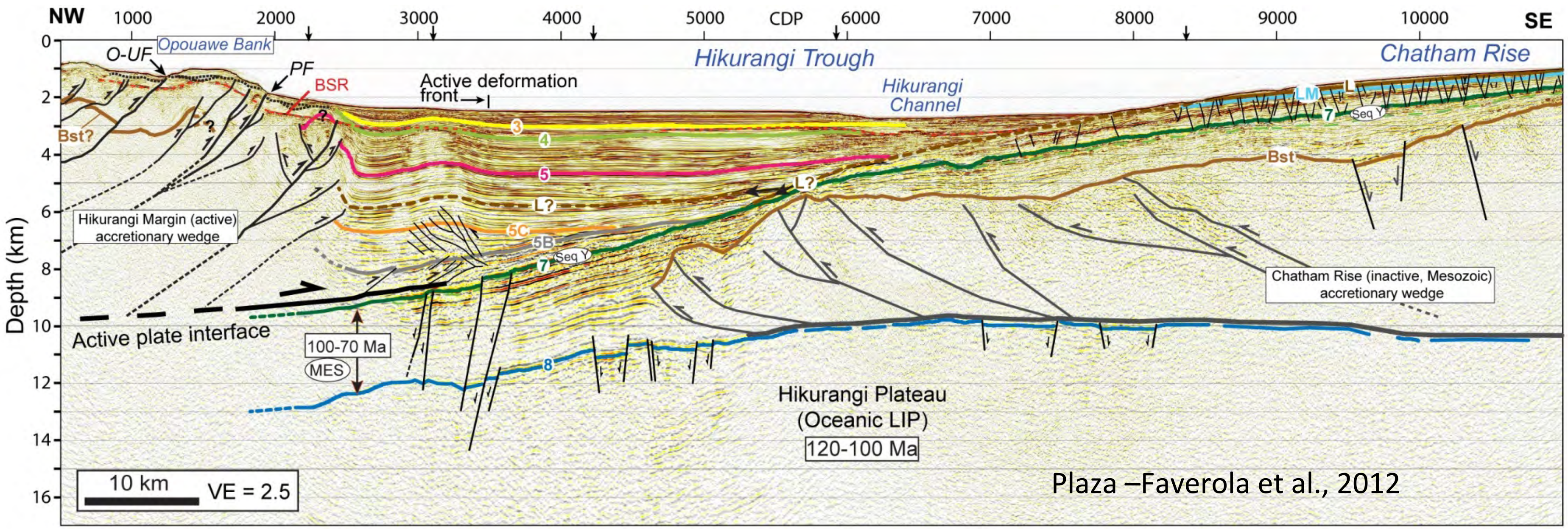
A 120 Ma LIP Plateau with axial trough turbidite system

Input sequence: North Hikurangi

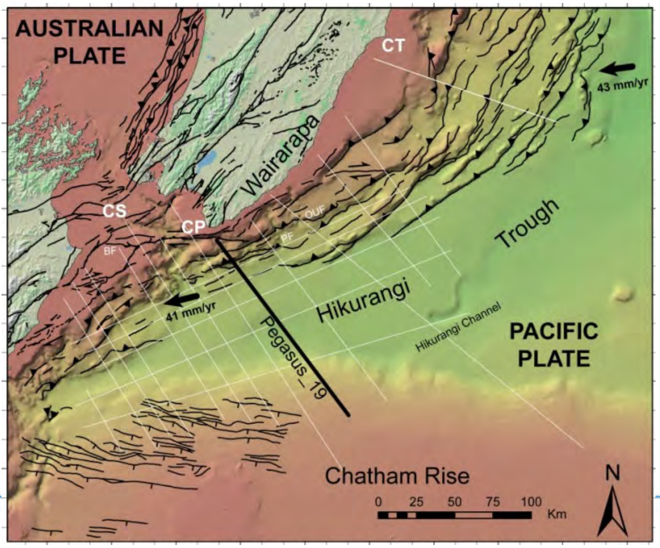


Barnes et al, unpubl

Input sequence: South Hikurangi



Plaza –Faverola et al., 2012

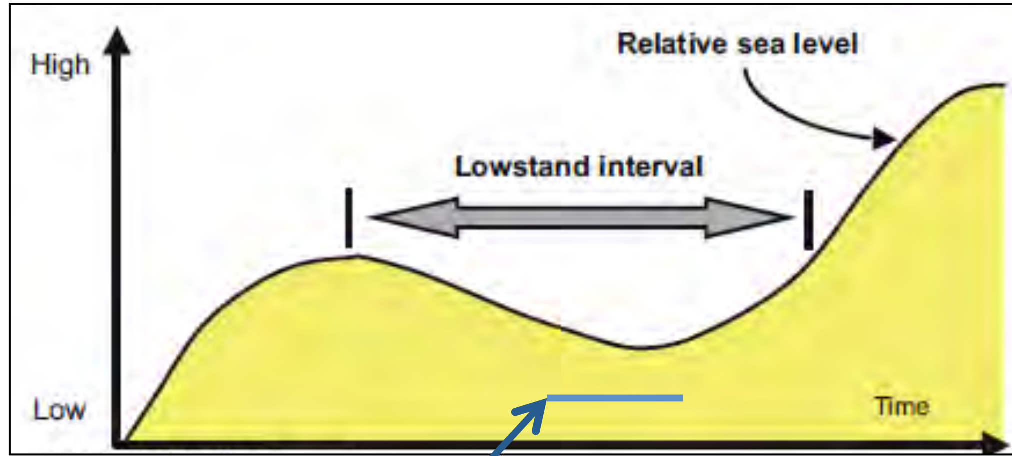


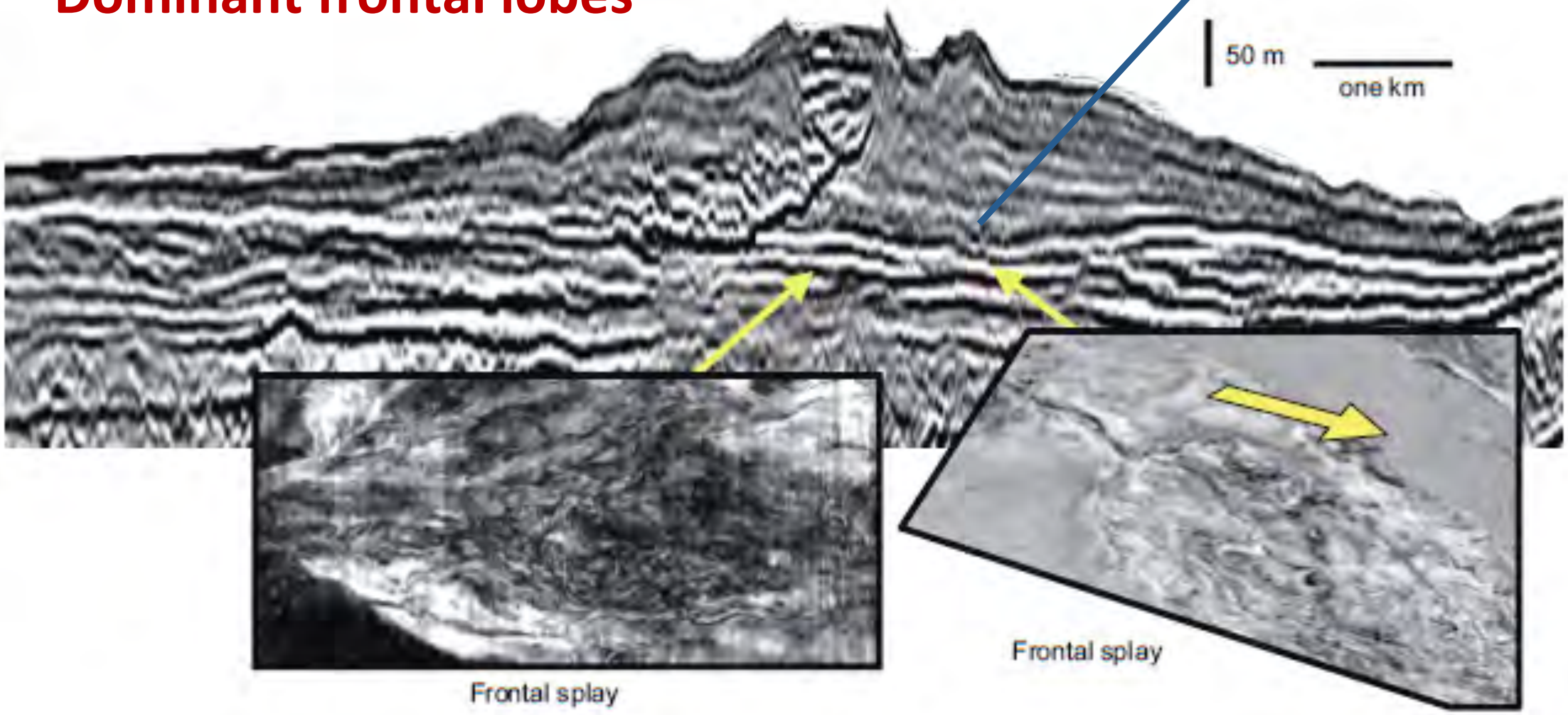
~6 km thick trench-fill, over.....
..... ~3 km thick Chatham Rise sequences

Early low-stand phase

Relatively high sand:mud channel-fan systems:

Dominant frontal lobes



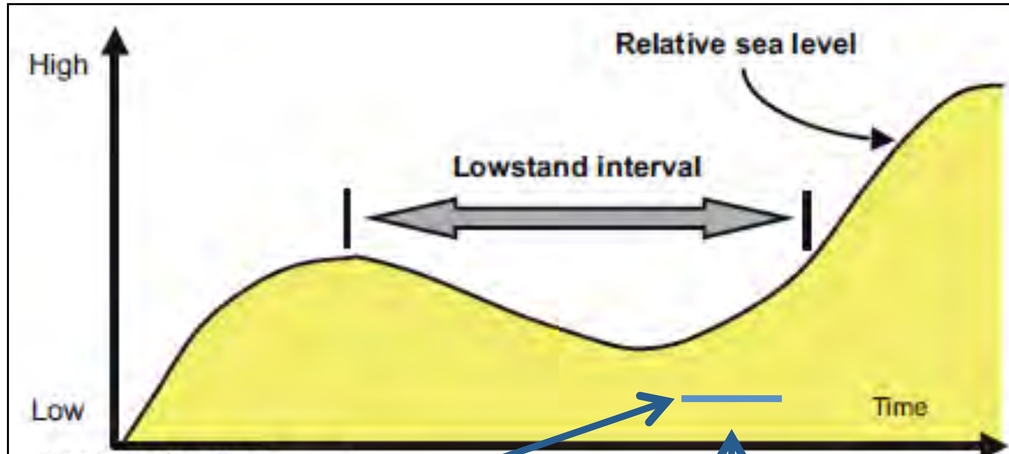


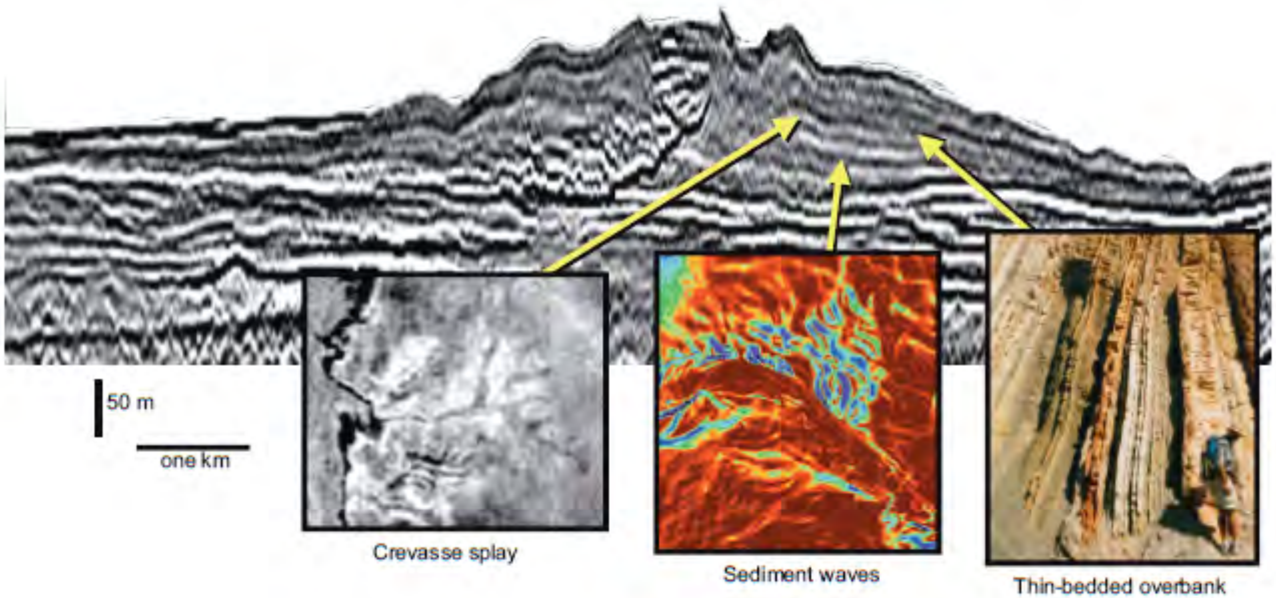
Posamentier & Walker 2006

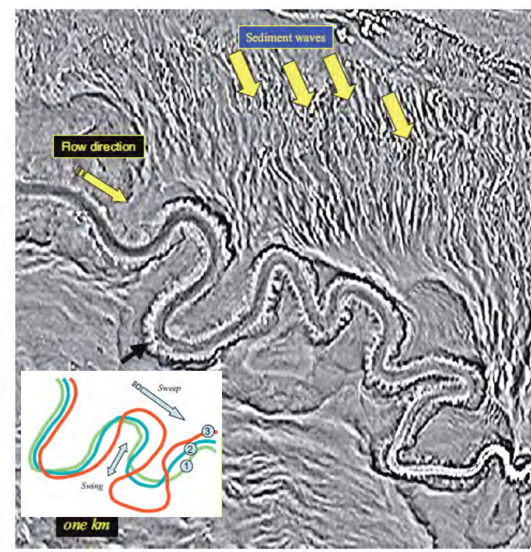
Late low-stand phase

Relatively low sand:mud

Long leveed singular channels over frontal lobes

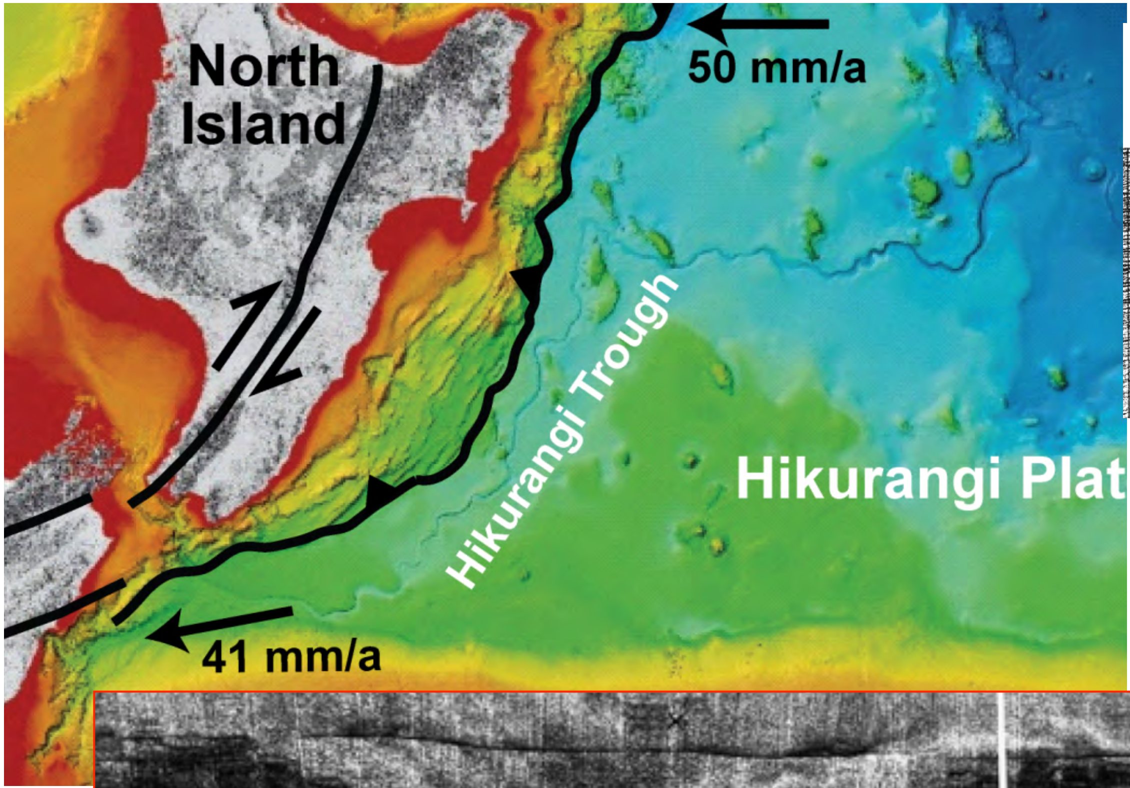


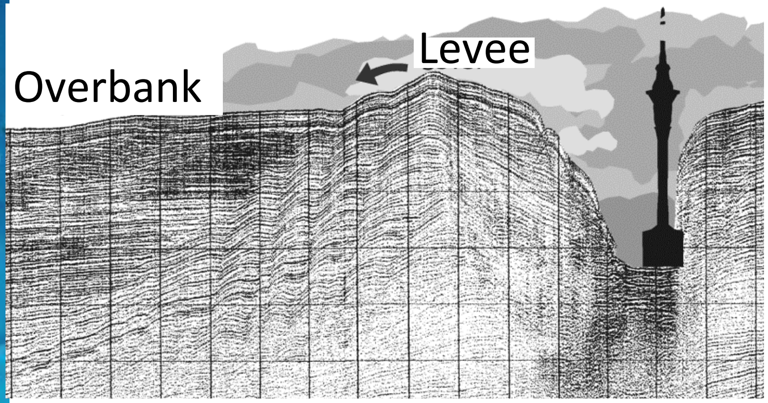


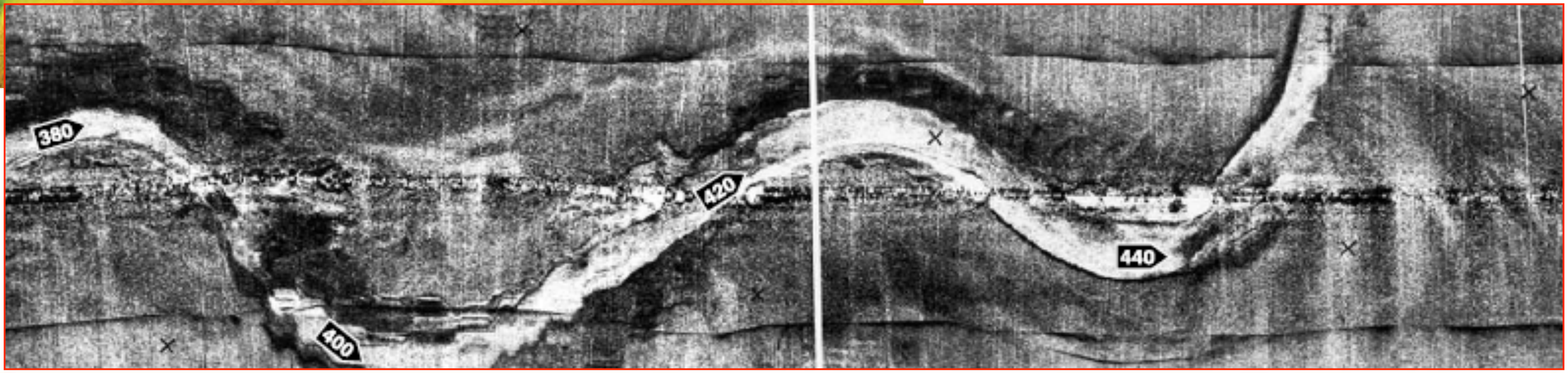


Posamentier & Walker 2006

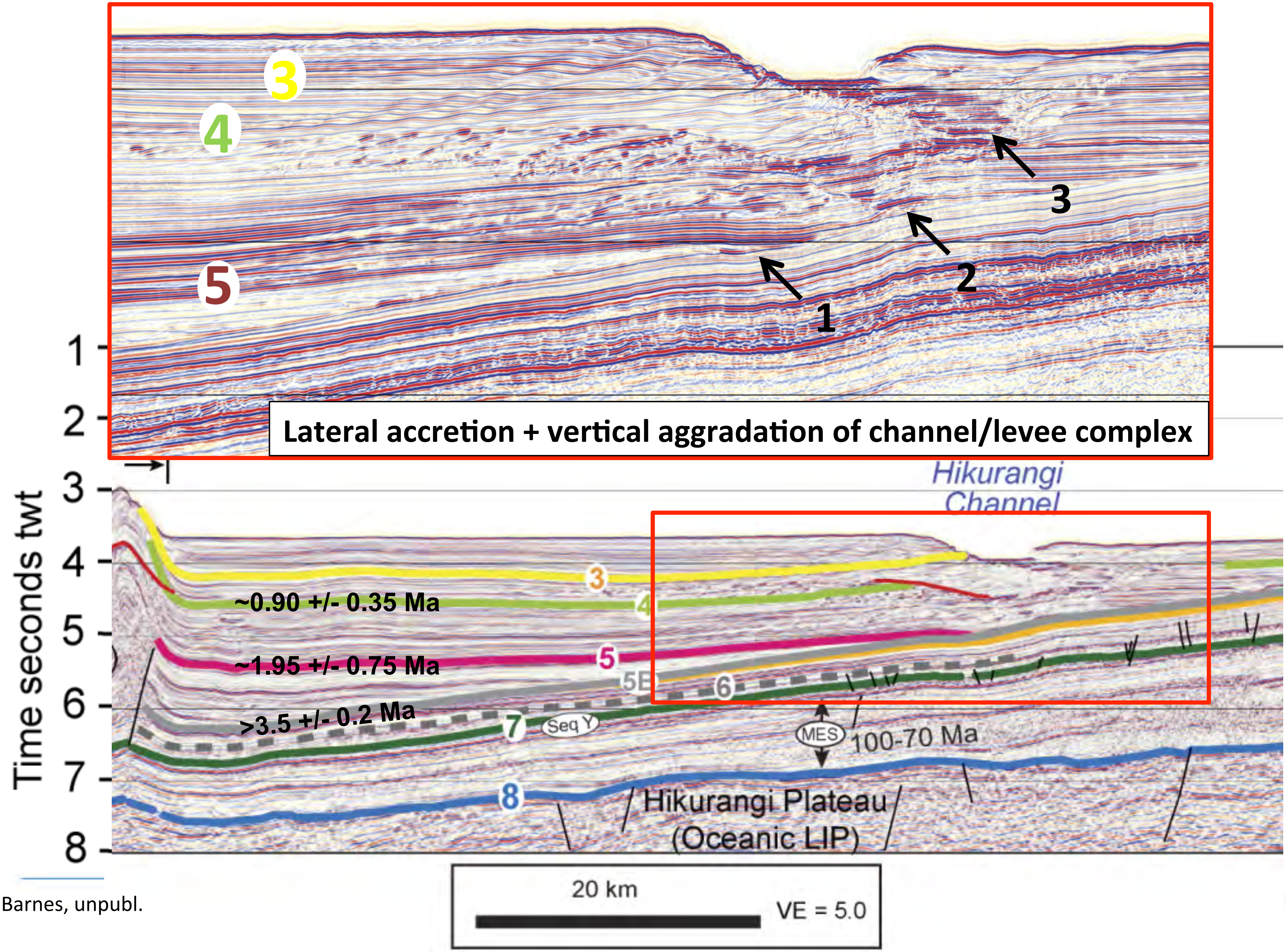
Input Sequence: Hikurangi trough and plateau





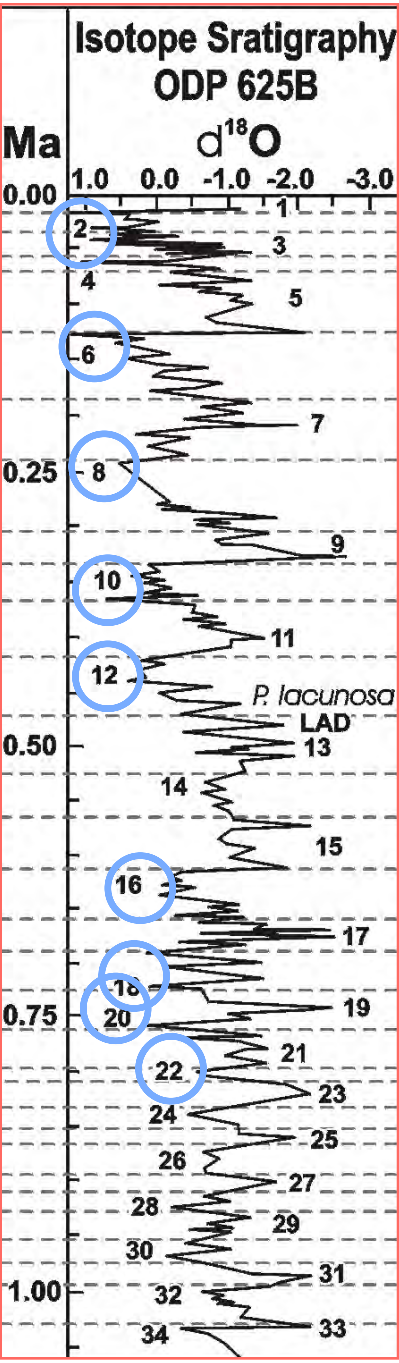


Lewis and Pantin, 2002

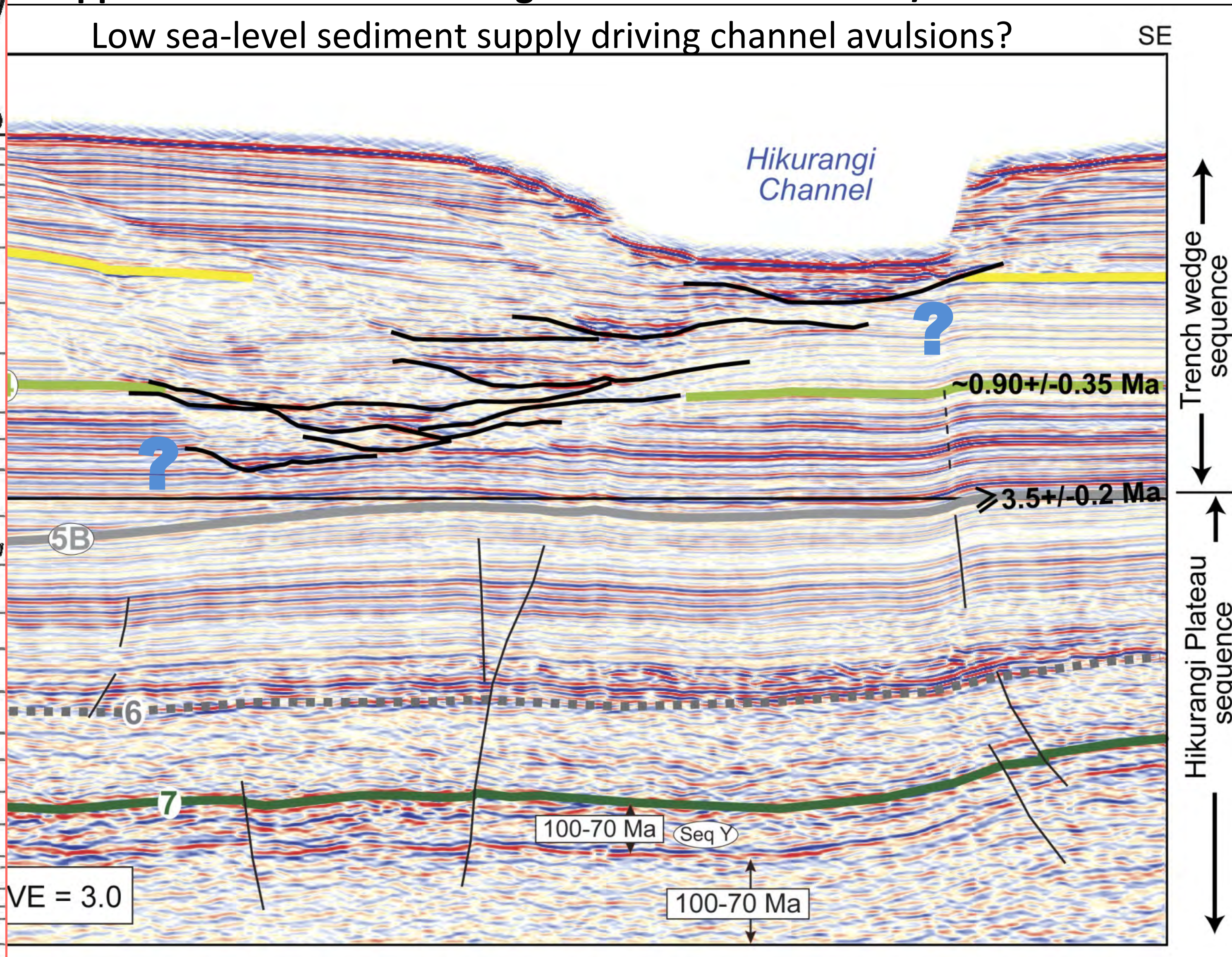


Barnes, unpubl.

Opportunities to construct age models from channel/levee evolution?

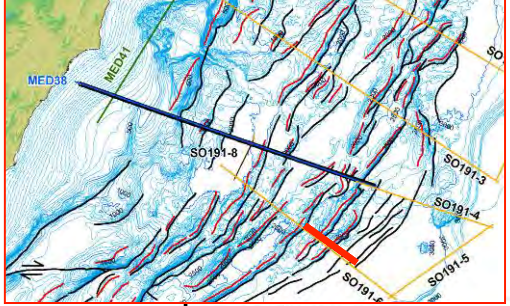


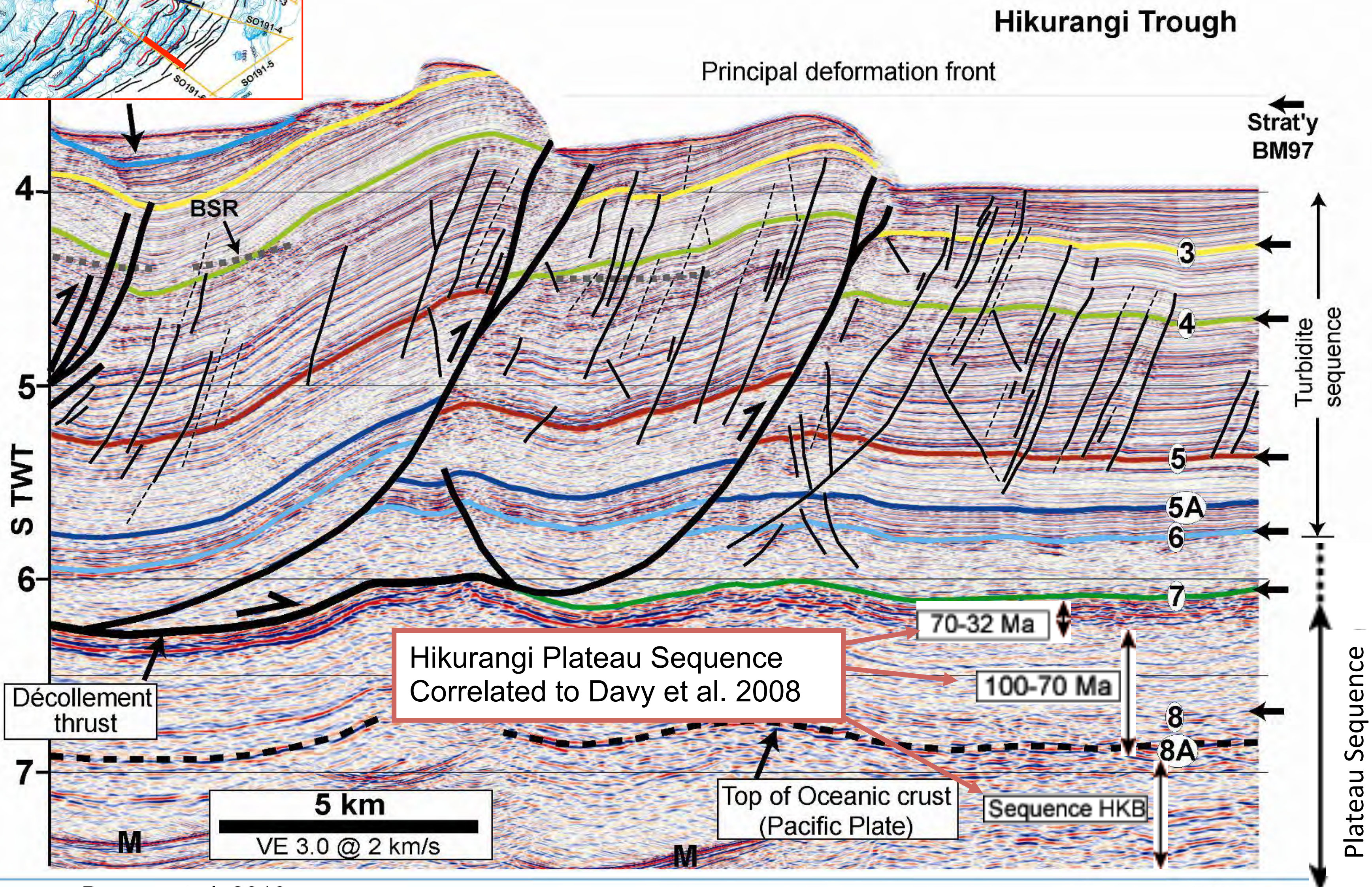
Low sea-level sediment supply driving channel avulsions?



Barnes, unpubl.

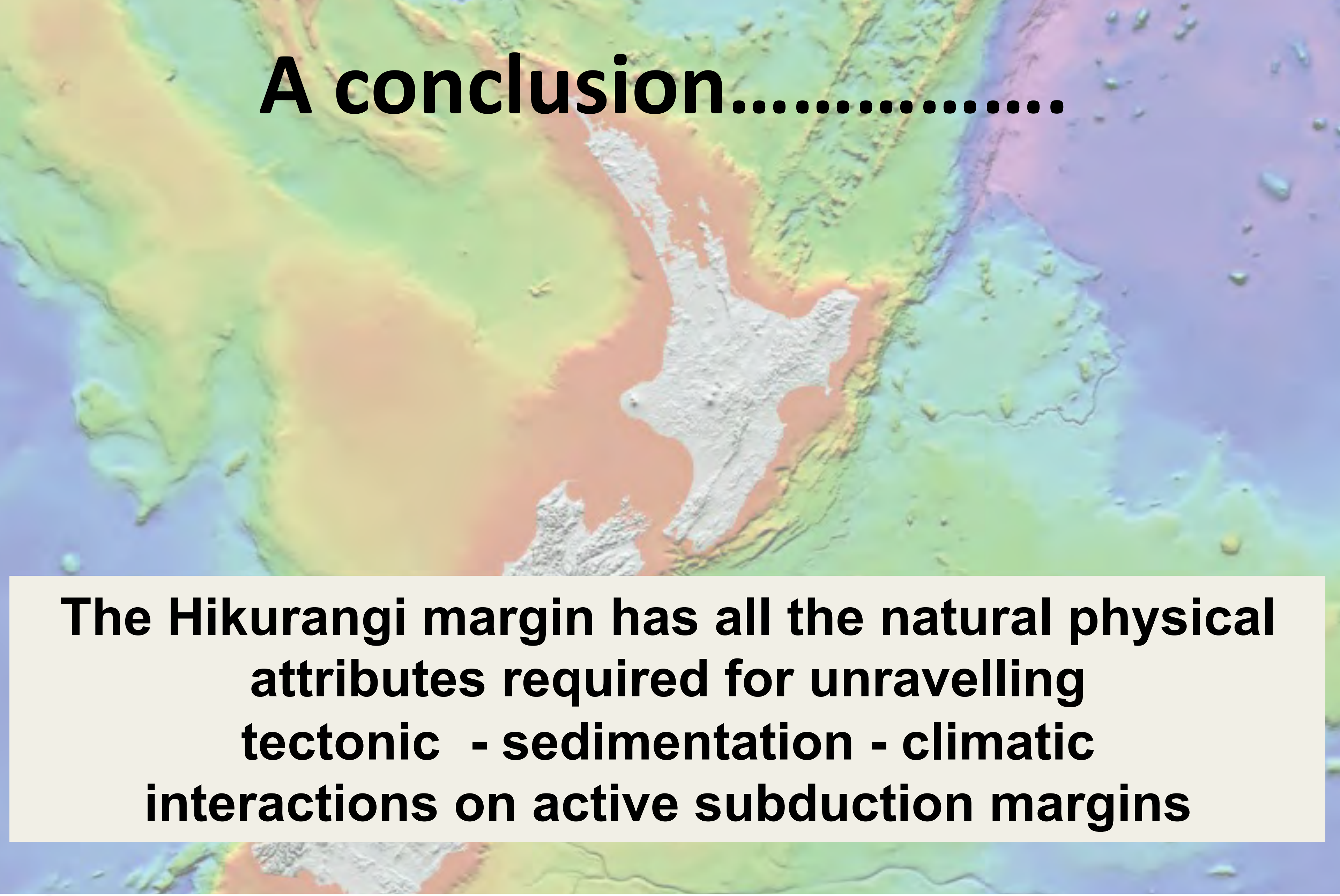
Seismic stratigraphy of accreting and subducting sequences





Barnes et al. 2010

A conclusion……………..



The Hikurangi margin has all the natural physical attributes required for unravelling tectonic - sedimentation - climatic interactions on active subduction margins