3-D Seismic Geomorphology of a Deepwater Slope Channel System: The Sequoia Field, Offshore West Nile Delta, Egypt*

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Abstract

Within the Nile Delta gas province, reservoirs are dominated by Pliocene slope channel systems, which are spectacularly imaged on 3-D seismic data. We deal with the detailed seismic geomorphology of the Sequoia channel system, focusing on the geometry and distribution of its component sandbodies, their 3-D evolution in response to channel filling and the impact this has on reservoir heterogeneity.

The reservoir stratigraphy comprises a heterogeneous succession of sandstones and mudstones organized into a composite upward-fining profile. Component sandbodies are dominated by laterally amalgamated channels, sinuous channels and channel with frontal splays, and are interpreted to be the products of deepwater, gravity-flow processes. Above a basal incision surface, the reservoir is highly sand-prone and comprises laterally amalgamated channels. The medial section of the reservoir is more aggradational and exhibits laterally isolated and sinuous channels. Within the upper part of the reservoir, channels are smaller, straighter and built of individual channels with frontal splay elements. Shale and thin-bedded facies become an increasingly important component of the stratigraphy in the upper parts of the reservoir. The main channel is buried by a prograding slope succession that includes lobate sandsheets. The stacking of facies within the Sequoia channel system implies a punctuated waning of sediment supply prior to eventual abandonment.

The channel system also shows considerable evidence for syn-sedimentary faulting, including a large-scale, down-dip widening of the channel across a field-traversing flexure, small-scale channel diversions around a fault-tip and intra-slope ponding of flows on a footwall high. Sequoia has the geometry, dimensions and internal sandbody organization that are consistent with the infilling of a 3rd-order lowstand channel incision. The channel fill culminates in a blanketing shale unit which delineates a major correlatable hot shale event, and on seismic data corresponds to a prominent down-lap surface (candidate maximum flooding surface).

Given the vertical variability in reservoir quality, understanding reservoir architecture in terms of sandbody geometries and connectivity is vital since across most of the field the gas column occupies the most complex and heterogeneous part of the reservoir. Correspondingly, the basal sand-rich part of the reservoir is likely to significantly influence aquifer behaviour during production.

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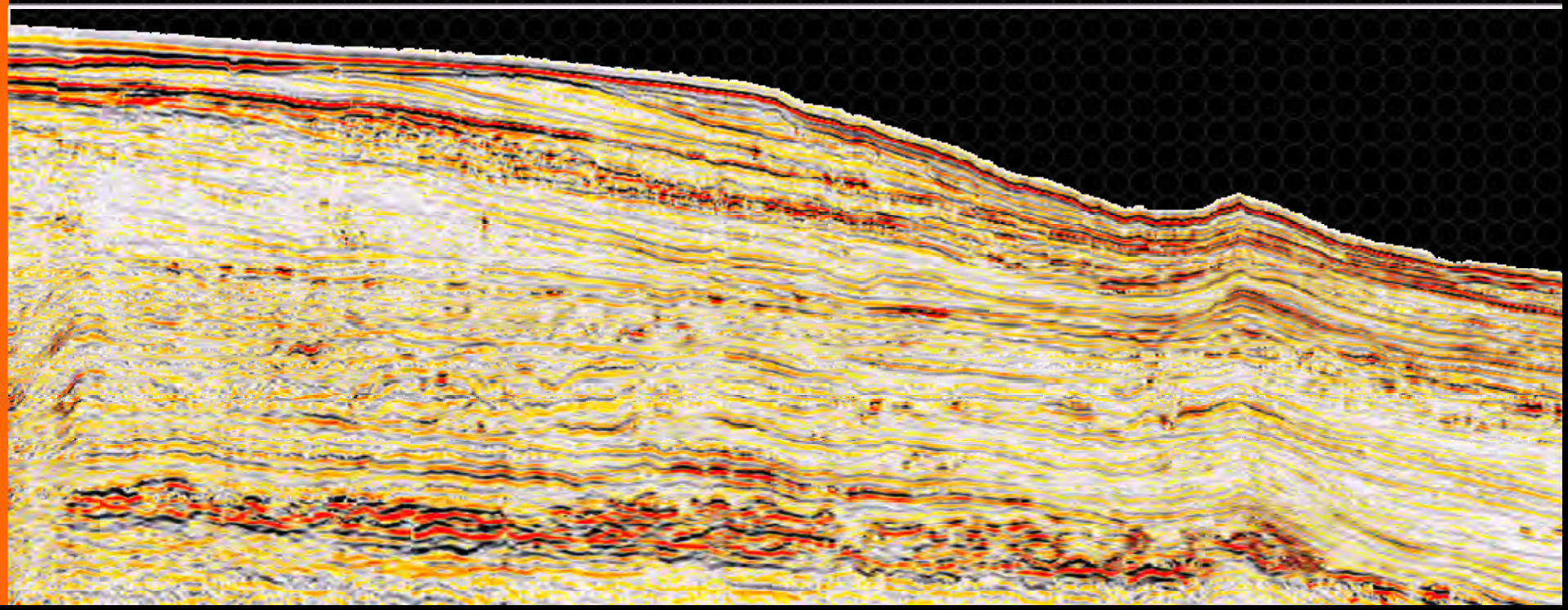
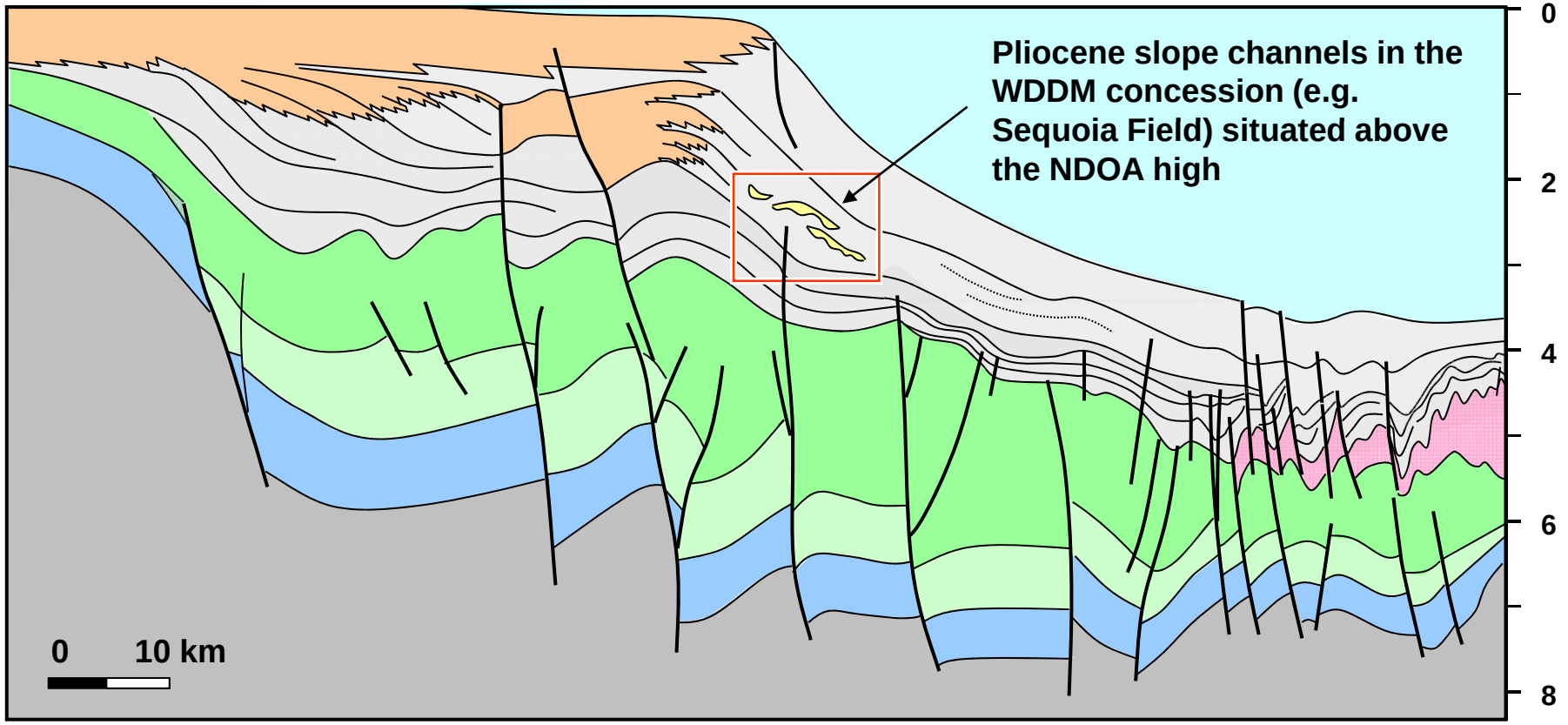


Presentation Outline

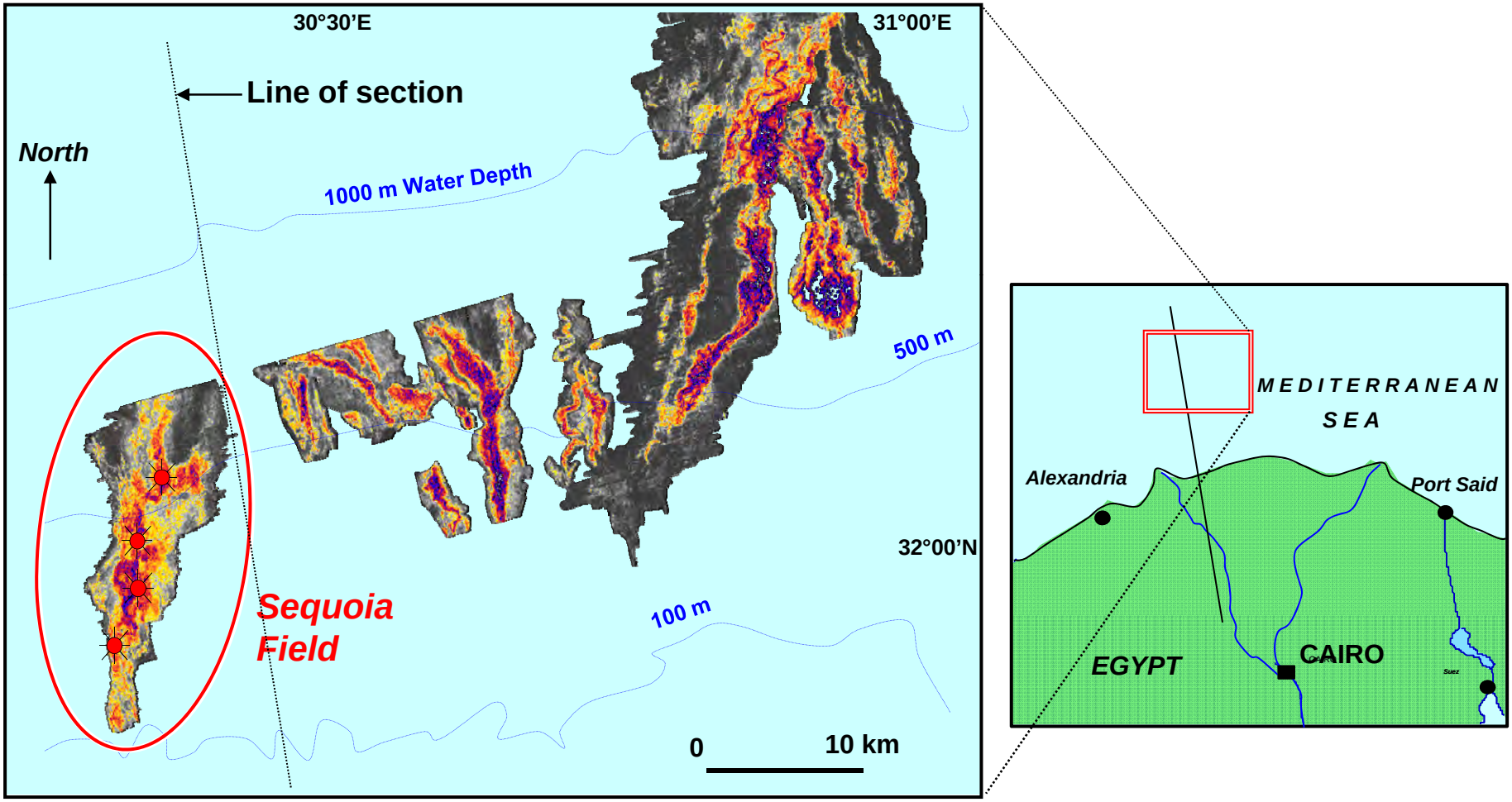
- Regional Setting
- Sequoia Field Overview
- Sedimentology
- Large-Scale Reservoir Architecture
- Sequence Stratigraphic Context
- Component Sandbodies
- Channel System Evolution
- Conclusions - Implications for Reservoir Heterogeneity

Nile Delta – Tectono-Stratigraphic Setting



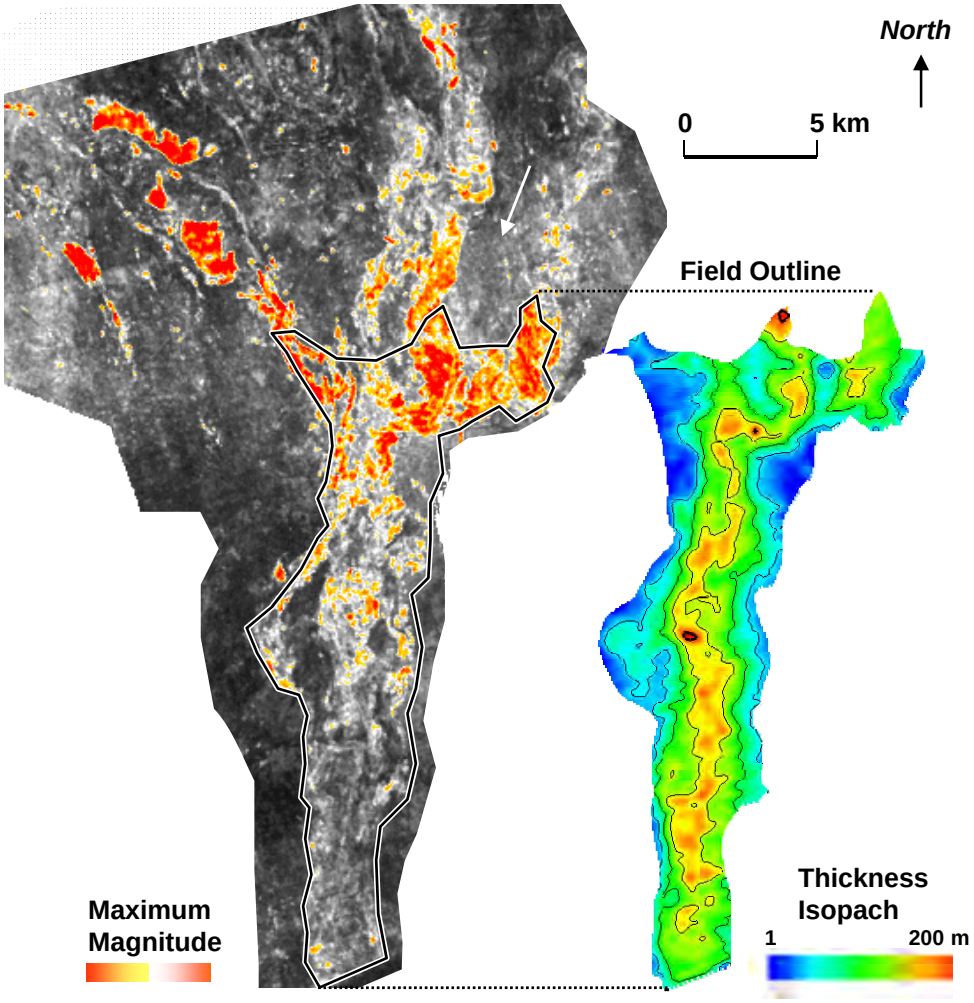
Cross-section modified after Aal *et al.*, 2006

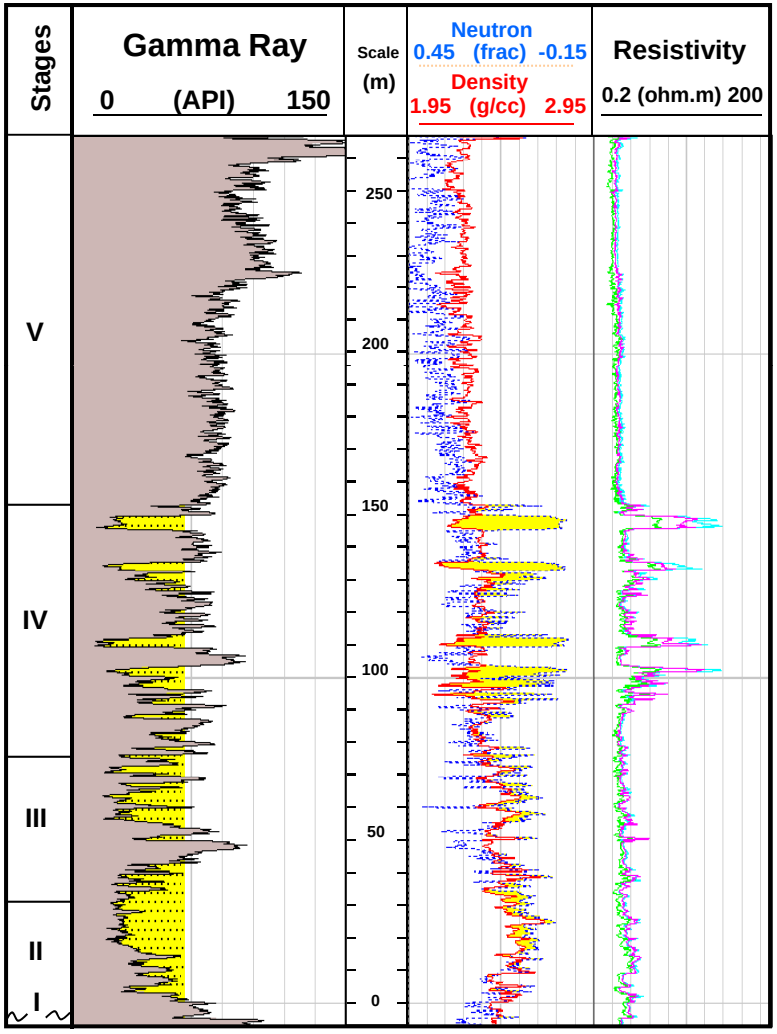
The West Offshore Nile Delta, Egypt



Prolific Pliocene gas province with multi-TCF fields

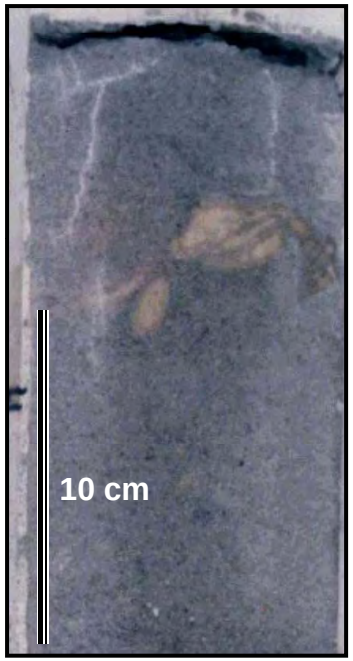
The Sequoia Field – Geological Overview





Sequoia channel system - 10's km long, *c.*5km wide and up to 200m thick

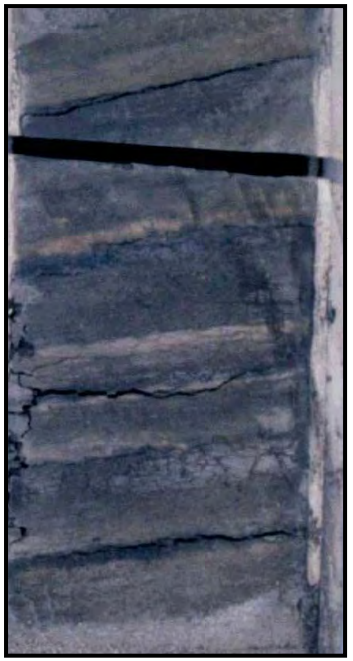
Sedimentological Character



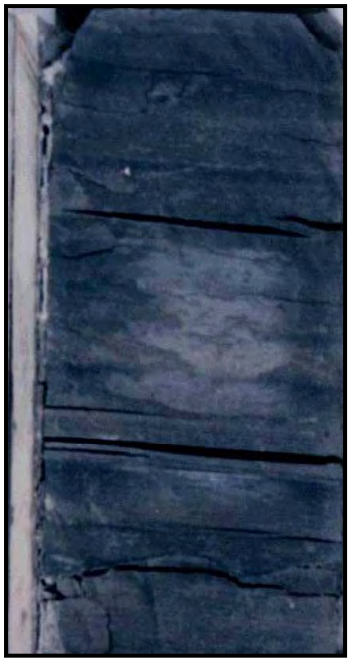
Massive sandstones – erosional bases and commonly sharp tops.

Graded sandstones

Injected sandstone beds



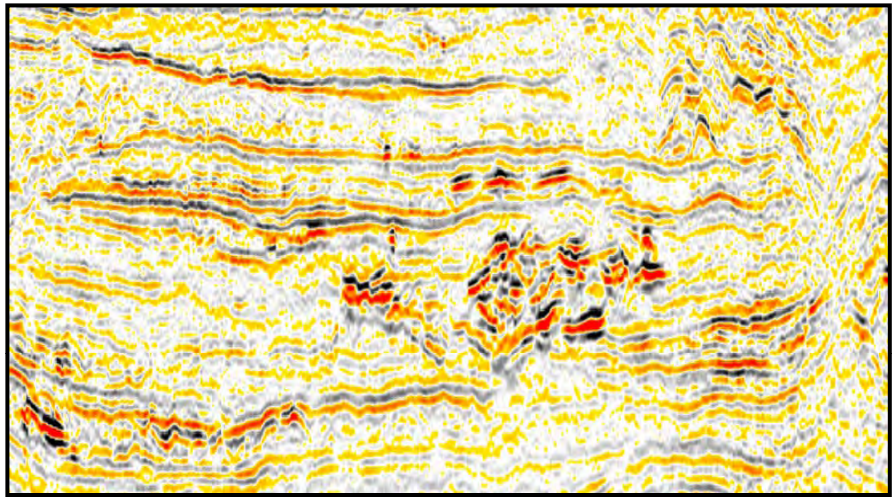
Thinly bedded (cm-scale) sands and shales

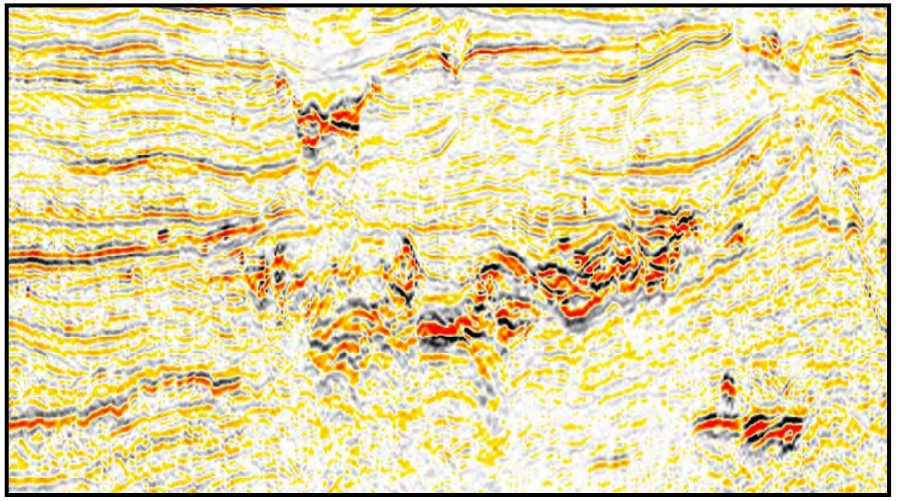


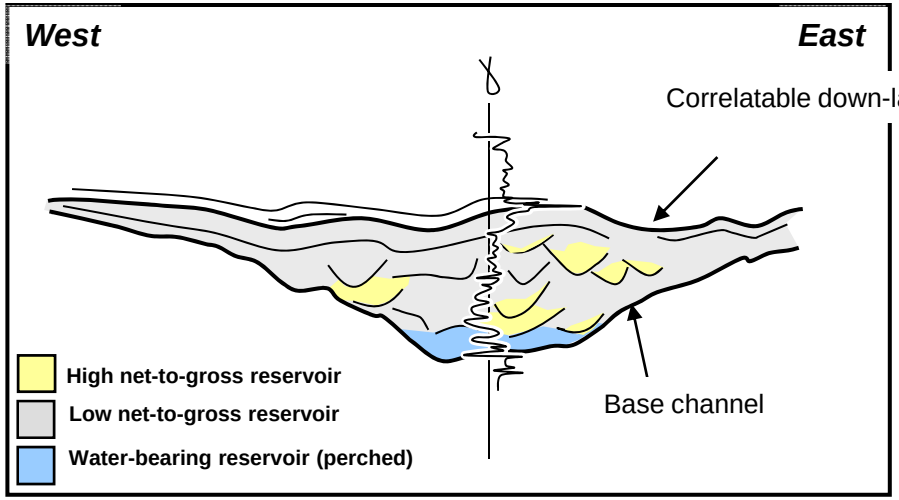
Laminated pelagic shales

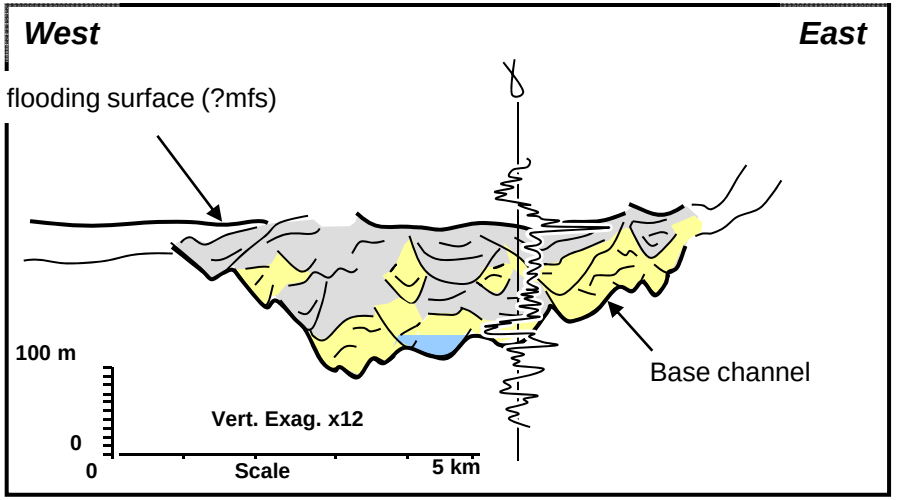
A range of sandstone and thinly bedded, channelised gravity flows

Large-Scale (Strike) Reservoir Architecture



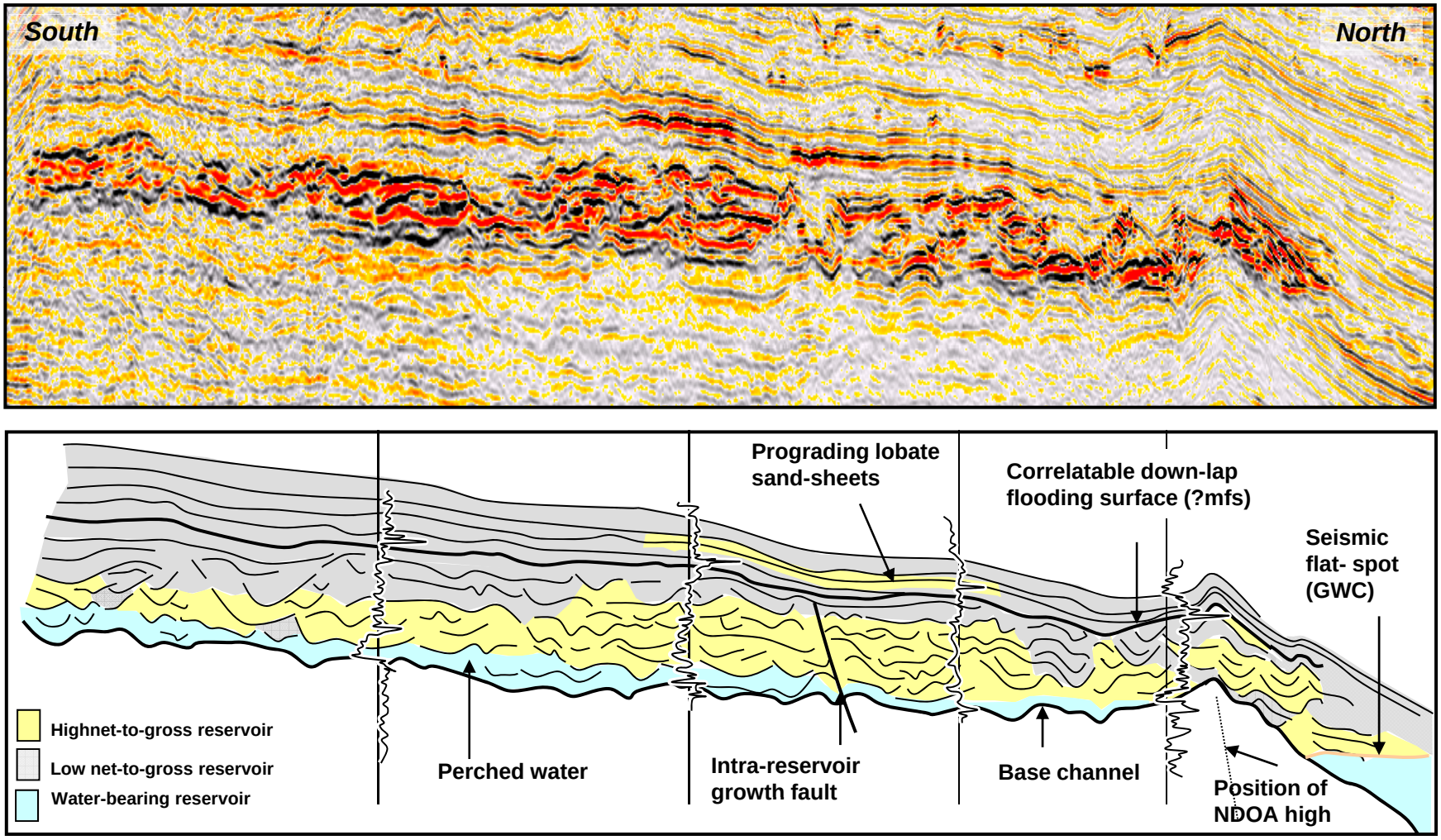






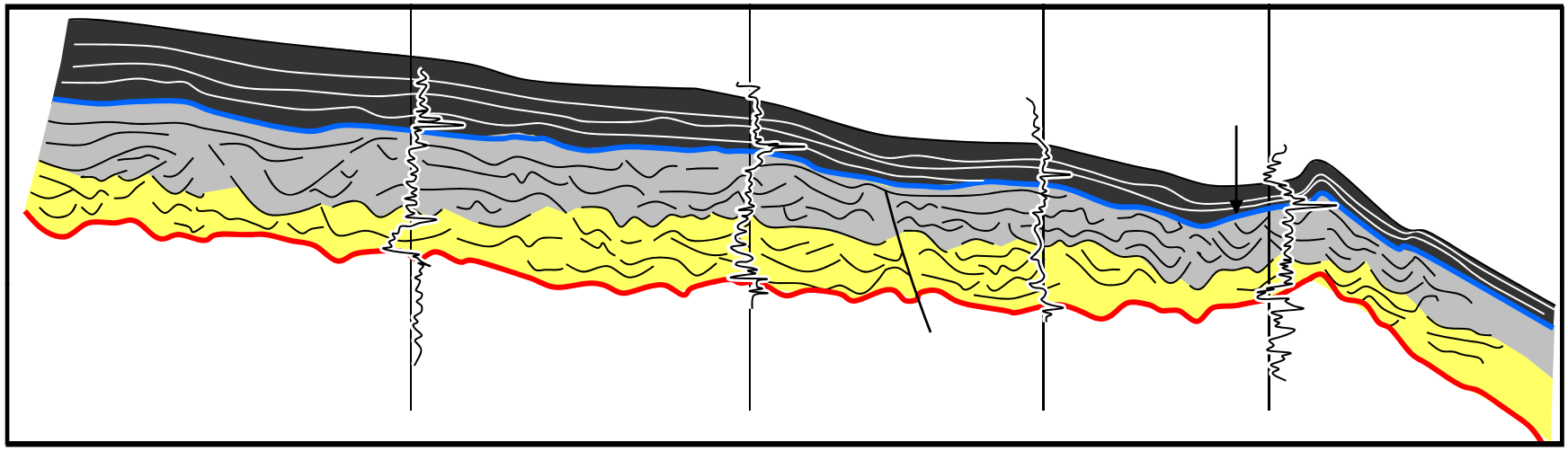
Major basal erosion surface with ‘nested’ channelised fill

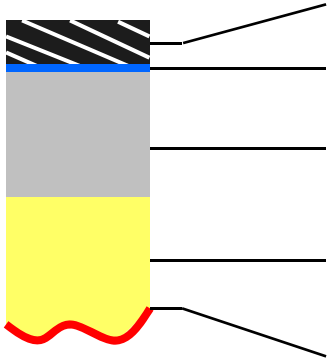
Large-Scale (Dip) Reservoir Architecture



Perched water in topographic lows – unconnected to regional aquifer?

Sequence Stratigraphical Context





Prograding top-seal slope deposits — Highstand Systems Tract

Correlatable seismic down-lap surface — Maximum Flooding Surface

Low net-to-gross with thin-beds and small sandy channels — Late Lowstand-Transgressive Systems Tract

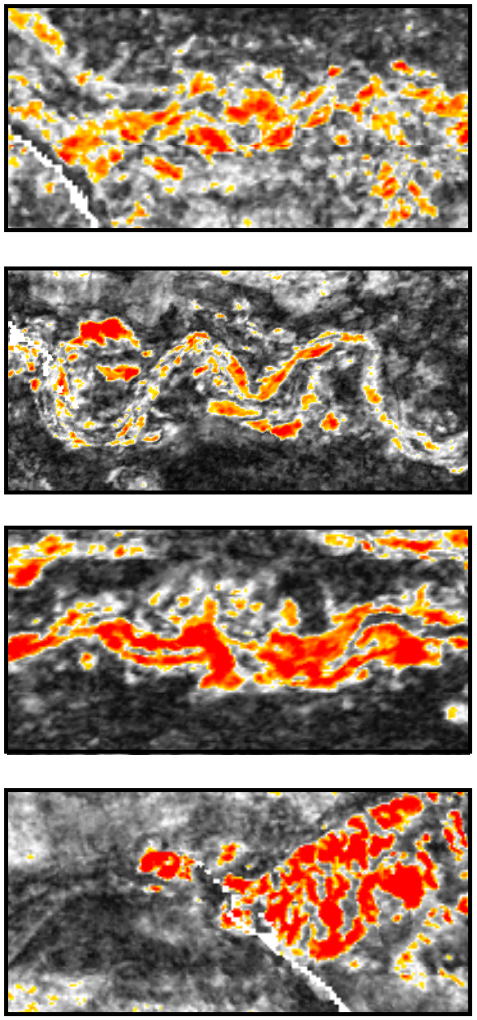
High net-to-gross with with well developed channel sandbodies — Lowstand Systems Tract

Major slope incision surface — Sequence Boundary

Lowstand incision with late lowstand to transgressive fill?

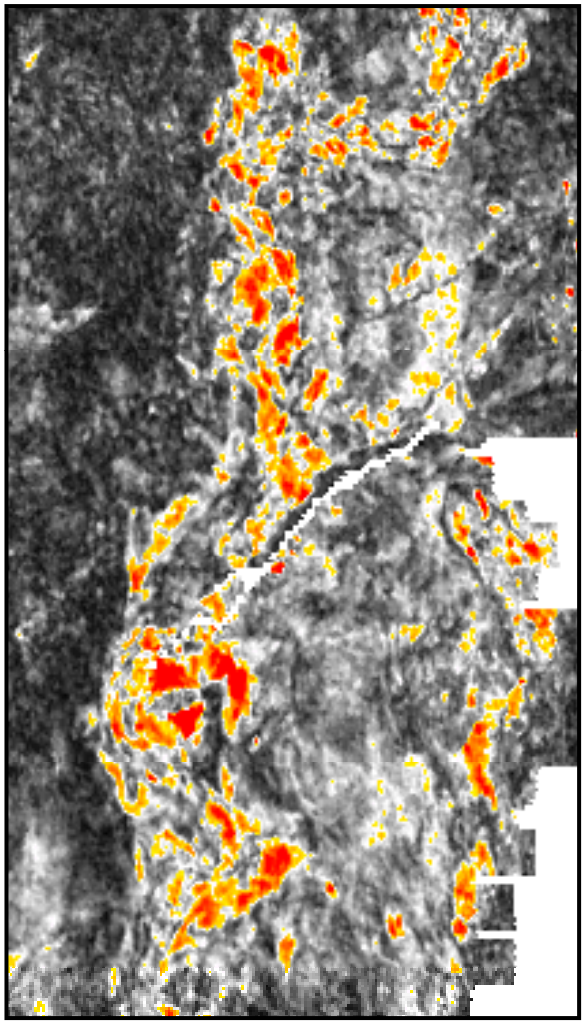
Component Sandbodies

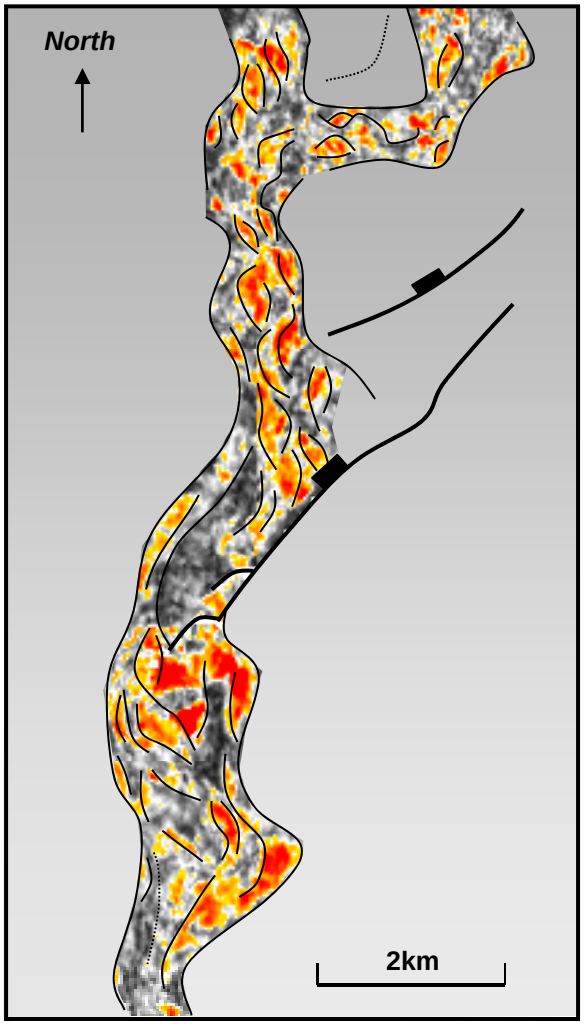
- Laterally amalgamated channels
- Aggrading sinuous channels
- Channels with frontal splays
- Prograding sandsheets



Seismically-defined elements calibrated by core and FMI data

Laterally Amalgamated Channels

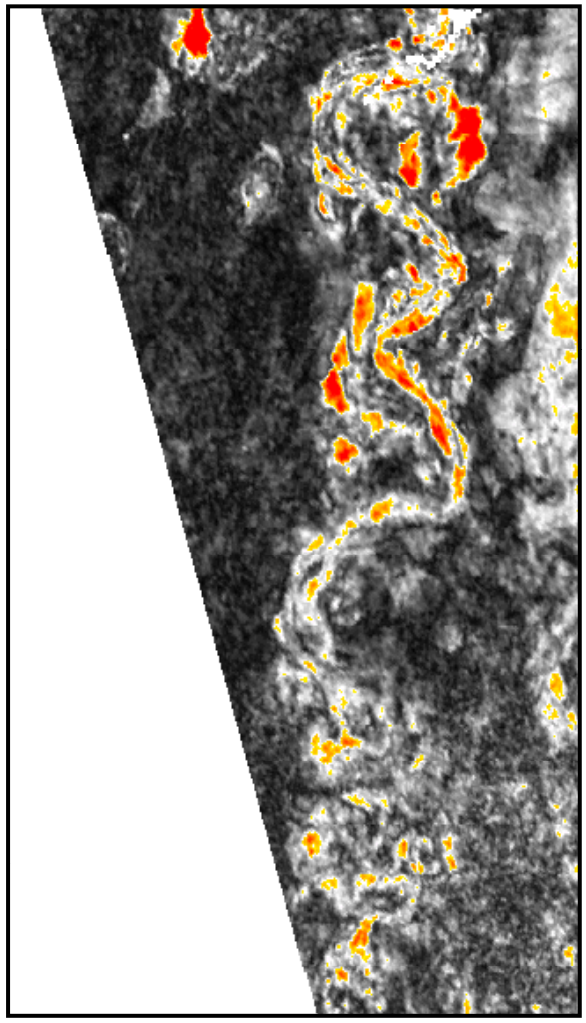


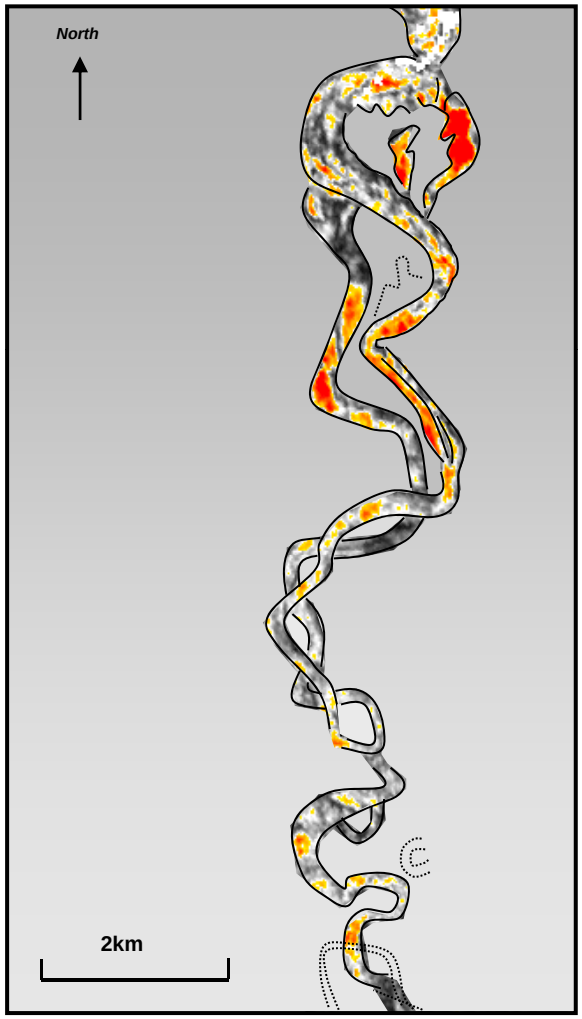


- Channel ‘belt 1-2km wide
- Remnant ‘pods’ 100’s m scale
- Channels up to 30m thick

Basal part of channel system dominated by laterally stacked channels

Aggrading Sinuous Channels

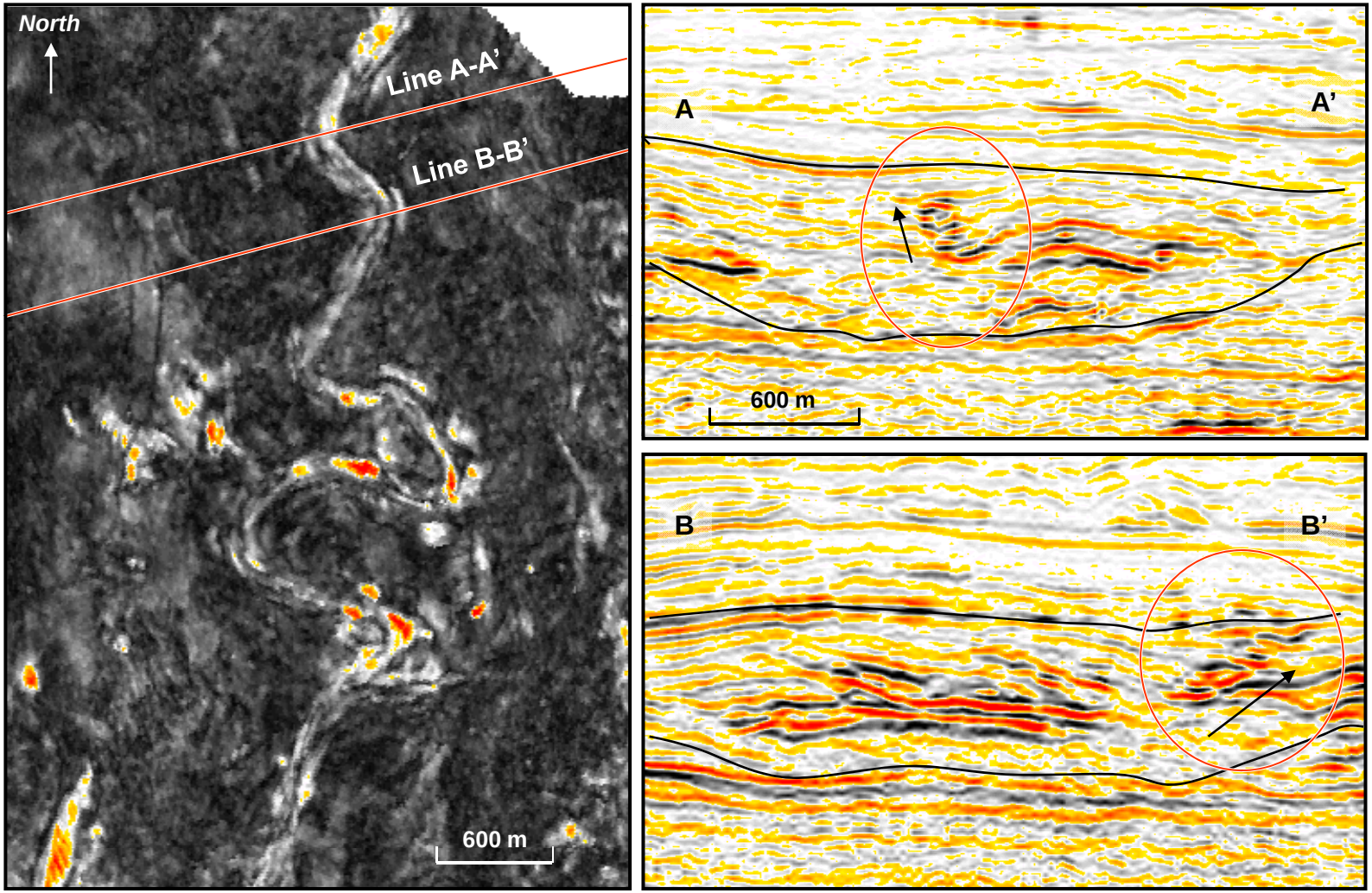




- Channels 10's km long and 50-200m wide
- Thickness' of 10-20m and stacks up to 80m thick.

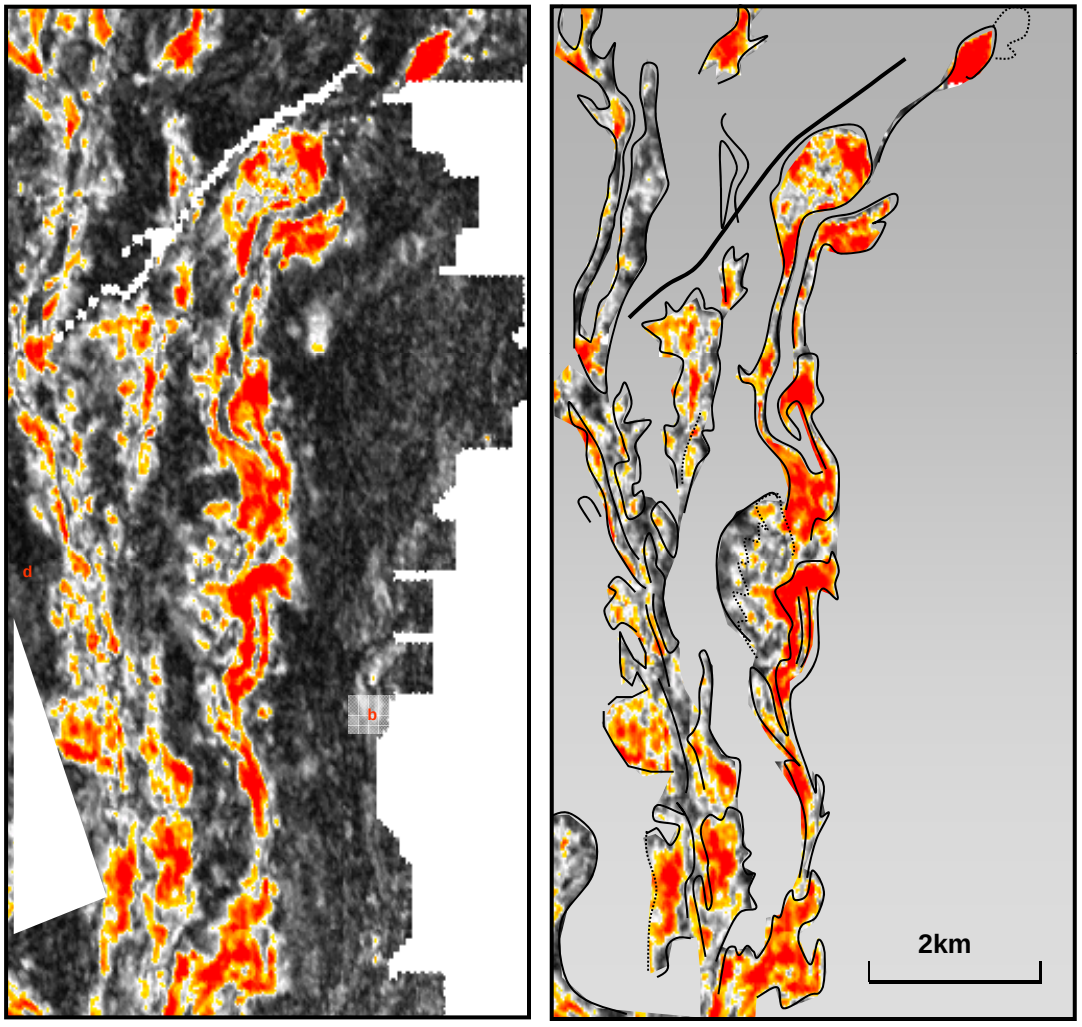
Medial parts of stratigraphy dominated by aggradational channels

Aggrading Sinuous Channels



Aggradational stacking pattern with limited lateral migration

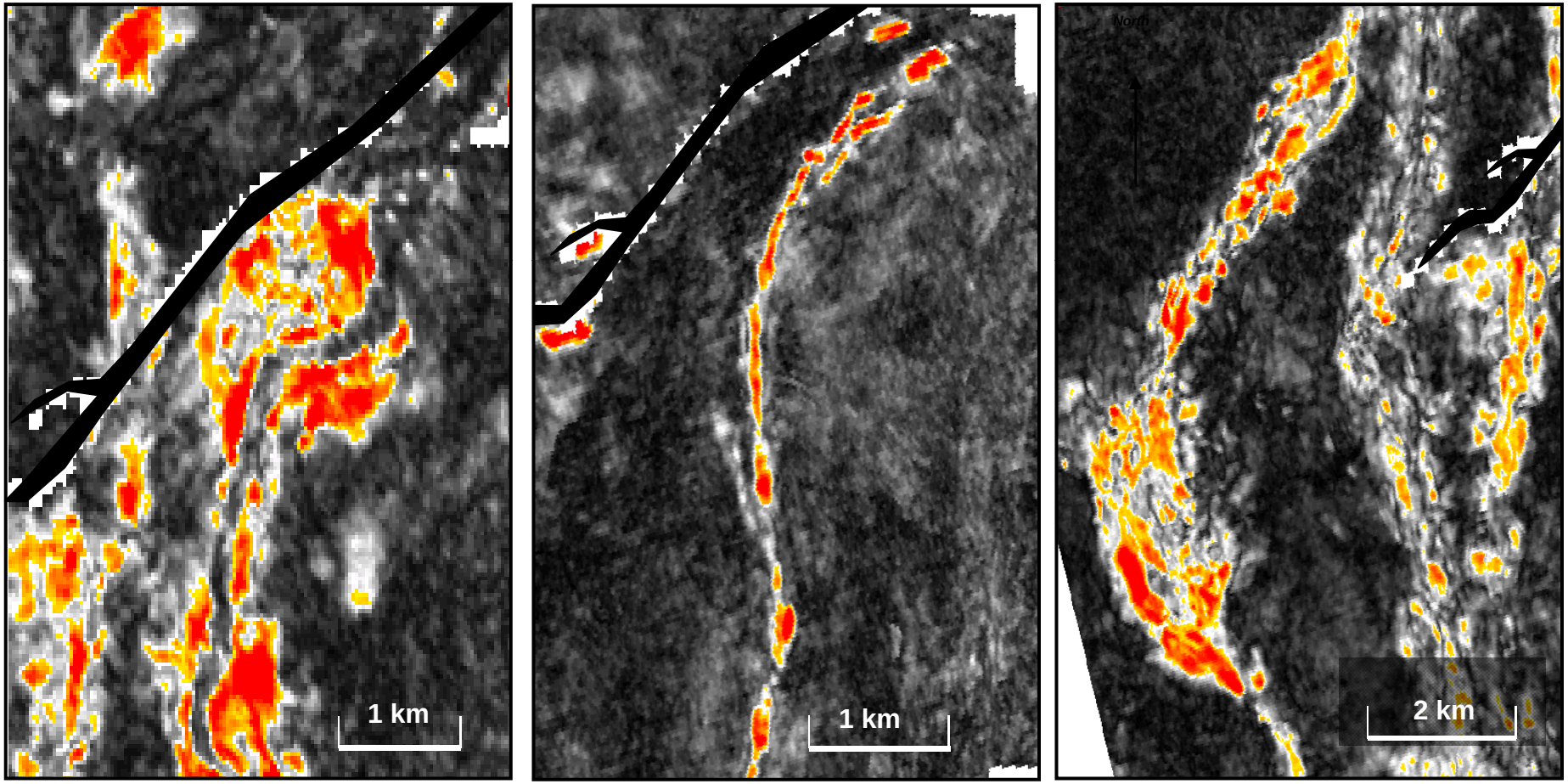
Channels with Frontal Splays



- Channel components are 1-2km long and c.100m wide
- Frontal splays are 1-2km long and 500m and 2km wide
- Sandbodies c.10-15m thick
- Composite sandbodies built of low efficiency flows

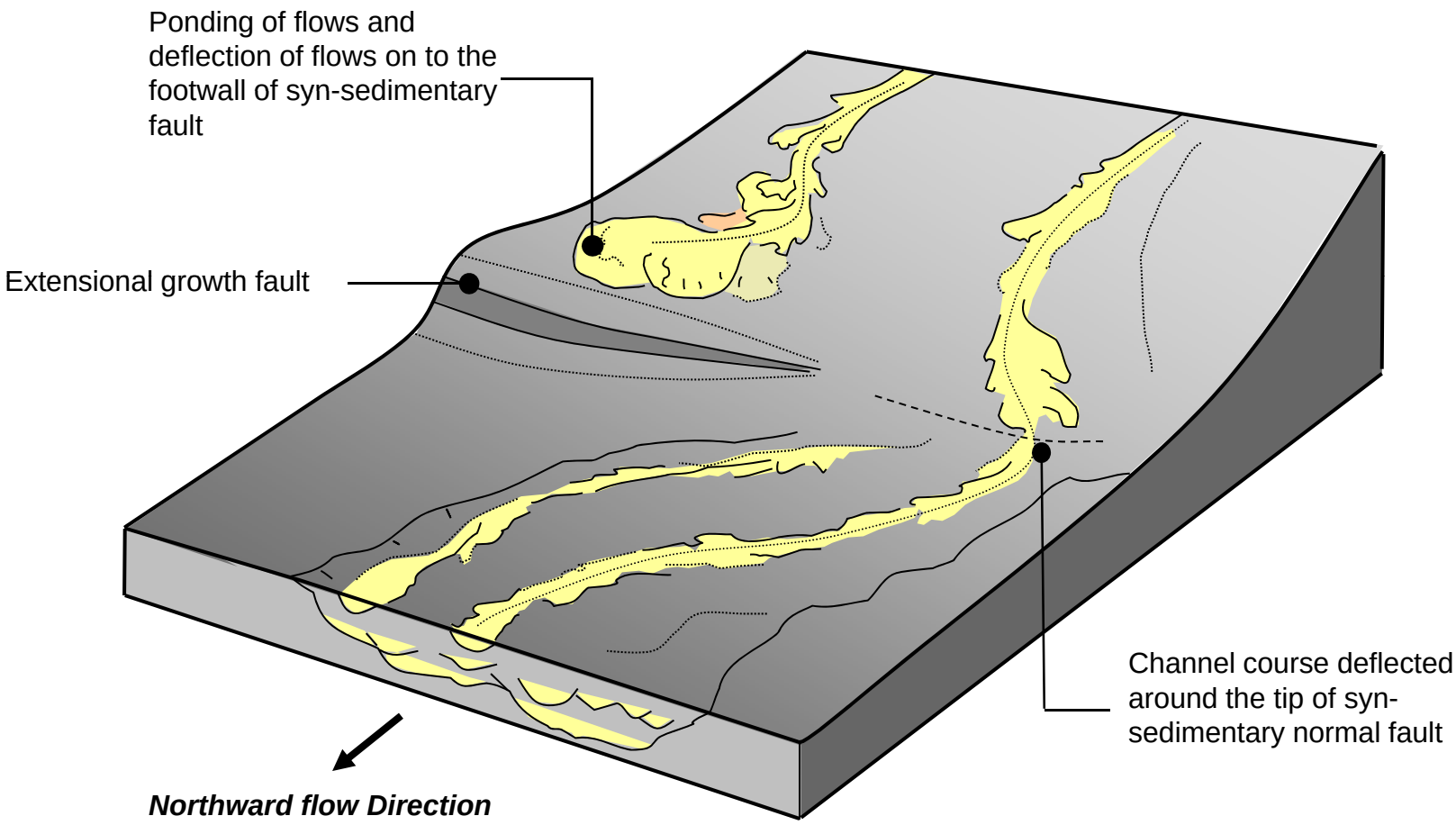
Composite channelised sandbodies built of low efficiency flows

Syn-Sedimentary Tectonics



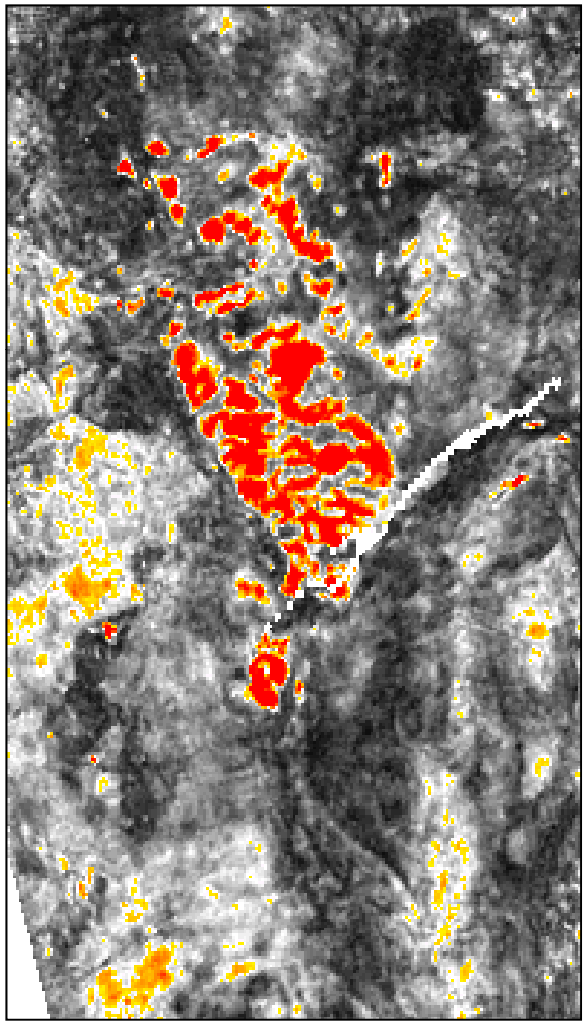
Channel diversions and ponding suggest syn-depositional tectonics

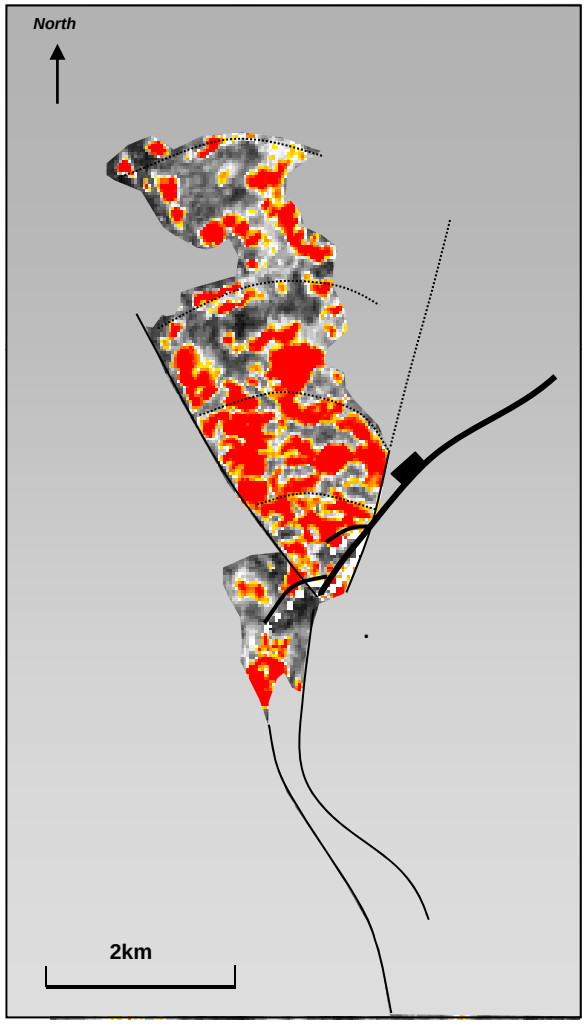
Syn-Sedimentary Tectonics



Channel diversions and ponding suggest syn-depositional tectonics

Prograding Sandsheets





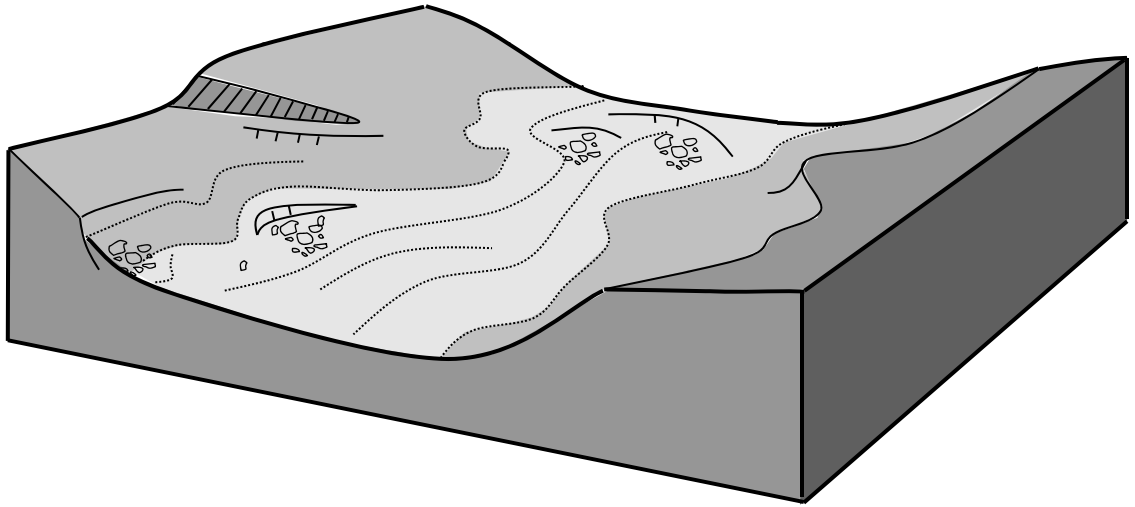
- Lobate planforms up to 4km wide down-dip
- Sandsheets are c.10m thick
- Fed by very narrow (50-100m wide) sinuous channels
- Shingled stacking

Further suggestion of syn-depositional tectonics?

Stratigraphic Evolution of the Channel System

Stage I

Sediment by-pass, erosion and slumping – Channel initiation

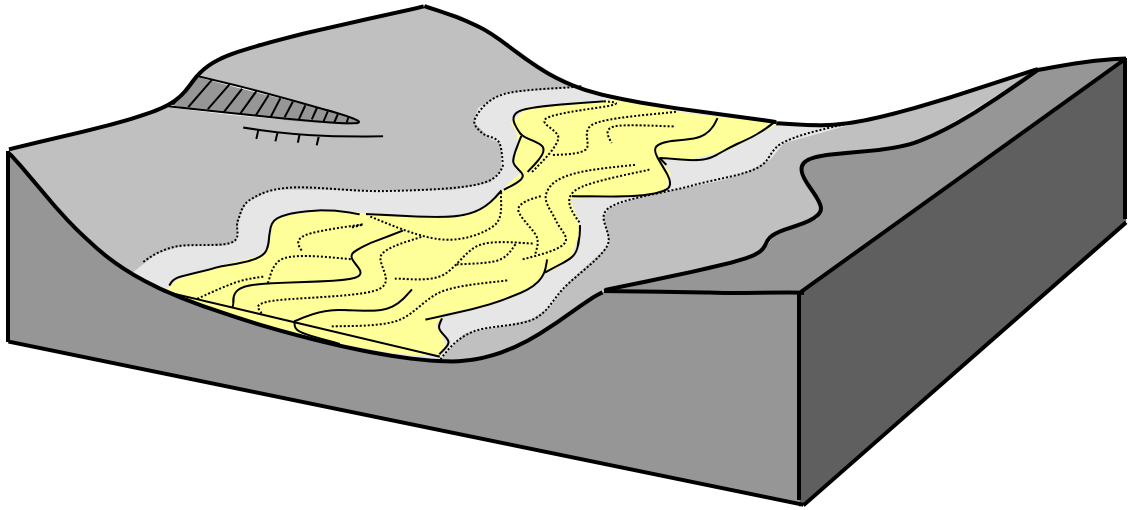


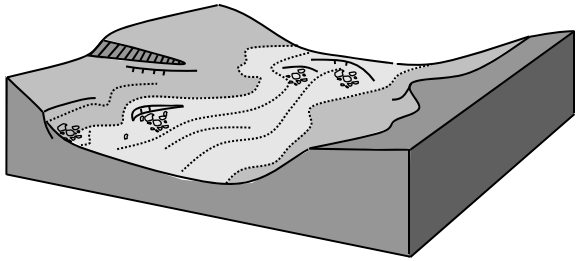
6 stages in the evolution of the Sequoia channel system

Stratigraphic Evolution of the Channel System

Stage II

Laterally amalgamated channels



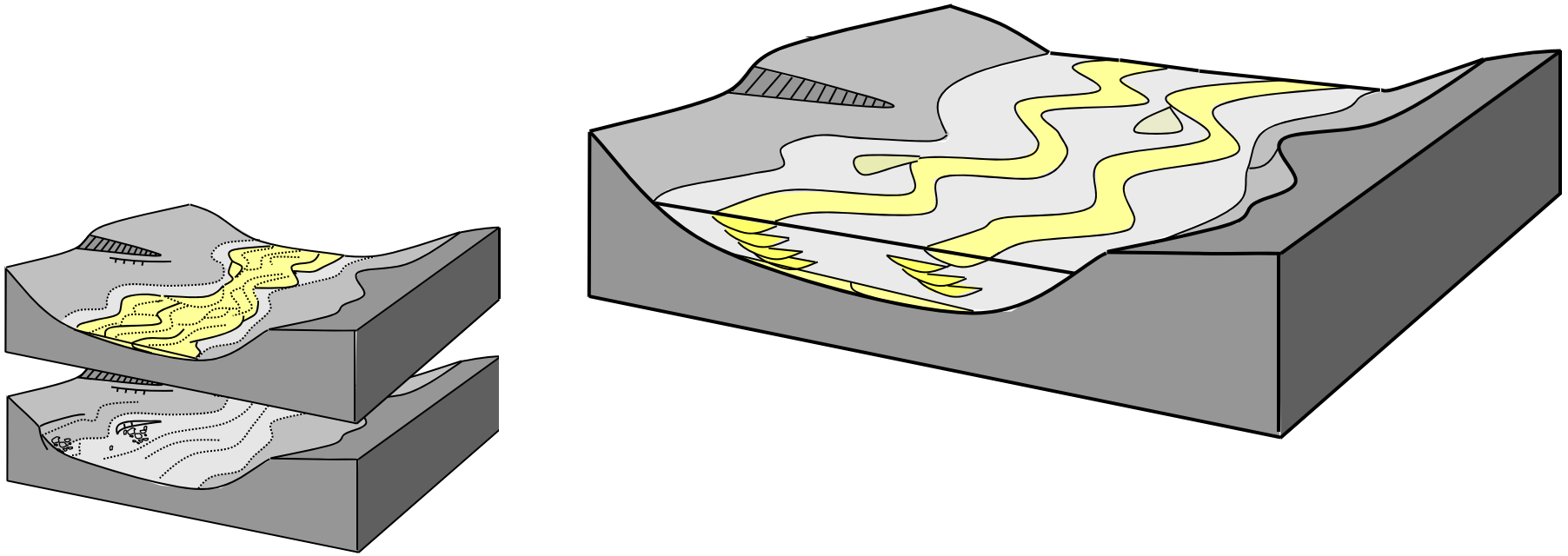


6 stages in the evolution of the Sequoia channel system

Stratigraphic Evolution of the Channel System

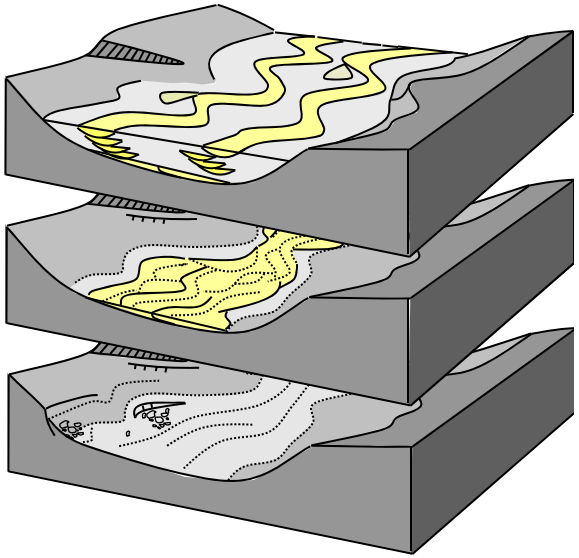
Stage III

Aggrdational sinuous channels



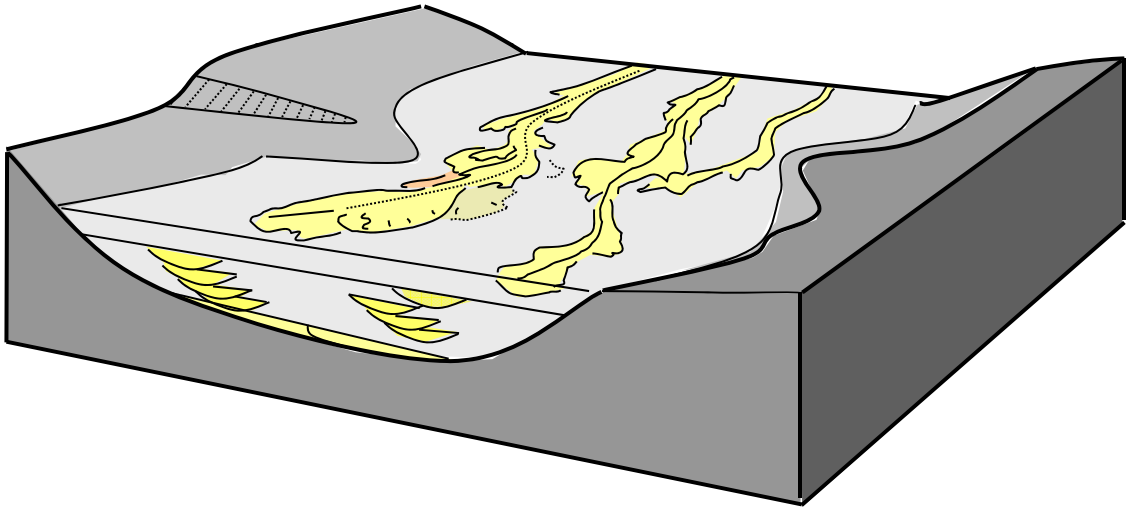
6 stages in the evolution of the Sequoia channel system

Stratigraphic Evolution of the Channel System



Stage IV

Channel with frontal splays and leveed channels



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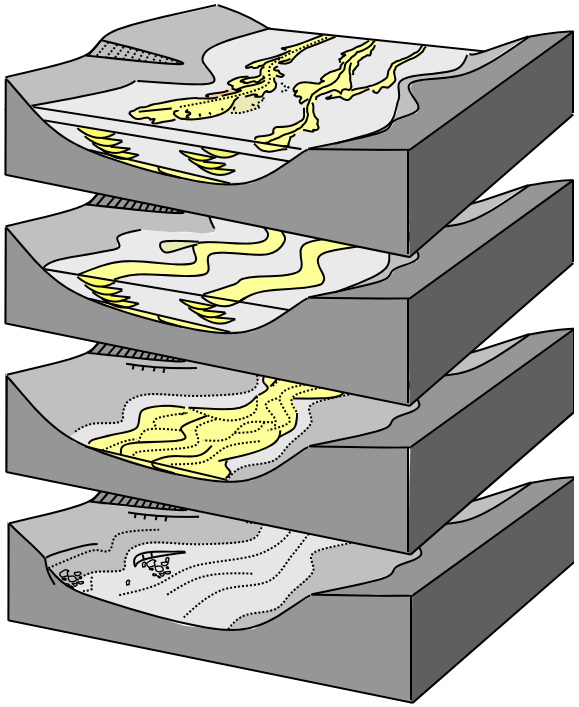
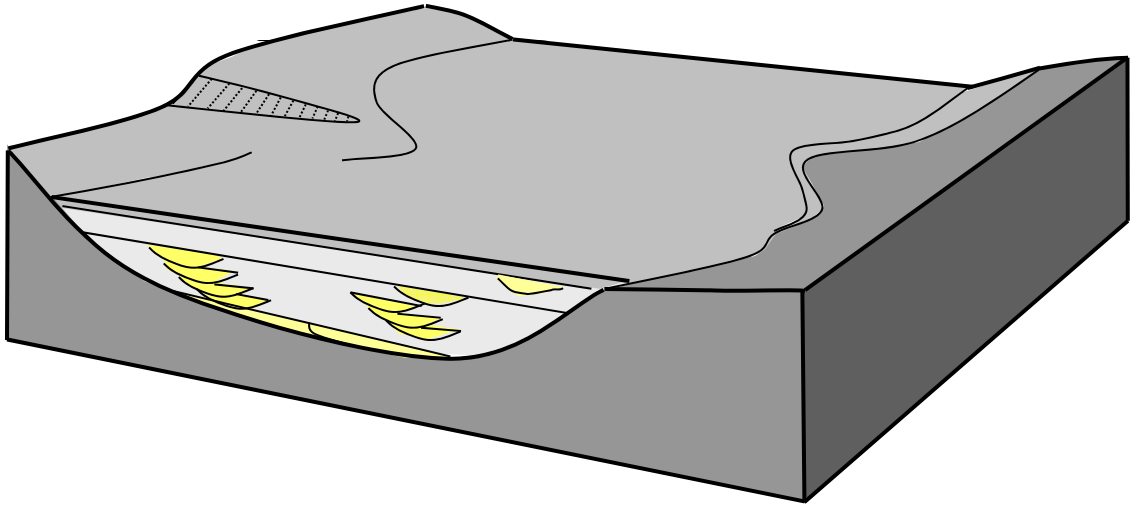
Stratigraphic Evolution of the Channel System



Stage V

Abandonment and maximum flooding



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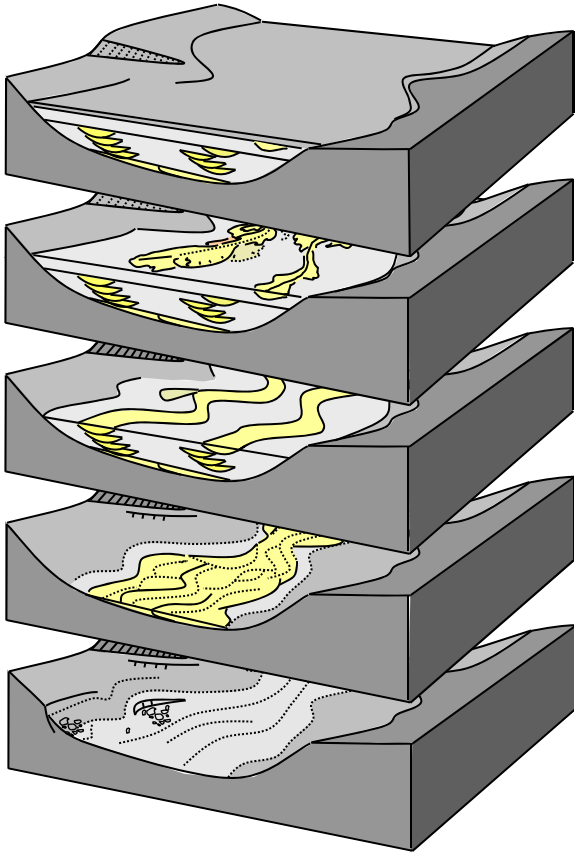
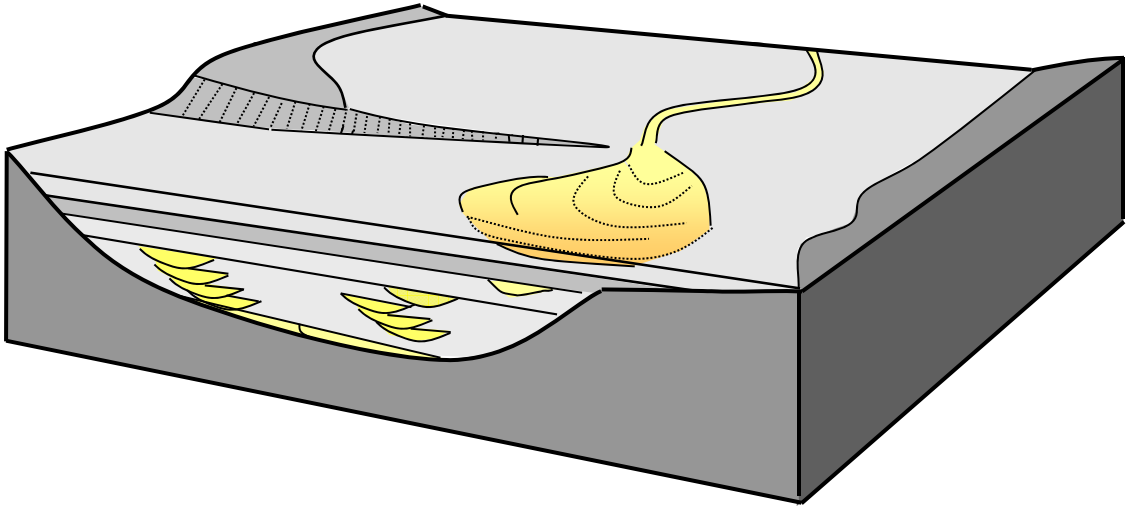
Stratigraphic Evolution of the Channel System



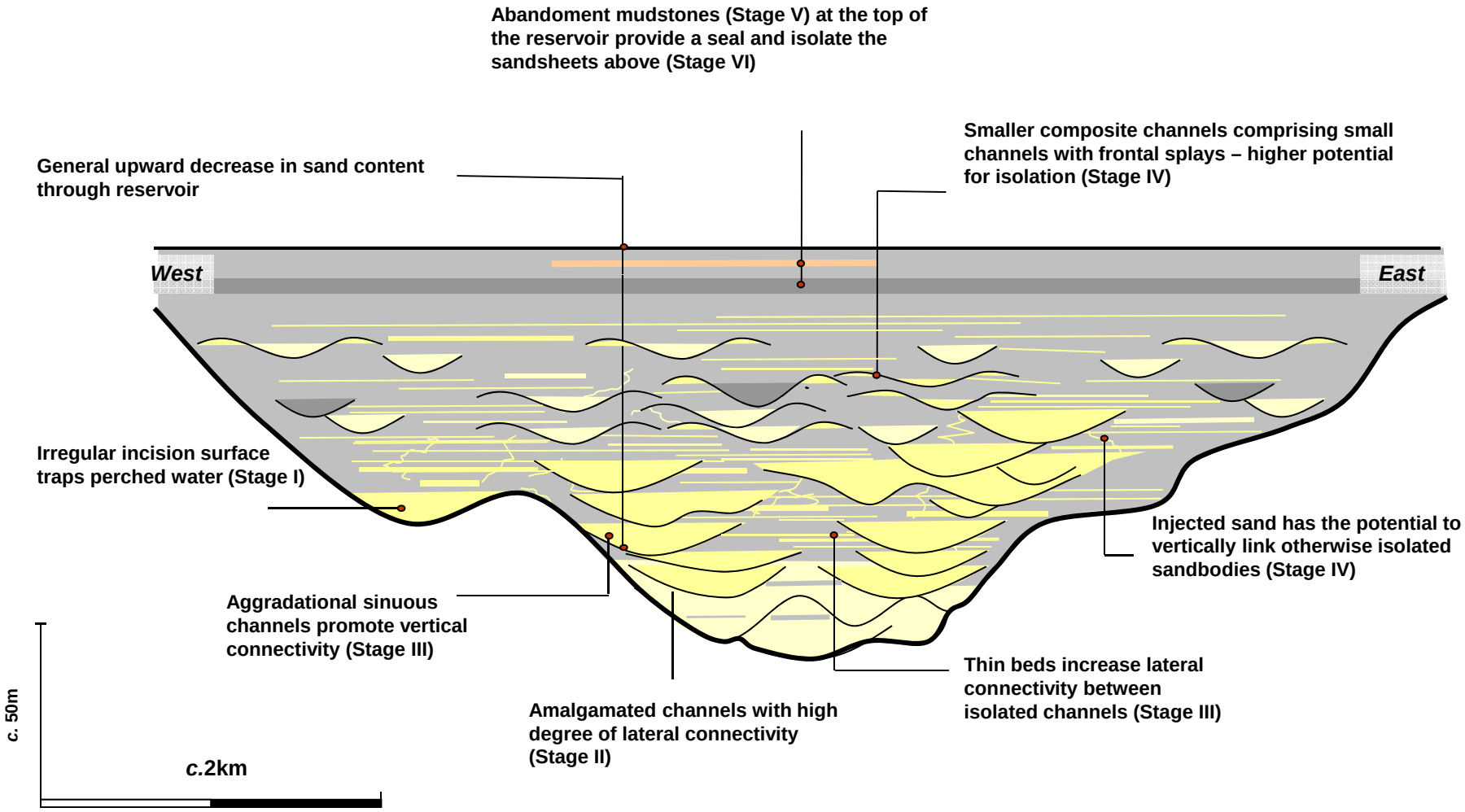
Stage VI

Prograding sandsheets



6 stages in the evolution of the Sequoia channel system

Conclusions – Impact on Reservoir Heterogeneity



Reservoir heterogeneity intimately linked with channel system evolution

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Aal, A.A. El Barkooky, M. Gerrits, H.-J. Meyer, M. Schwander, and H. Zaki, 2006, Tectonic evolution of the eastern Mediterranean Basin and its significance for the hydrocarbon prospectivity of the Nile Delta deep-water area: GeoArabia, v. 6/3, p. 363-384.

Cross, N.E., A. Cunningham, R.J. Cook, A. Taha, E. Esmaie, and N. El Swidan, 2009, Three-dimensional seismic geomorphology of a deep-water slope-channel system: The Sequoia field, offshore west Nile Delta, Egypt, AAPG Bulletin v. 93, p. 1063-1086.