Geomorphic Responses of Slope Channel Systems to Growing Thrusts and Folds, Deepwater Niger Delta*

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Abstract

Gravity-driven seaward-verging thrusts, landward-verging back-thrusts and associated folds often characterize the slope and deepwater settings of passive margins. These structures, found in the toe-thrust region of the system, exert a significant control on sediment gravity flows because they create and determine the location and configuration of sediment depocentres and transport systems. However, to fully understand the interaction between sediment gravity flows and seabed topography we need to evaluate and quantify the geomorphic response of sub-marine channels to deformation in areas such as the deepwater Niger Delta, where the degree of tectonic shortening can be well constrained. We first mapped folds and thrusts from 3-D seismic data, and used these data to quantify the history of fold growth. We then used the seabed bathymetry and the depth-to-base of channels to build 50 m resolution Digital Elevation Models (DEM) in Arc-GIS. From the DEMs, we extracted channel long-profiles across growing structures for both the modern channels and the associated channel containers identified from the seismic data. We measured channel geometry at regular intervals along the channel length to evaluate system response to tectonic perturbation. Results show that the growth rate of structures having seabed relief is between 0.2 mm/yr to 0.25 mm/yr. Modern seabed channels have profiles that are generally linear and respond to actively growing structures with small to moderate increases in gradient (at most 0.5°) and increasing the depth of channel incision (up to 50%), but in most cases show no significant change in channel width. This suggests the width to depth ratio of submarine channels to be much less sensitive to local variations in channel gradient than their sub-aerial counterparts. However, the basal profiles of the entire channel container are generally convex-up with up to 1.5-2° gradient changes over zones of active structural uplift with a corresponding narrowing in the width of the channel container and substantial erosion of underlying fold crests. Previously published data from buried deepwater channels has suggested that channels both incise more and decrease their width in response to an increase in gradient. Our work shows that this is only true for a long-lived channel complex and not necessarily for one individual seabed channel.

References Cited

Mayall, M., L. Lonergan, A. Bowman, S. James, K. Mills, T. Primmer, D. Pope, L. Rogers, and R. Skeene, 2010, The response of turbedite slope channels to growth-induced seabed topography: AAPG Bulletin, v. 94/7, p. 1011-1030.

Corredor, F., J.H. Shaw, and F. Bilotti, 2005, Structural styles in the deep-water fold and thrust belts of the Niger Delta: AAPG Bulletin, v. 89/6, p. 753-780.

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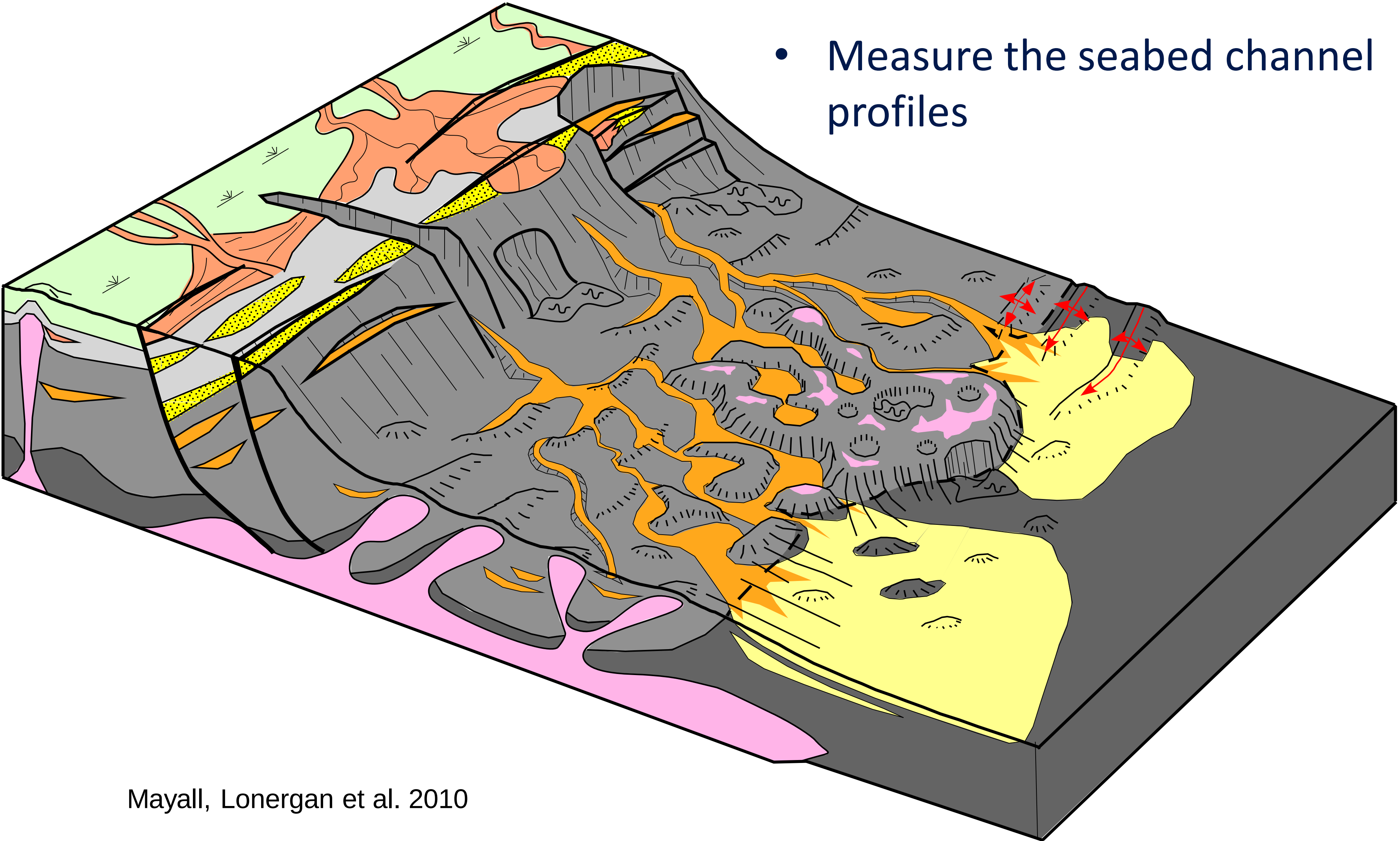
Study objectives

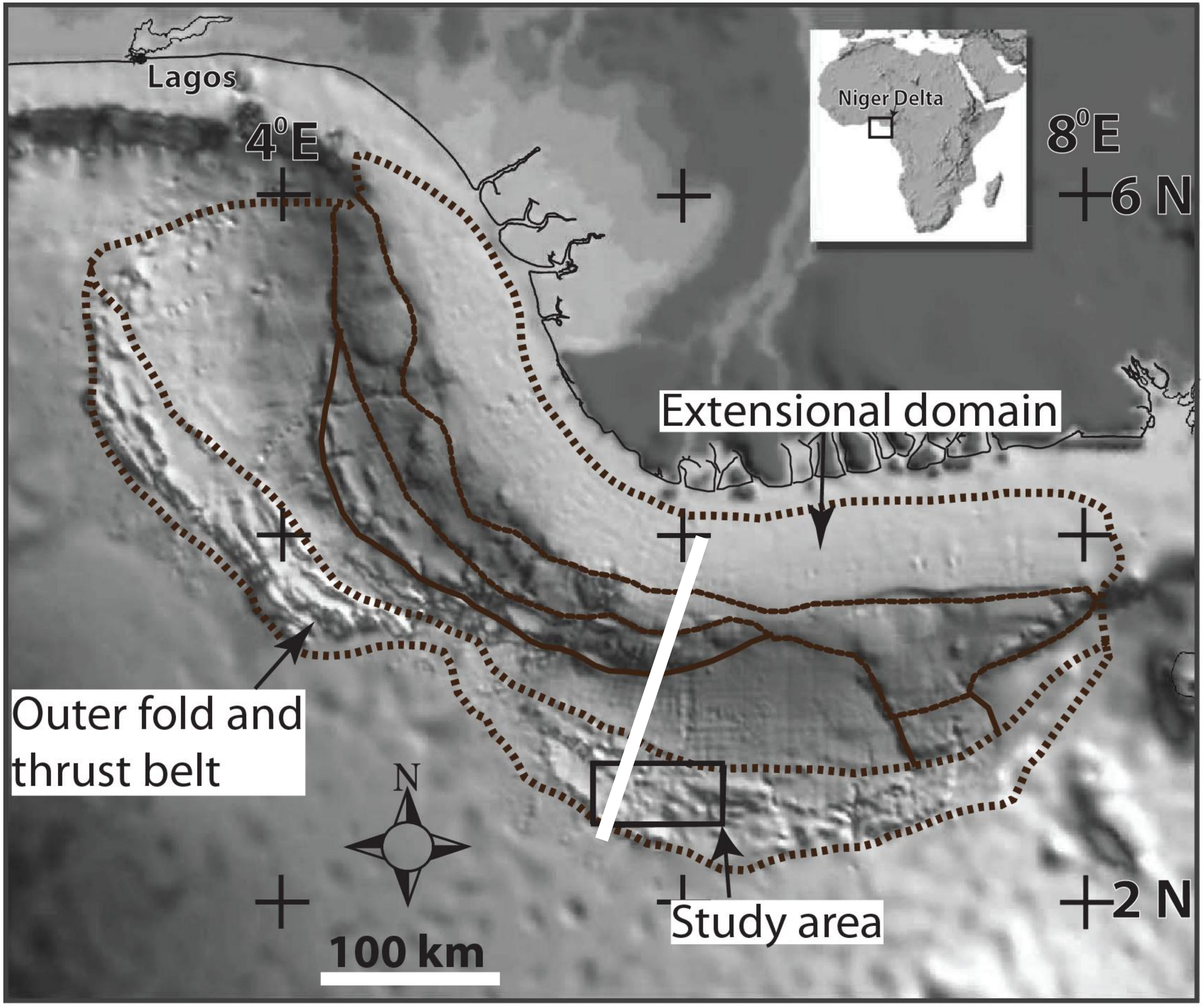
- To analyze the growth histories of folds



- Measure the seabed channel profiles

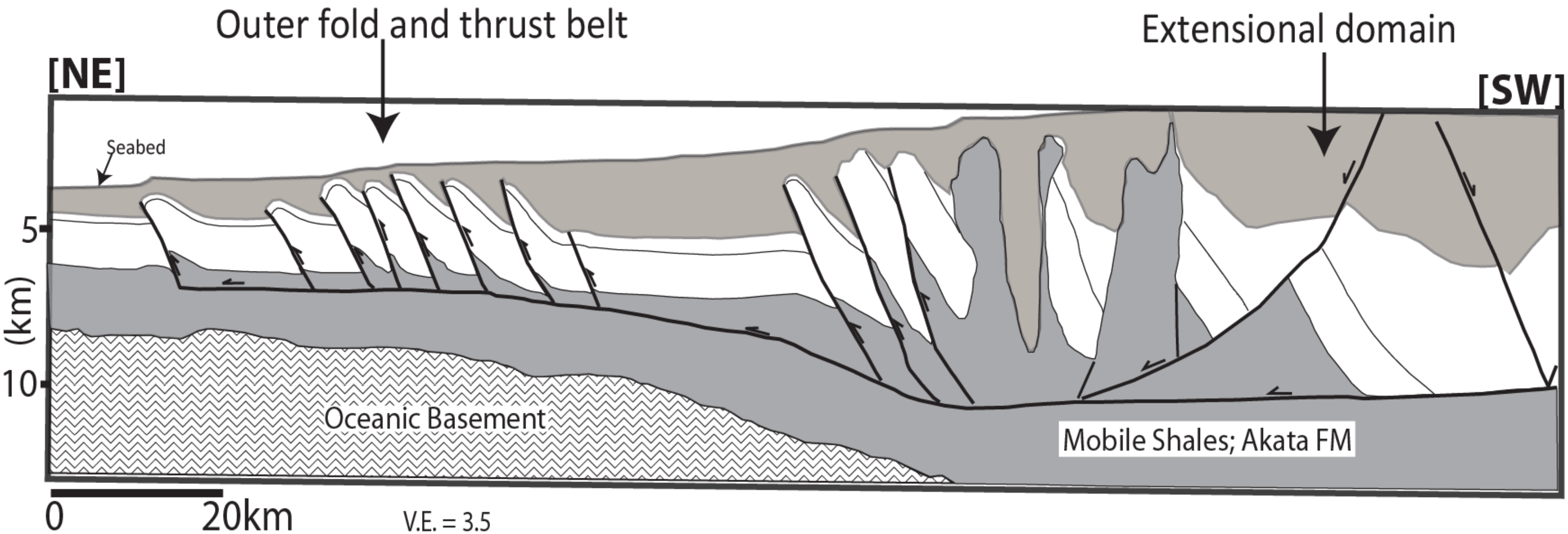
Mayall, Lonergan et al. 2010

Study area & Data



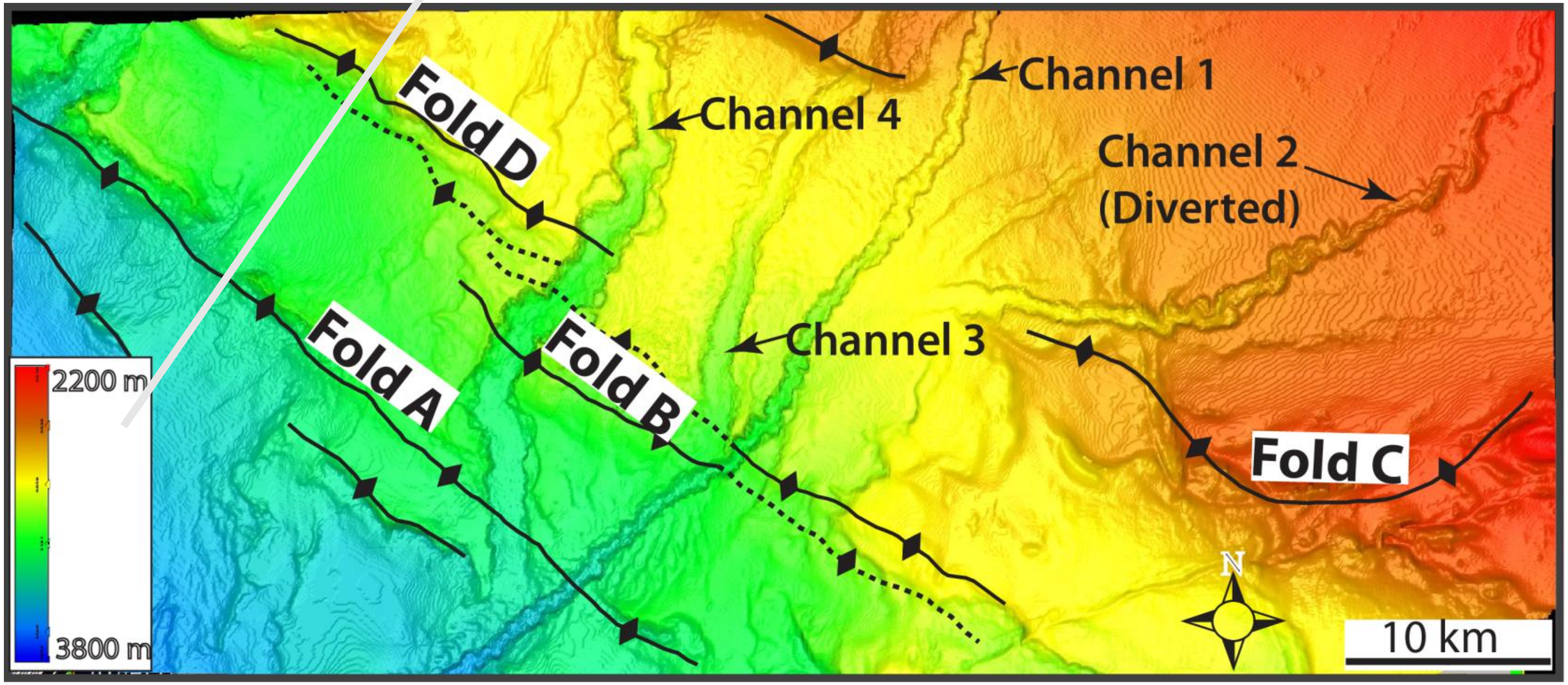
Modified from Corredor et al., 2005

Regional section



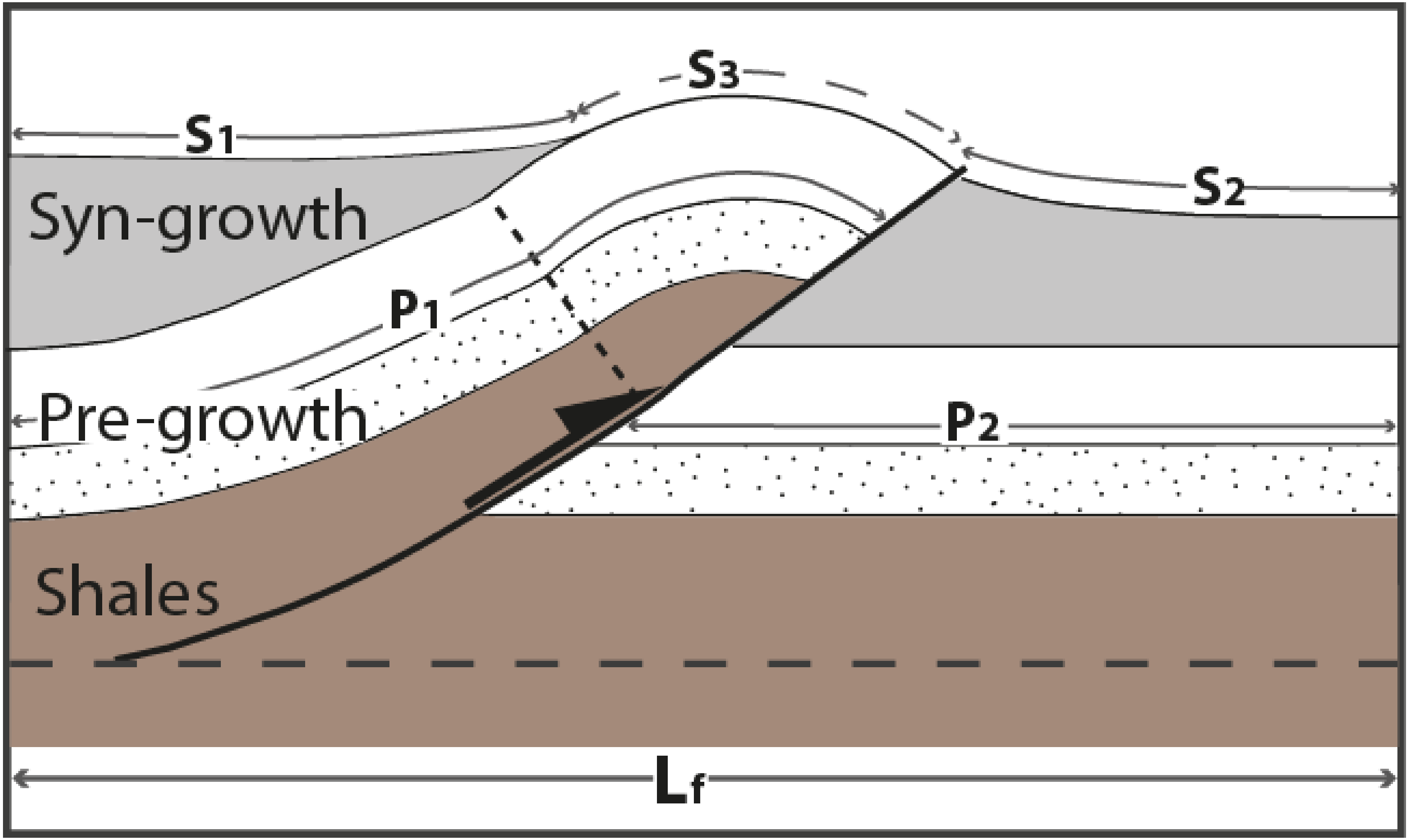
Modified from Corredor et al., 2005

Seabed map



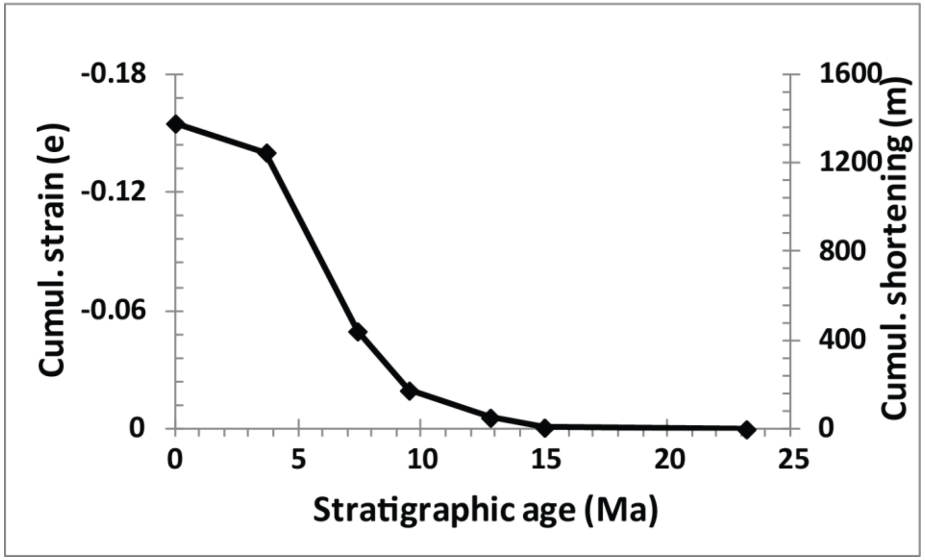
Channel 1
Channel 4
Channel 2
(Diverted)
Fold D
Channel 3
Fold A
Fold B
Fold C
2200 m
3800 m
N
10 km

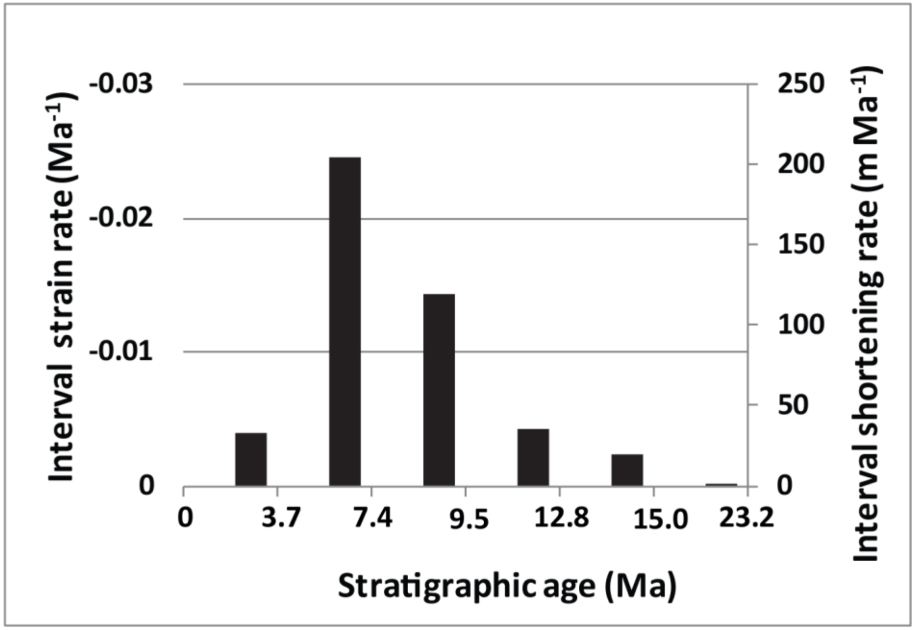
Measuring fold shortening



Strain (e) = $(\mathbf{L_f} - \mathbf{L_0})/\mathbf{L_0}$

Cumulative strain through time

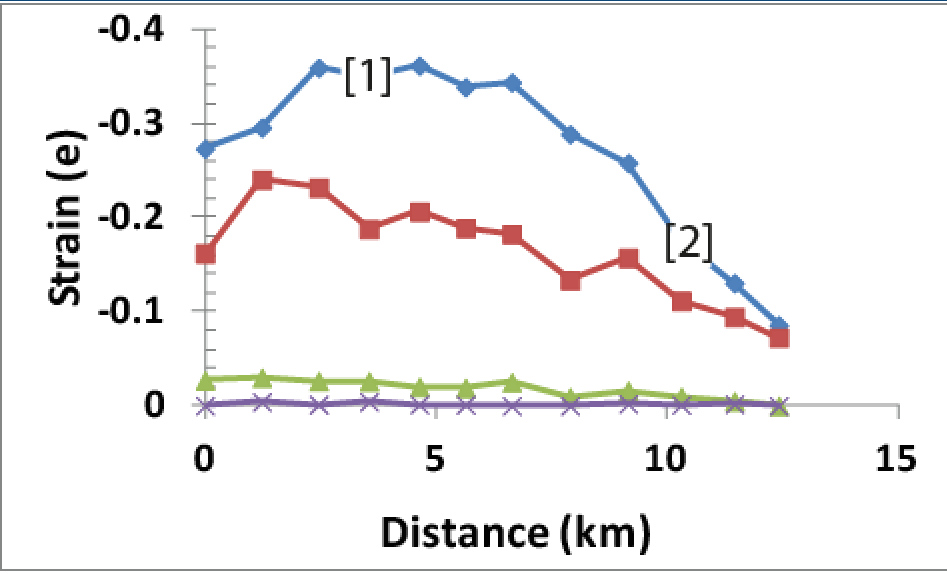


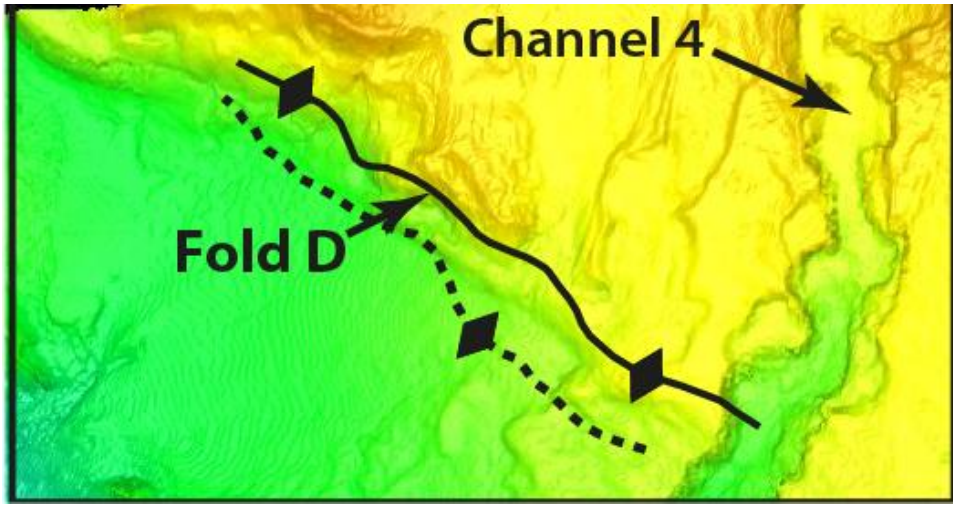


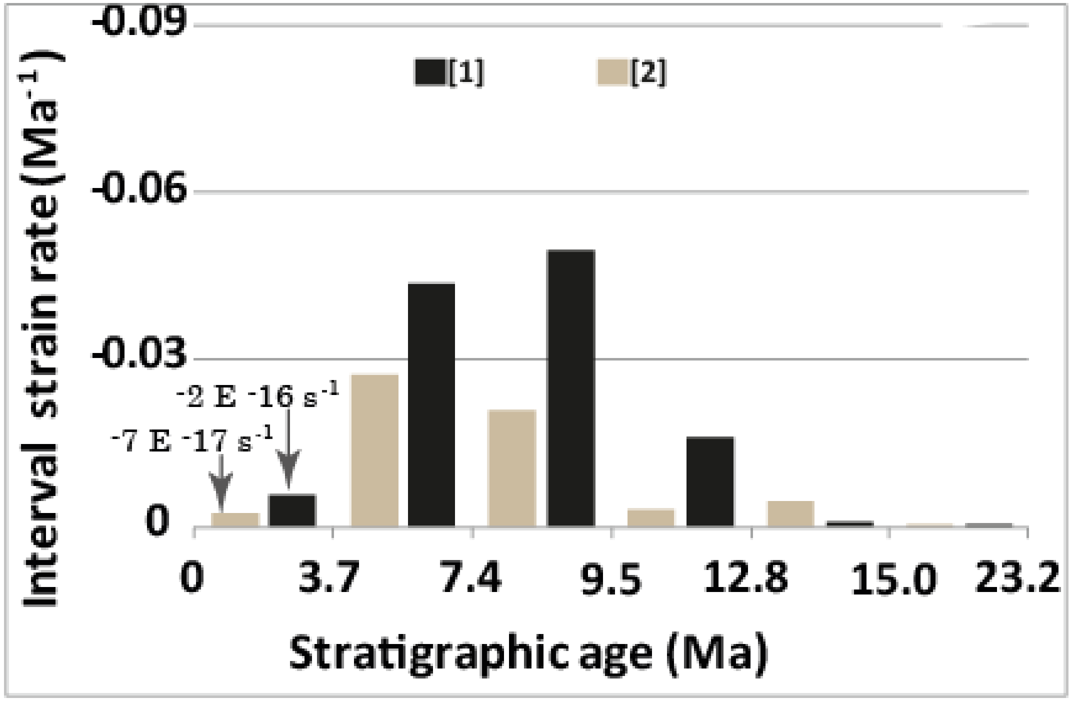
Strain and channel response

Spatial variation in strain and influence on channel pathways

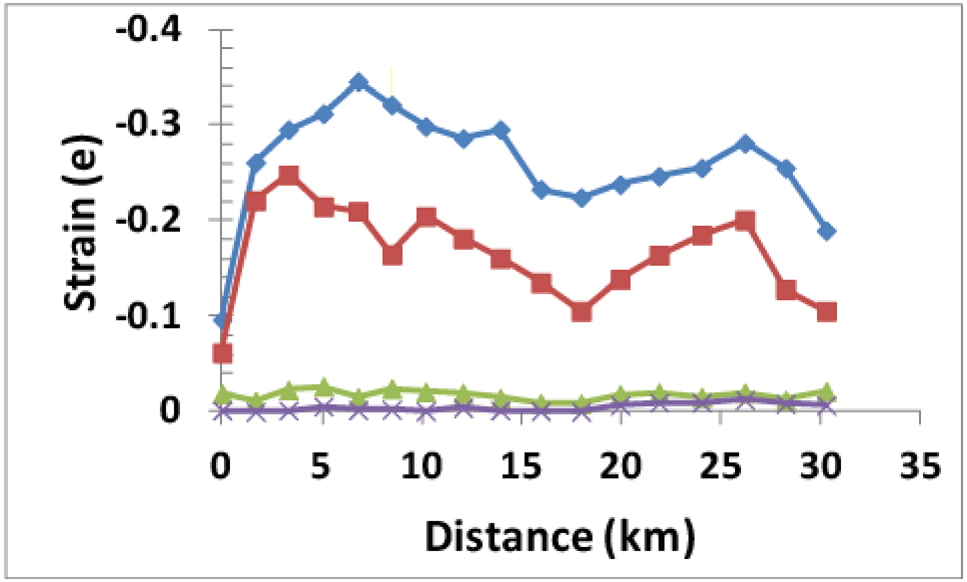
Strain and channel response[Fold D]

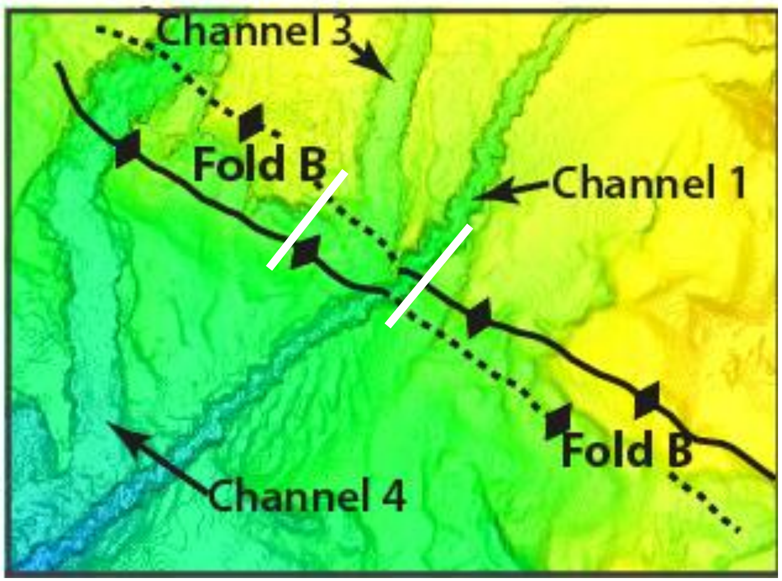




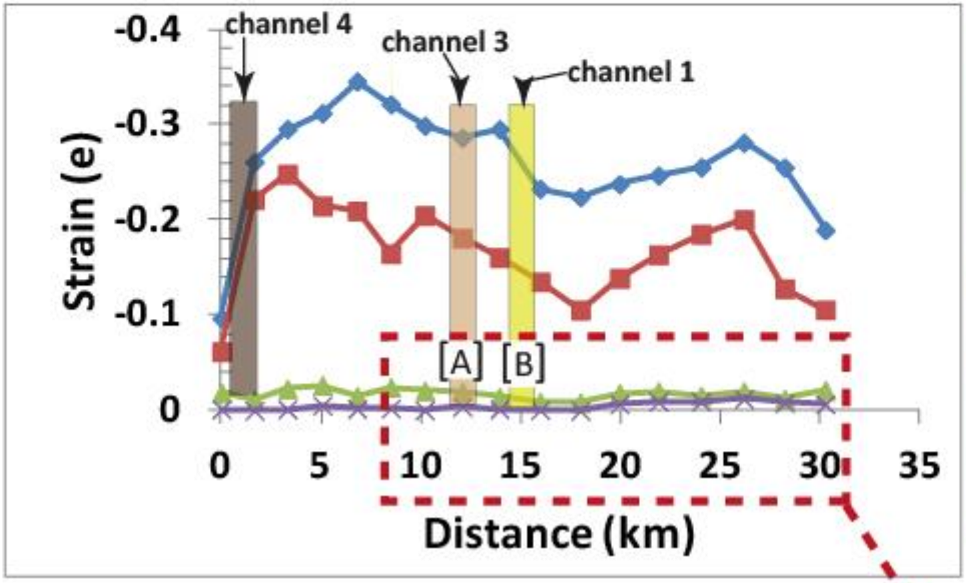


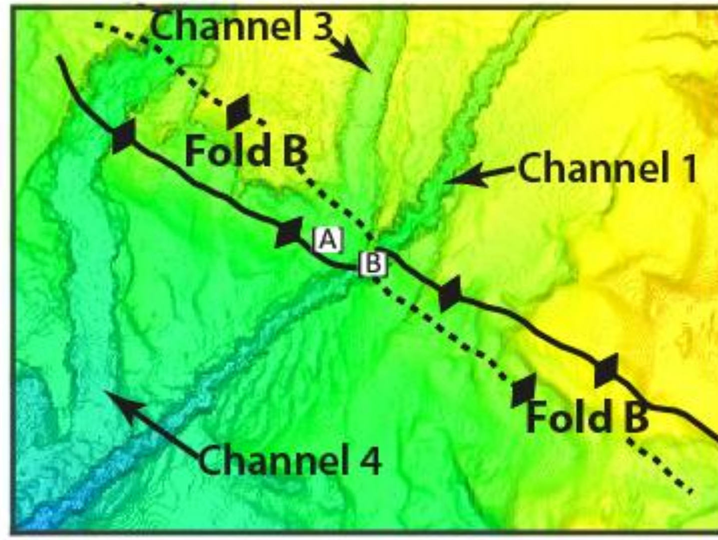
Strain and channel response[Fold B]

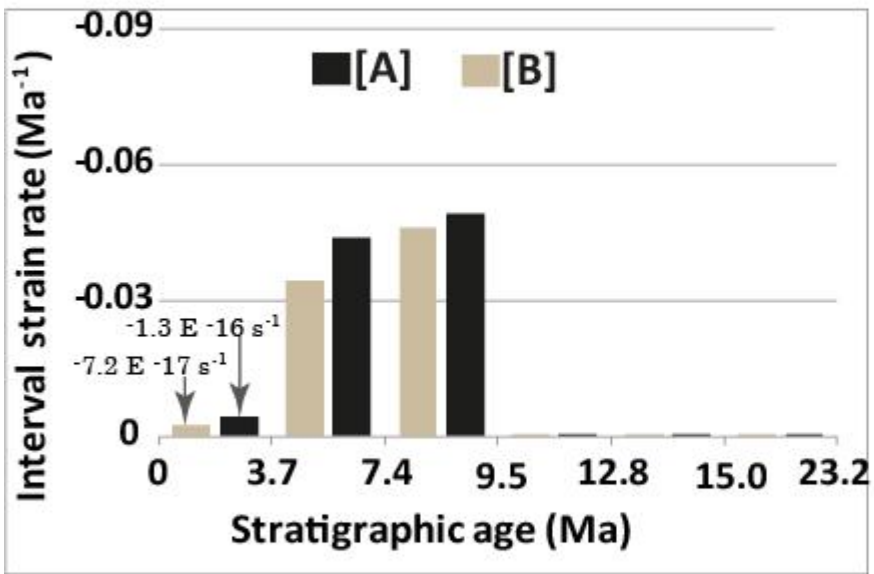


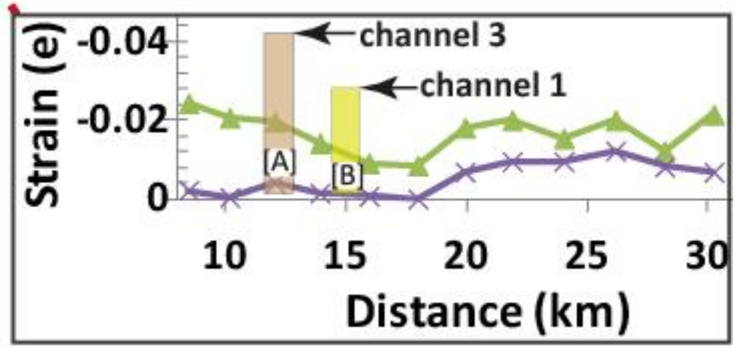


Strain and channel response[Fold B]

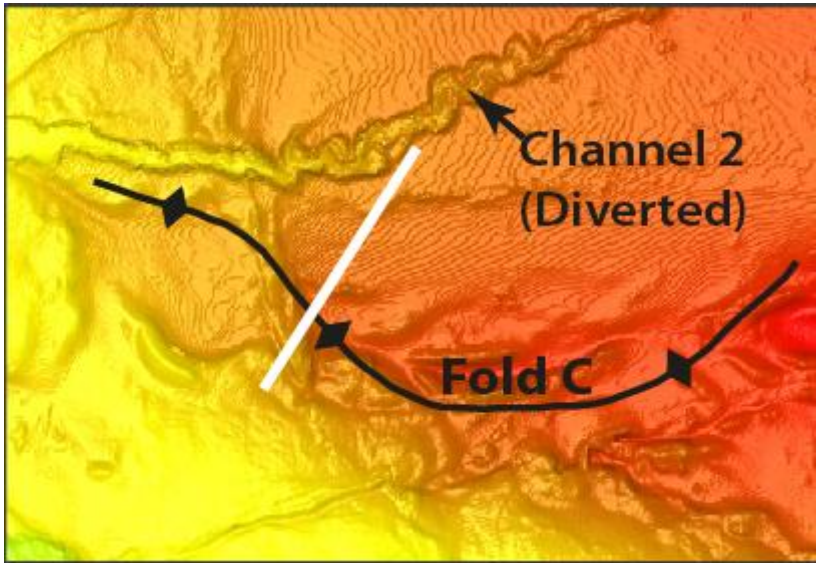


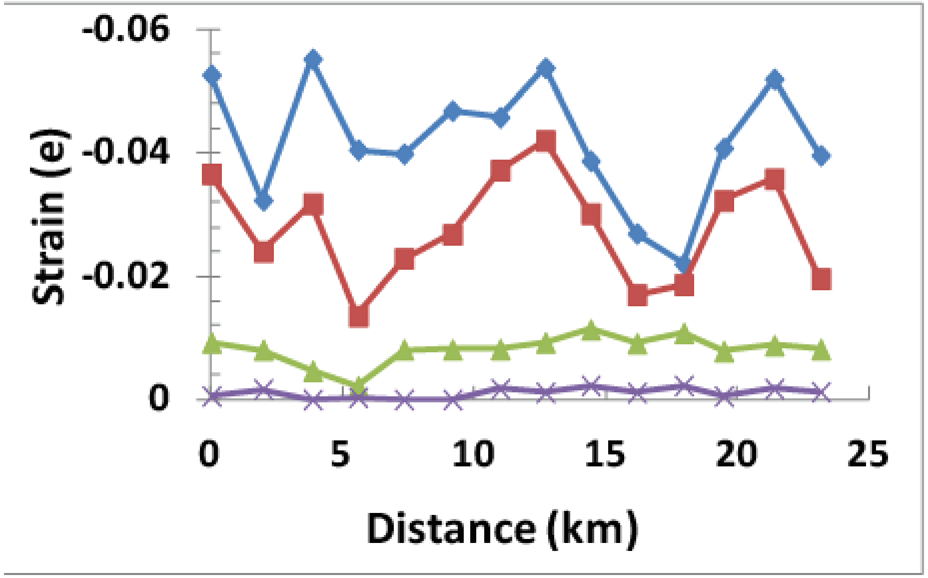






Strain and channel response[Fold C]





Summary [part 1]

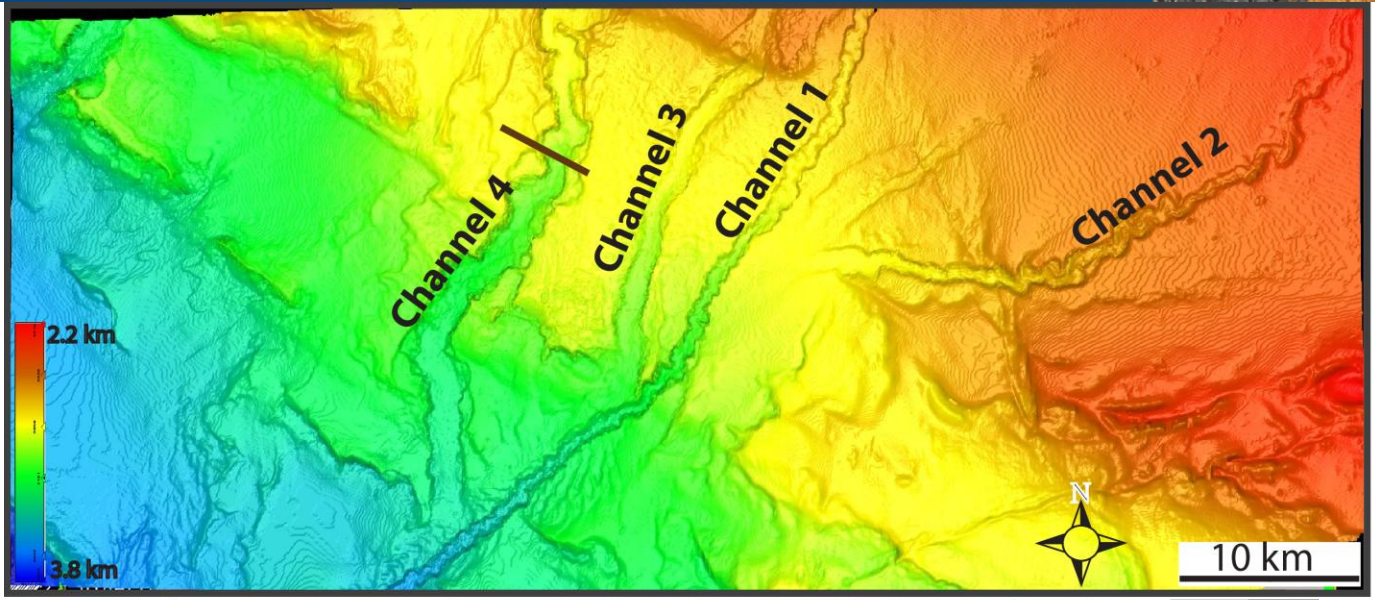
- Submarine channels cross folds in positions of recent interval strain minima (less than **$1 \times 10^{-16}\ s^{-1}$**)

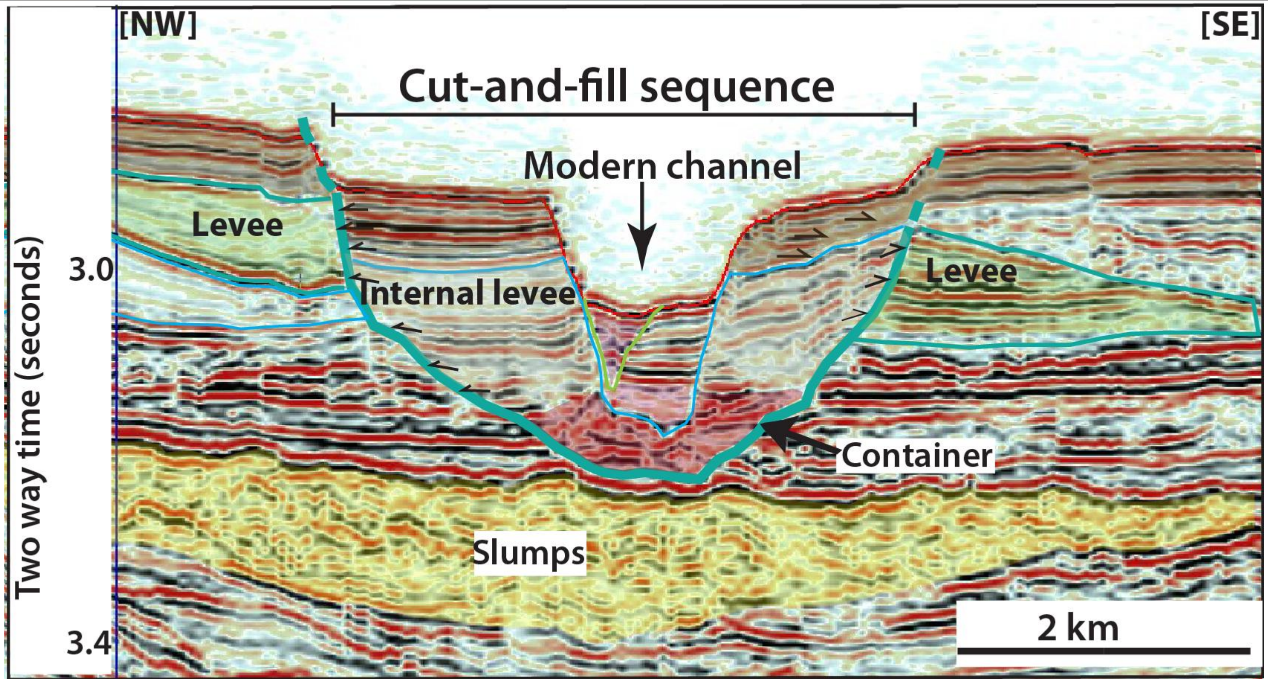
- Position of strain minima as recorded on older horizons may not be a good indicator of where future channels will cross the structure

- It appears that wide folds, with very low strain may cause channel diversion

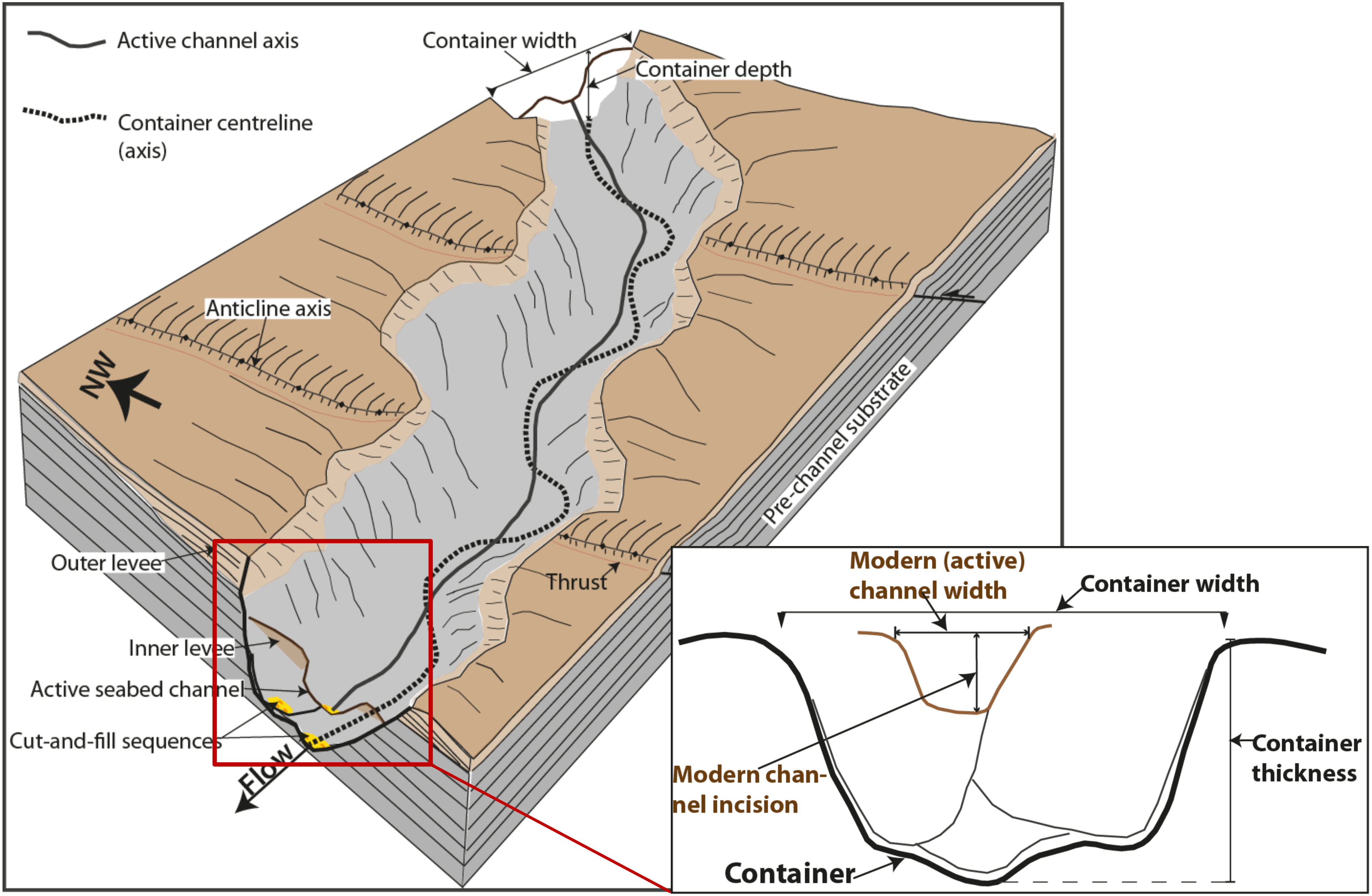
Channel profiles and tectonic perturbation

Channel geometry

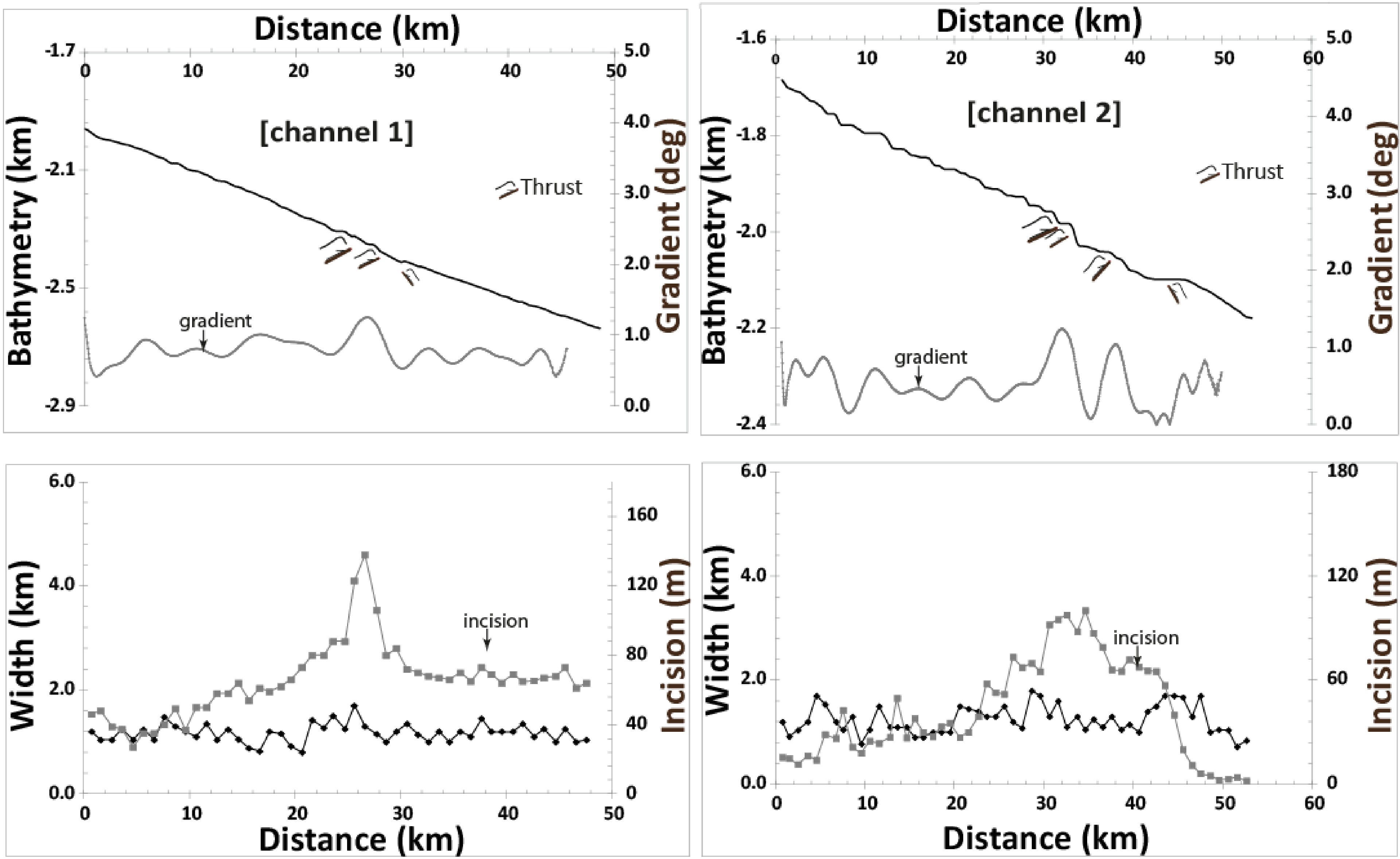




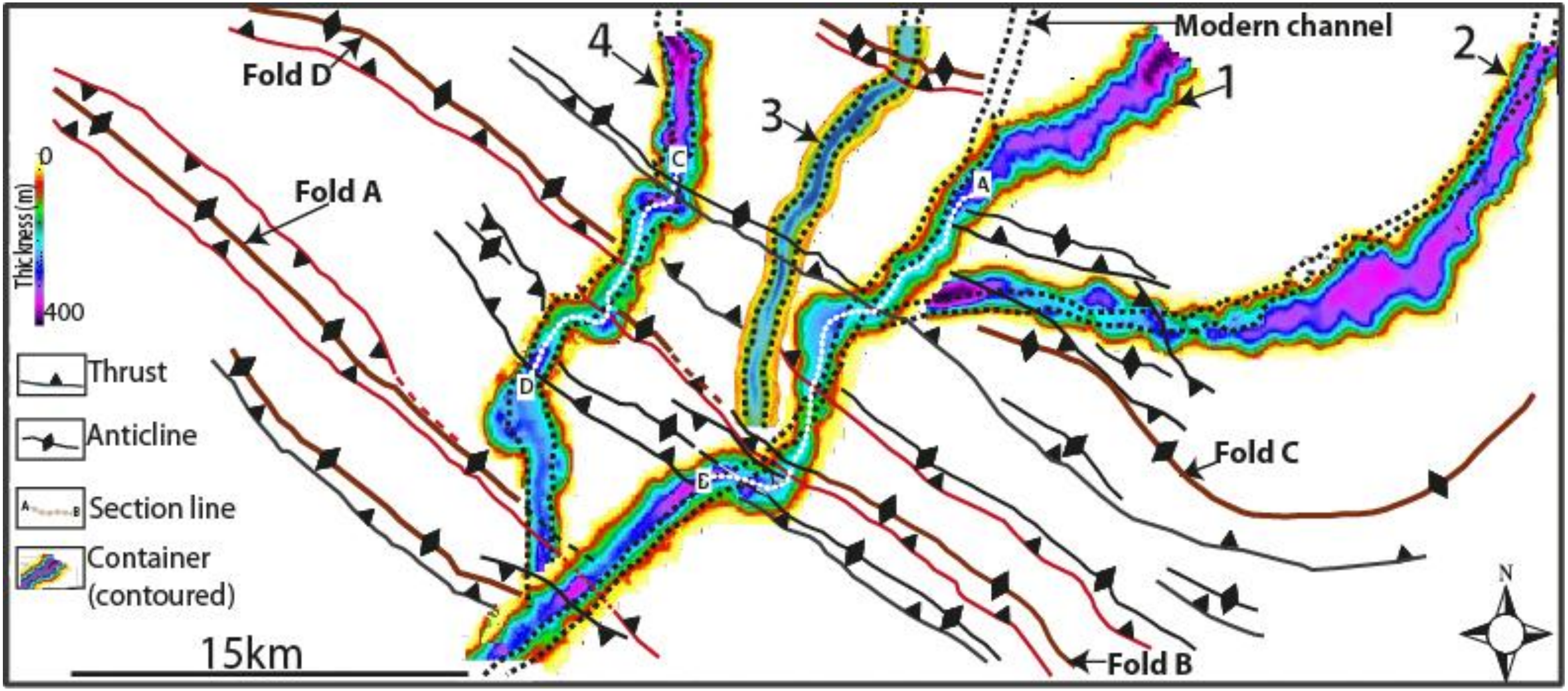
Channel container



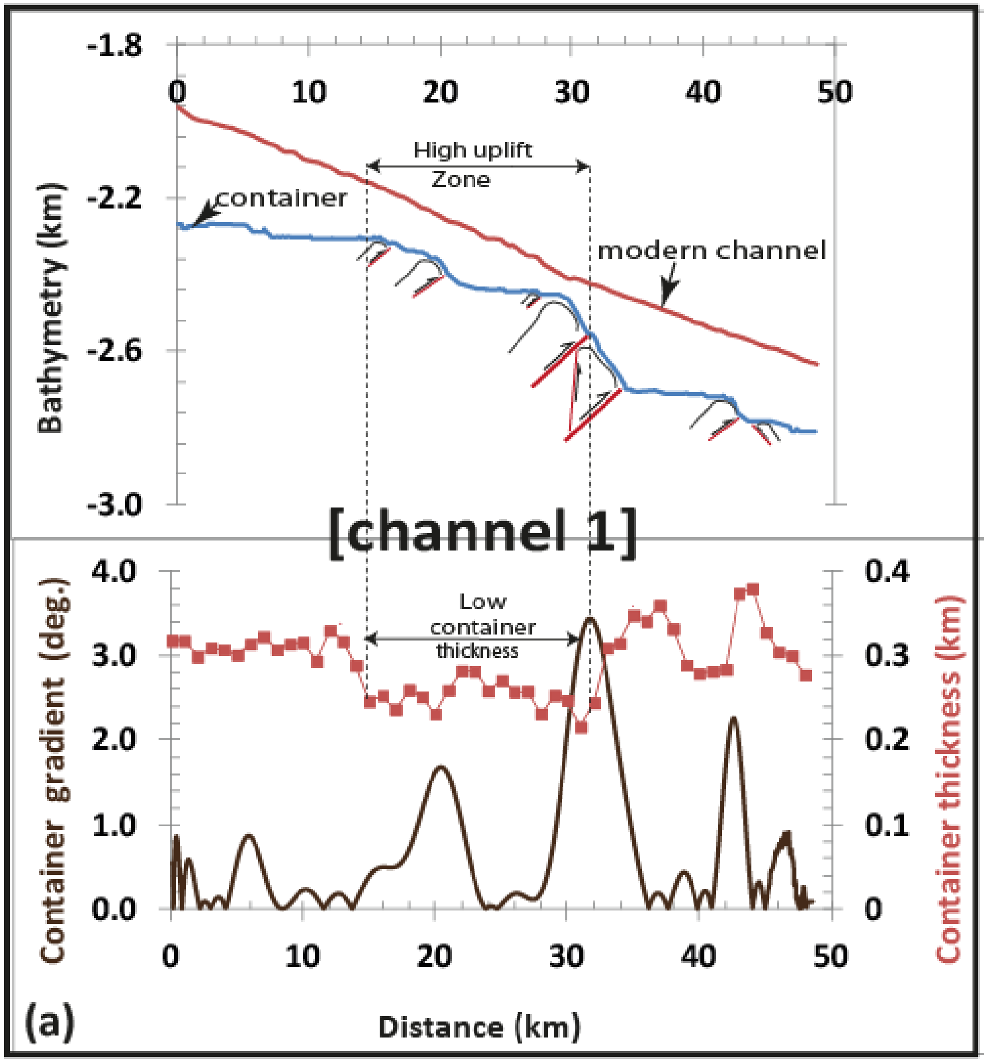
Modern channels [profile,width,depth]

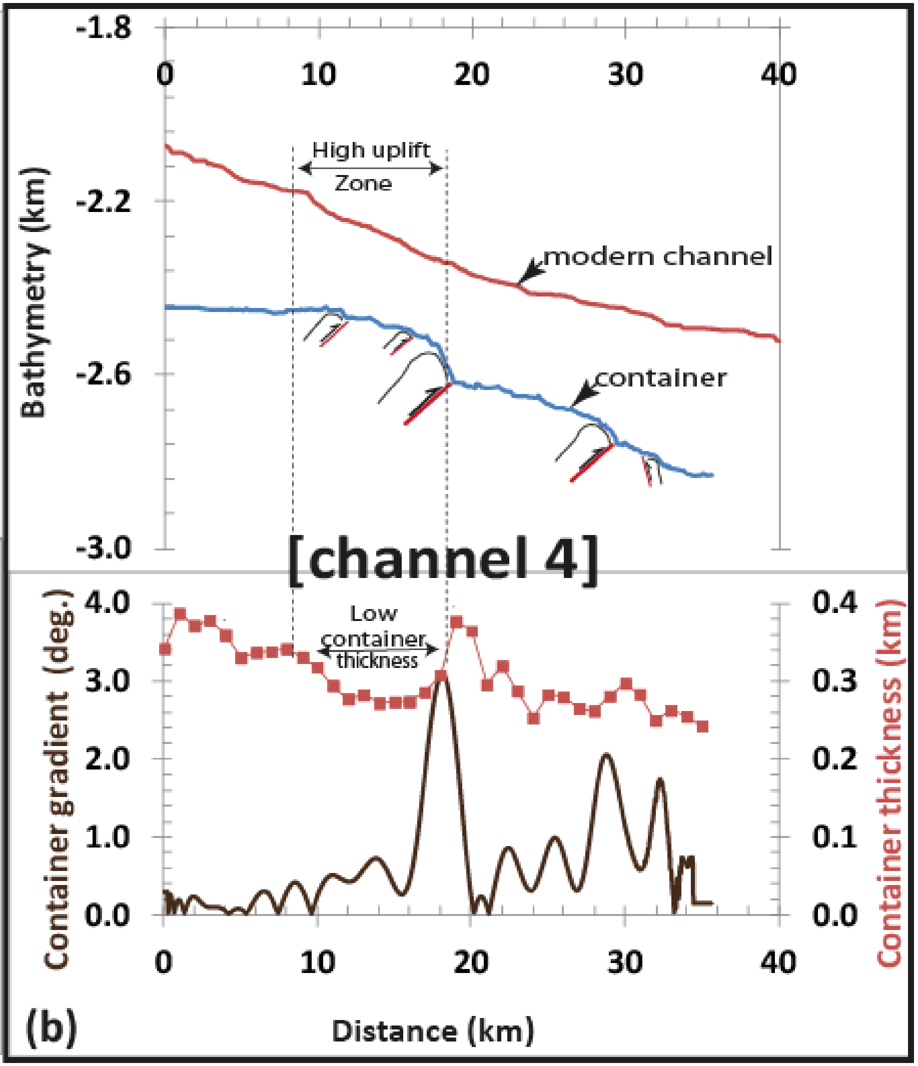


Channel containers [thickness map]



Summary [part 2]





Conclusions

• On a large scale, structural growth causes channels to deflect or divert, but can also cross active structures at linkage points where strain rates are less than **1×10^{-16} s^{-1}** .

• Modern channel profiles are generally linear and the container profiles are convex-up and irregular

• Modern channels respond to growing structures with significant gradient increase by producing more incision, but with no systematic changes in width.

• In contrast, the channel containers show an overall reduction in width and time-integrated thickness of their fill over growing and/or recently active structures.

Thank You

Acknowledgements

PGS

Shell

PTDF