Giant Cretaceous Mixed Contouritic-Turbiditic Systems, Offshore Uruguay: The Interaction between Rift-Related Basin Morphology, Contour Currents and Downslope Sedimentation*

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Search and Discovery Article #30482 (2016)**
Posted December 26, 2016

*Adapted from oral presentation given at AAPG 2016 Annual Convention and Exhibition, Calgary, Alberta, Canada, June 19-22, 2016

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Abstract

The Cretaceous succession offshore Uruguay records the interaction between along- and down-slope processes with the underlying rift-controlled basin topography. A recently acquired 3D seismic survey, covering 13,500 km^2, images a spectacular array of sedimentary features including, in stratigraphic order, large sedimentary waves, giant sediment drifts and mixed turbiditic/contouritic systems. The sediment wave packages are related to two discrete sediment entry points. In planform the packages are approximately 30km wide and comprise a series of curvilinear ridges elongated parallel to the palaeo-slope; in dip section the packages are relatively tabular (c. 500m thick) but are internally composed of a series of low-angle clinoforms with down-stepping geometry, originating an apparent progradation. They are linked to an updip, thick prograding unit that delivered sediments into the basin until the Late Cretaceous. Above the sediment wave package a series of downdip converging, giant slope-attached sediment drifts can be traced along the continental slope for over 125km. The package exhibits a ‘pinch and swell’ architecture along strike with thicknesses varying between 100m in the moat regions to over a kilometer at the drift crest. Individually the drifts have wavelengths up to 45km and can be traced for over 100km perpendicular, and oblique, to the palaeomargin. Internally, the drifts comprise a series of packages that migrate from north to south, creating a series of laterally shifting depocentres. The location of these drifts is directly related to the interaction of a southwards flowing current with underlying basement topography. Enhanced drift development and clustering occurs up-current from basement highs (a

topographic backstop). Horizon terminations on the stoss side of the drifts suggest that sediments were eroded and reworked within the moat region. Whilst the drifts are dominantly acoustically transparent the moat regions tend to have the highest amplitudes, which are inferred to represent coarser grained material, transported downslope and reworked by currents. Downslope flows exploited the moat regions and subtle topographic lows within the drift, forming linear channel systems - some with local overspill – and lobes. Many of these features, which are only observed due to the size and quality of the dataset, pose questions about our fundamental understanding of margin morphologies and bedform development in the deep marine environment.

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Giant Cretaceous mixed contouritic-turbiditic systems, offshore Uruguay: the interaction between rift-related basin morphology, contour currents and downslope sedimentation

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AAPG 2016 ACE, Calgary, 19-22 June 2016

Acknowledgments: we thank BG and ANCAP for permission to present this study

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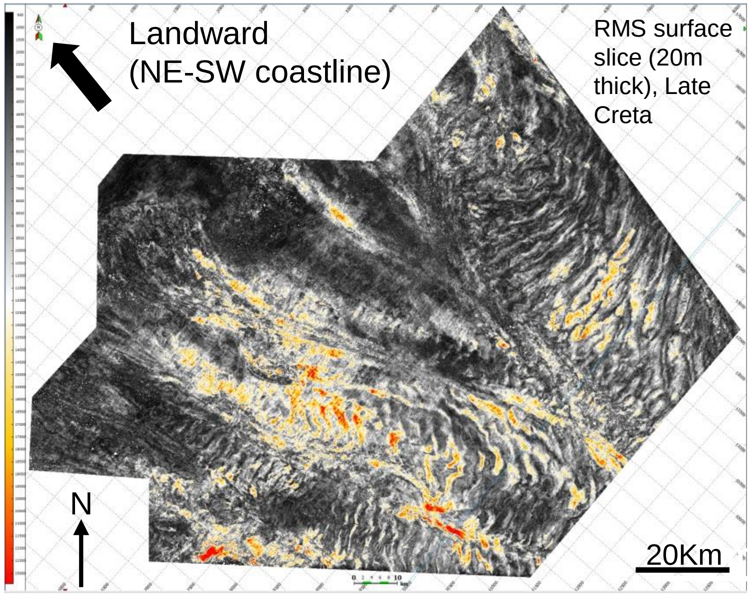
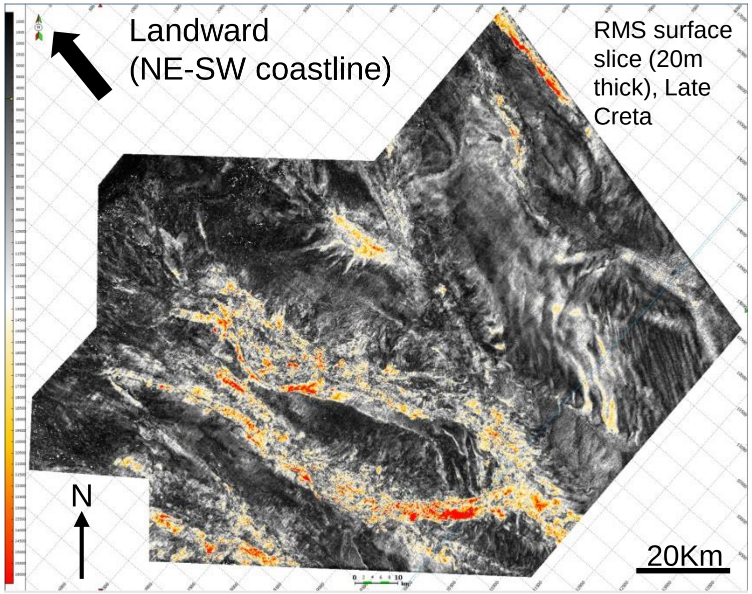
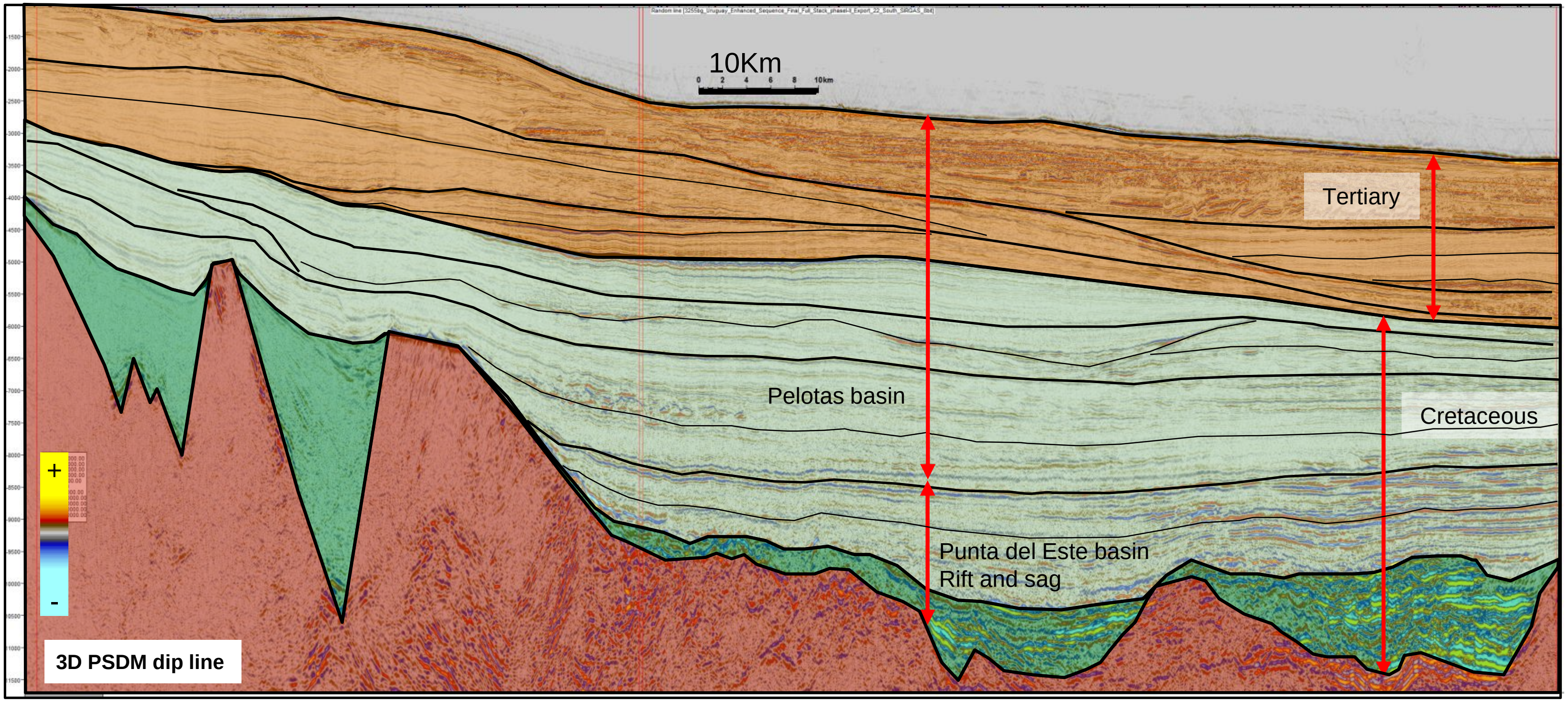
Outline of talk

- Objectives
  - Describe array of Cretaceous sedimentary features/depositional environments offshore Uruguay
  - Illustrate interplay between downslope and along slope processes (contourites vs. turbidites)
  - Discuss hybrid contouritic-turbiditic systems
- Regional context
- Cretaceous observations
  - Deltas (?), sediment waves, and slumps
  - Mounded drifts
  - Hybrid contouritic-turbiditic systems
- Discussion
- Conclusions

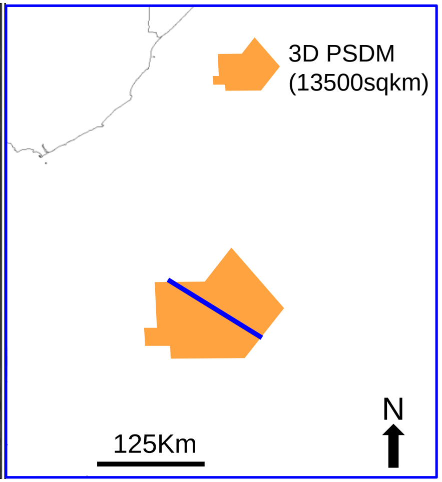




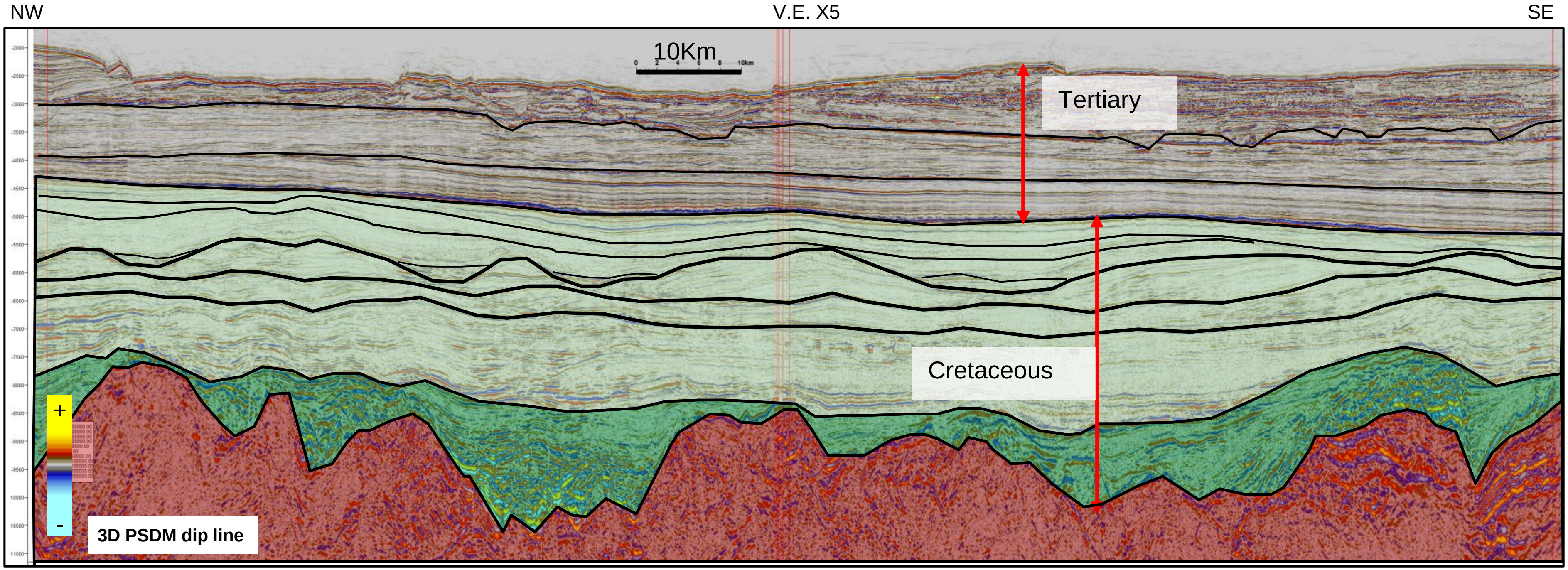
Regional Context - Dip



- Complex basement topography
- Focus on Pelotas basin
- Rift and sag phases (continental to very shallow marine)
- Drift: marine, progressive deepening
- Modern day-Tertiary terraced profile

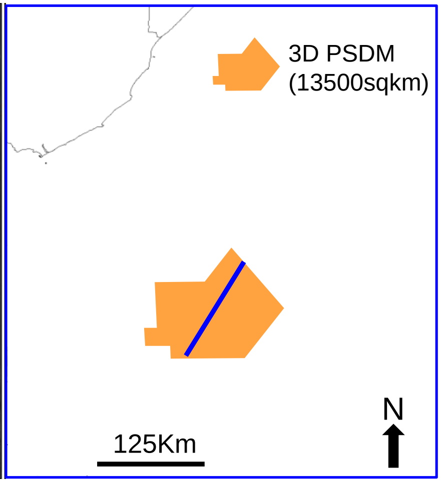


Regional Context - Strike

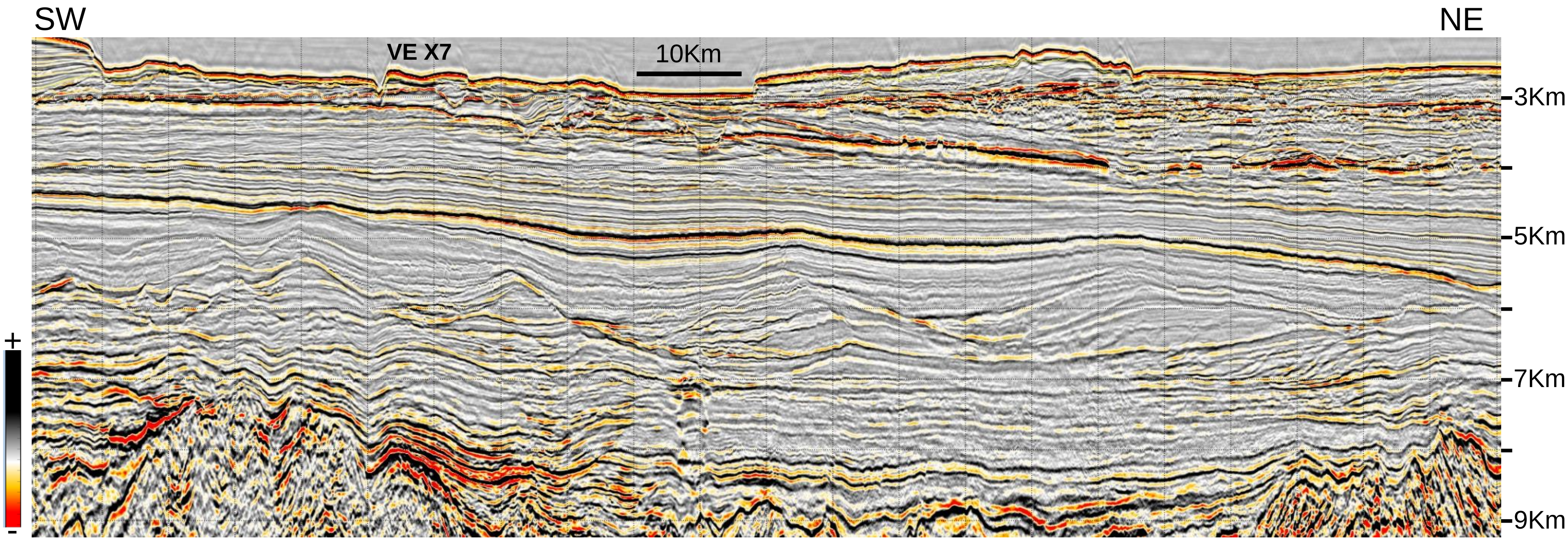


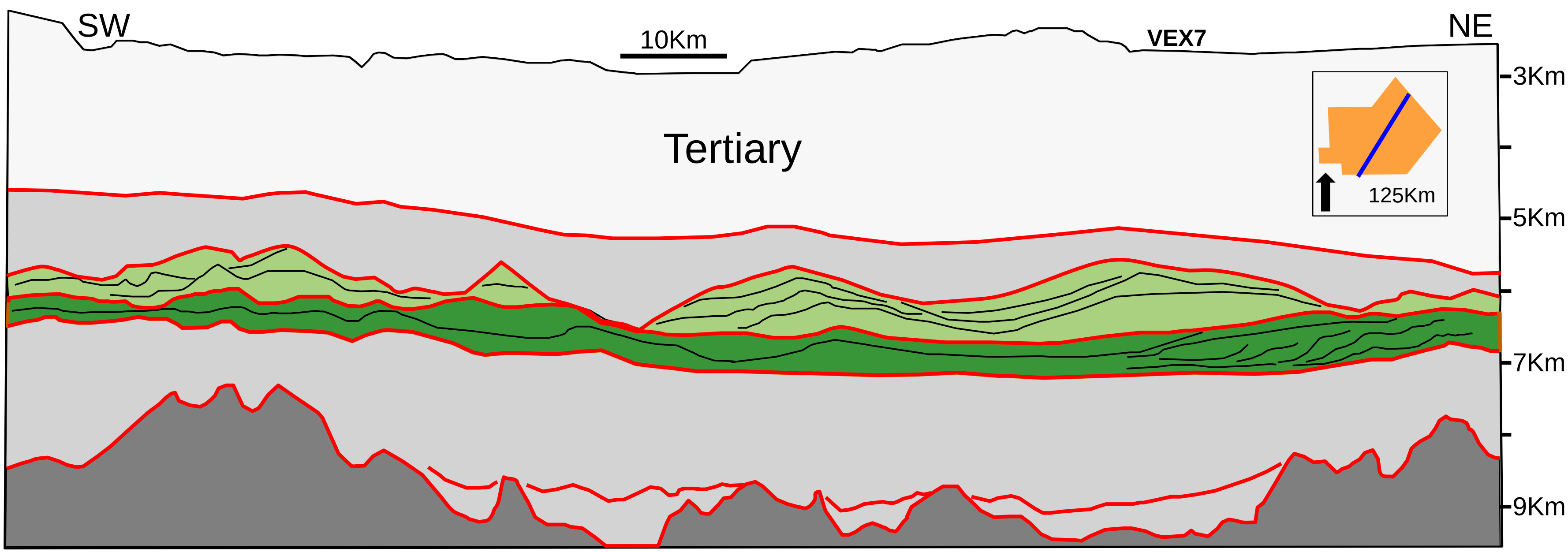
Key bounding surfaces within contouritic-turbiditic sequence

Tentative ages (based on regional work, nearest offset wells >100km to the NW, Lobo and Gaviotin)

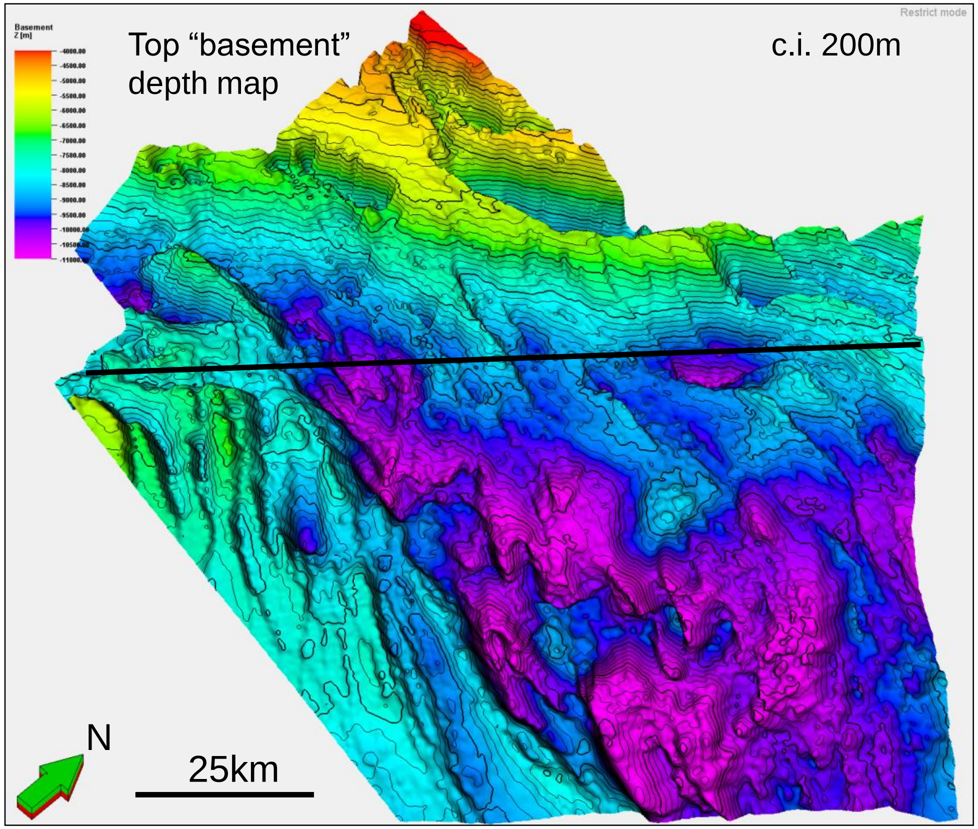


Cretaceous Basin Fill

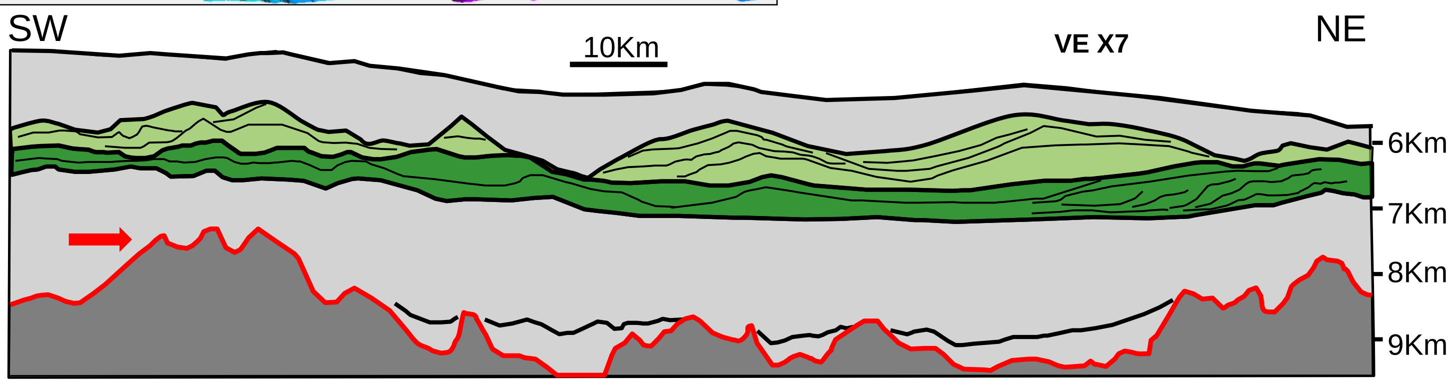




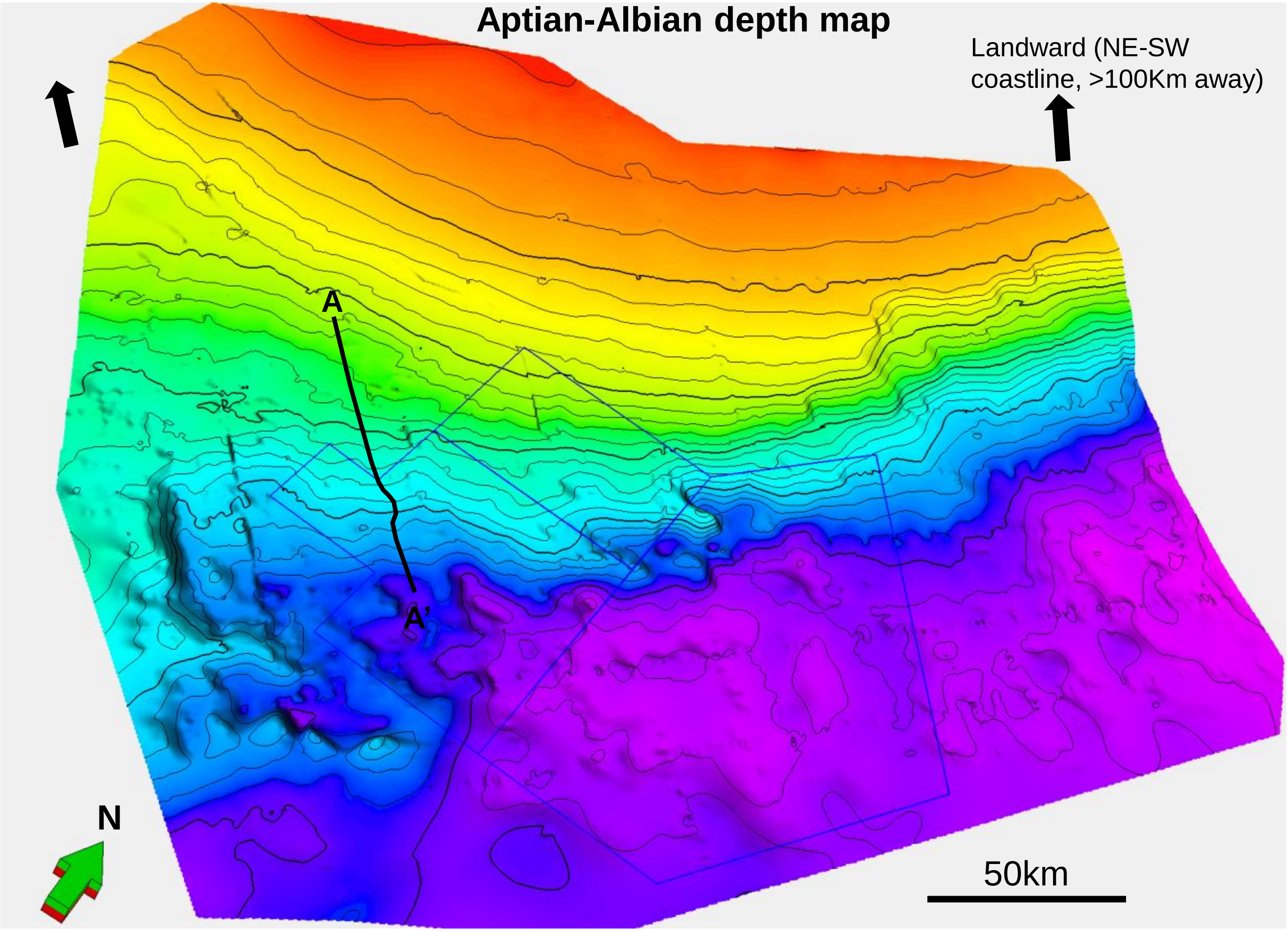
Basin evolution - Basement



- Rift-inherited basin topography
- Topography has major control on sediment dispersal system
- Progressive deepening of the basin, from continental/shallow marine to deep water environments



Offshore Uruguay – main sediment entry points



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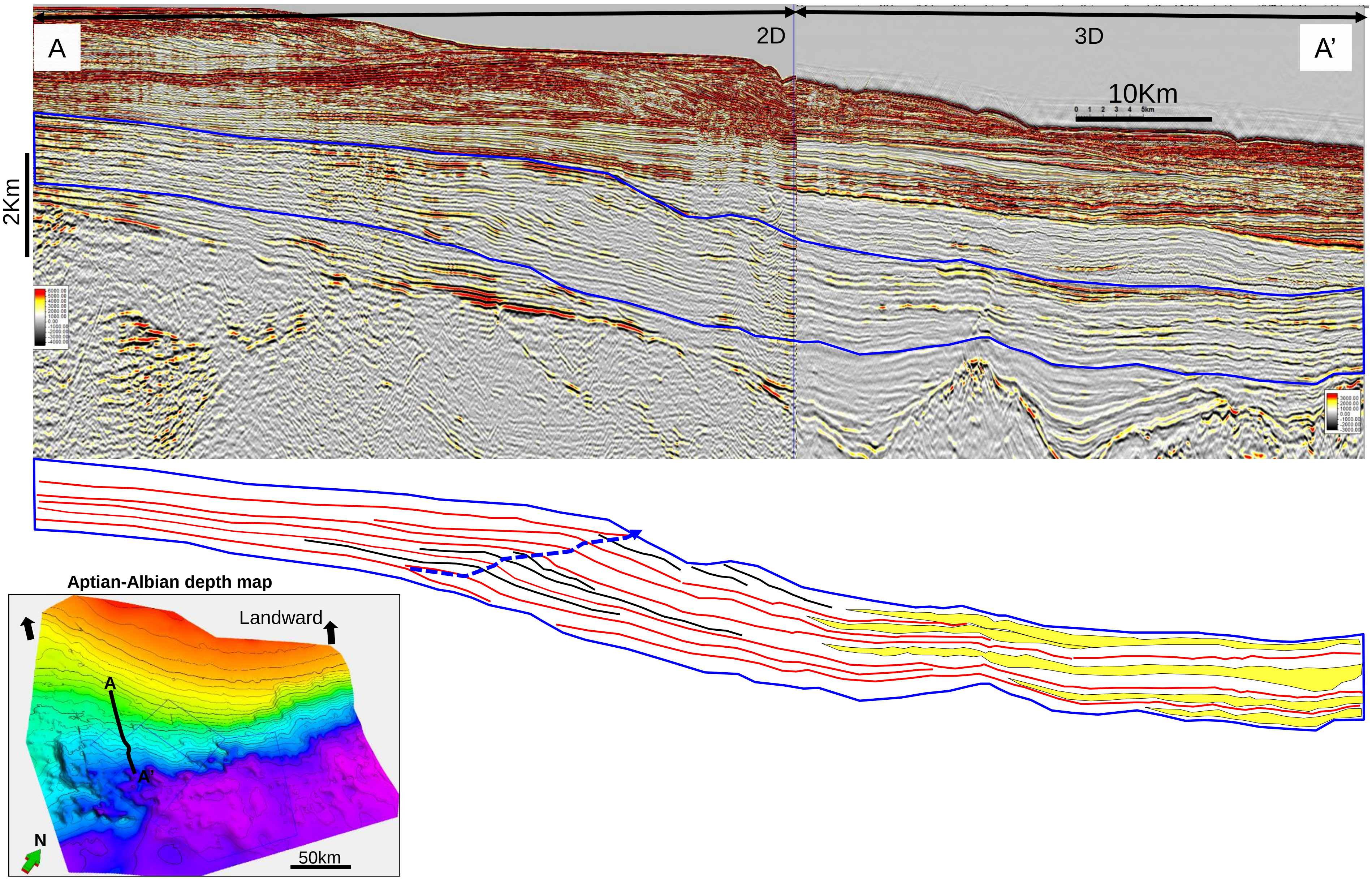
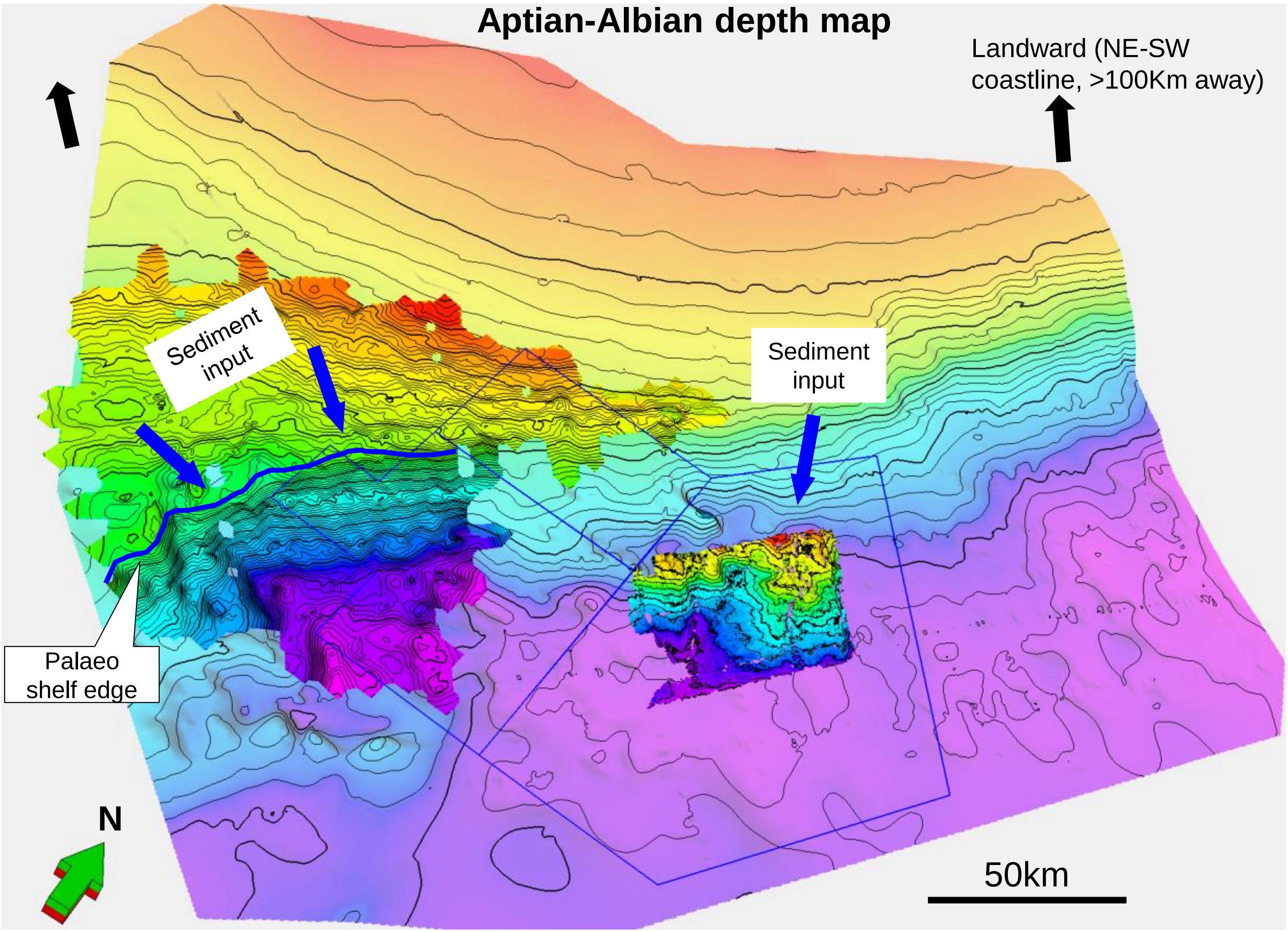
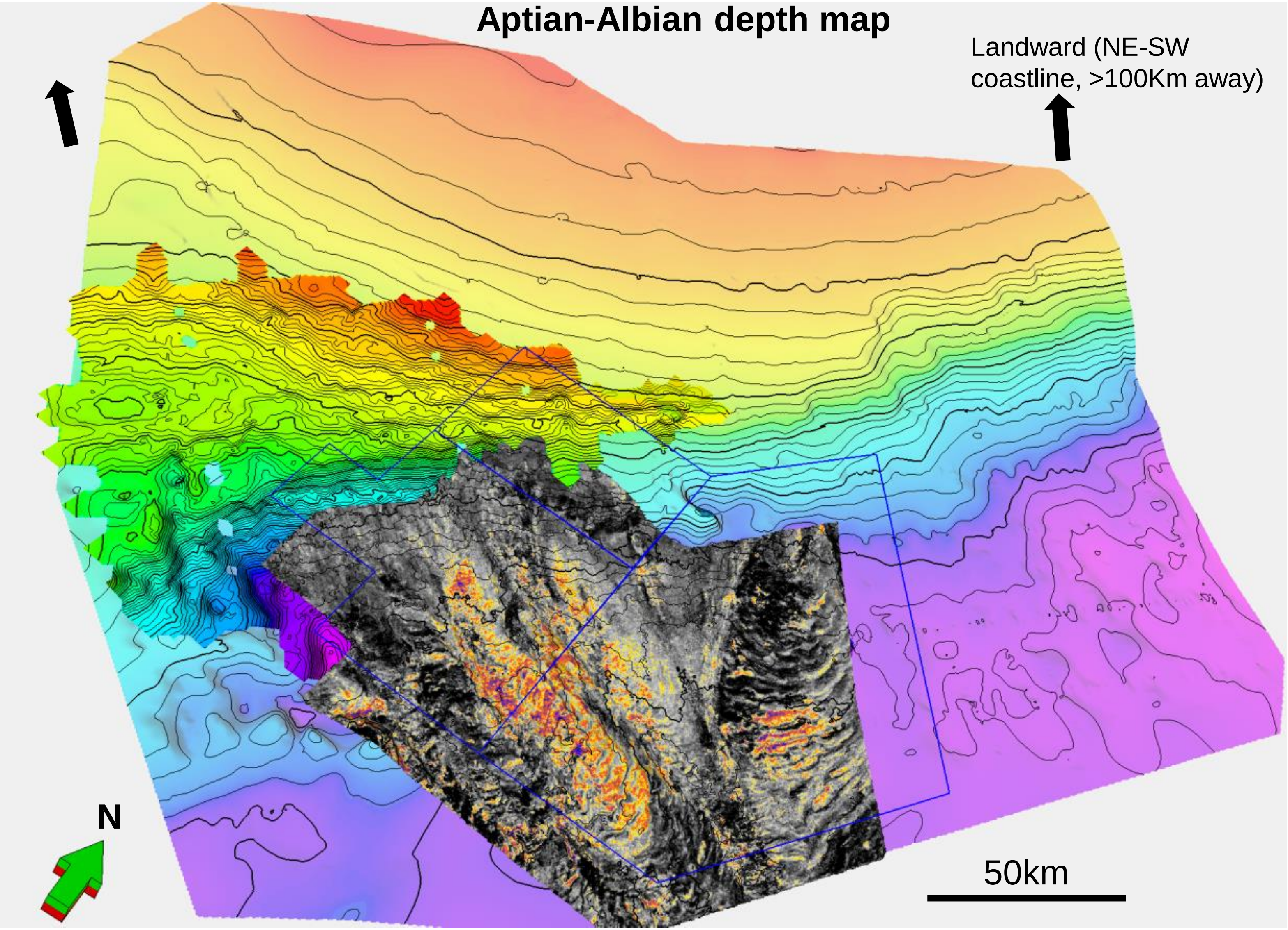


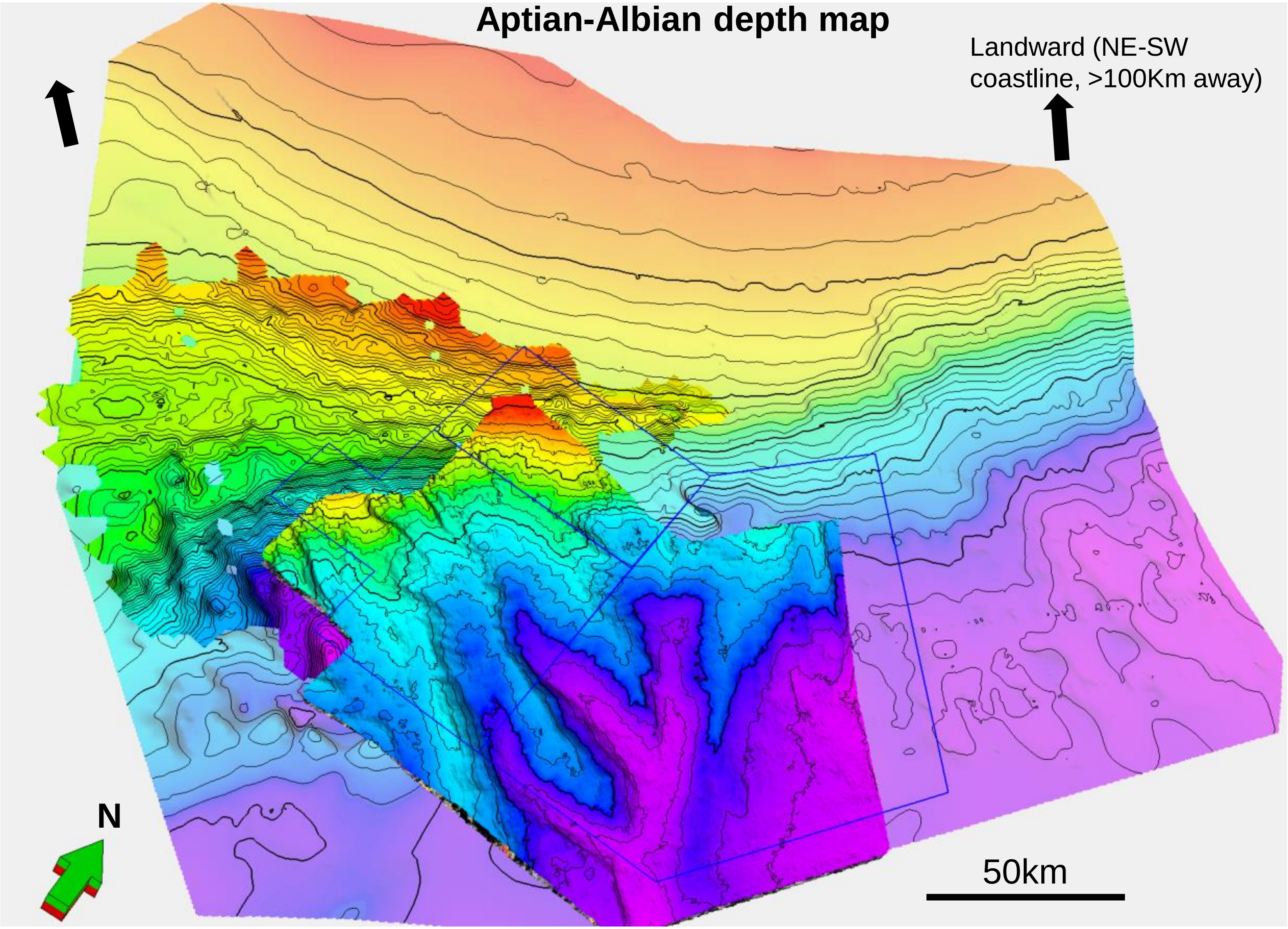
Offshore Uruguay – main sediment entry points



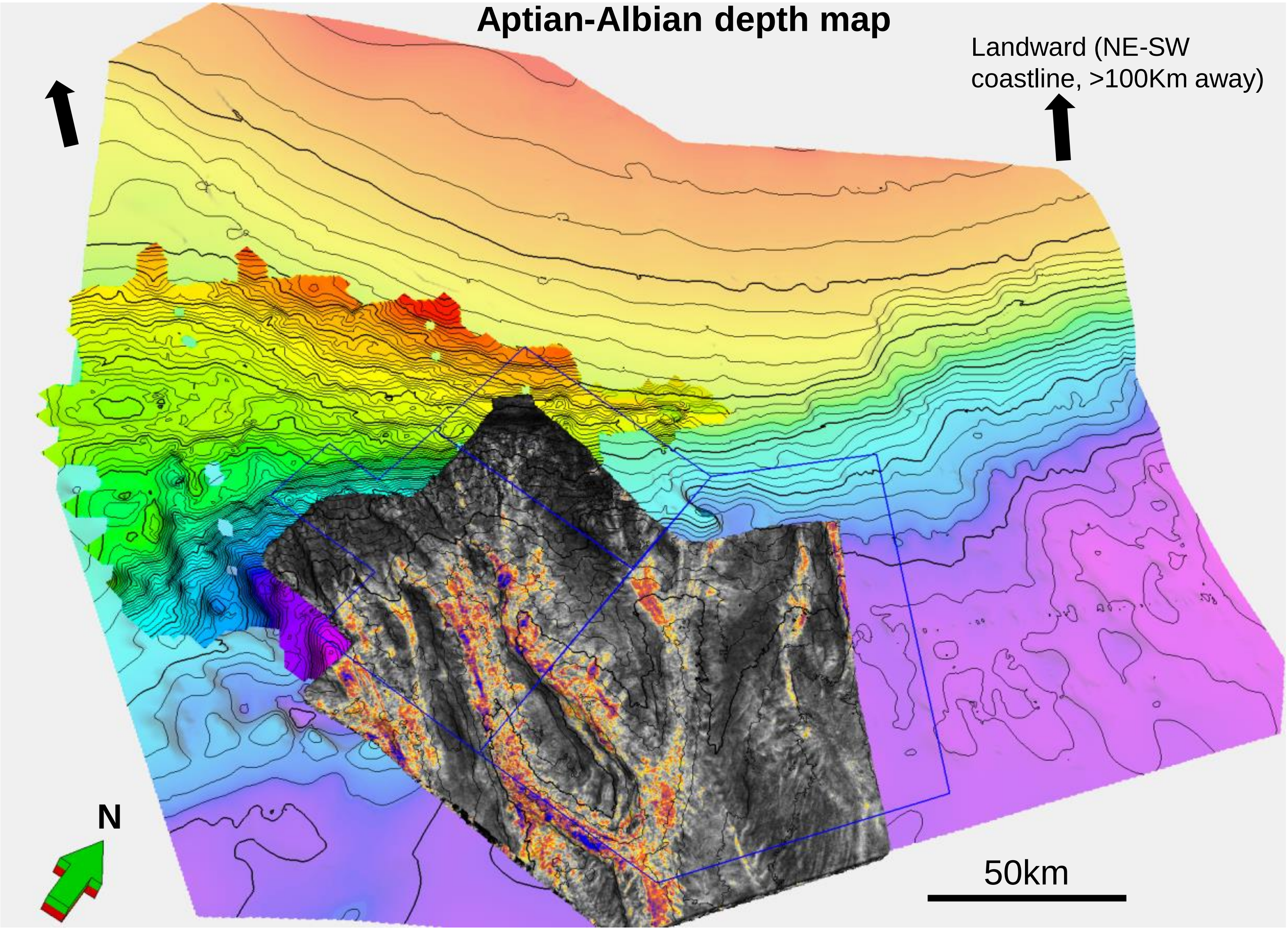
Offshore Uruguay – main sediment entry points



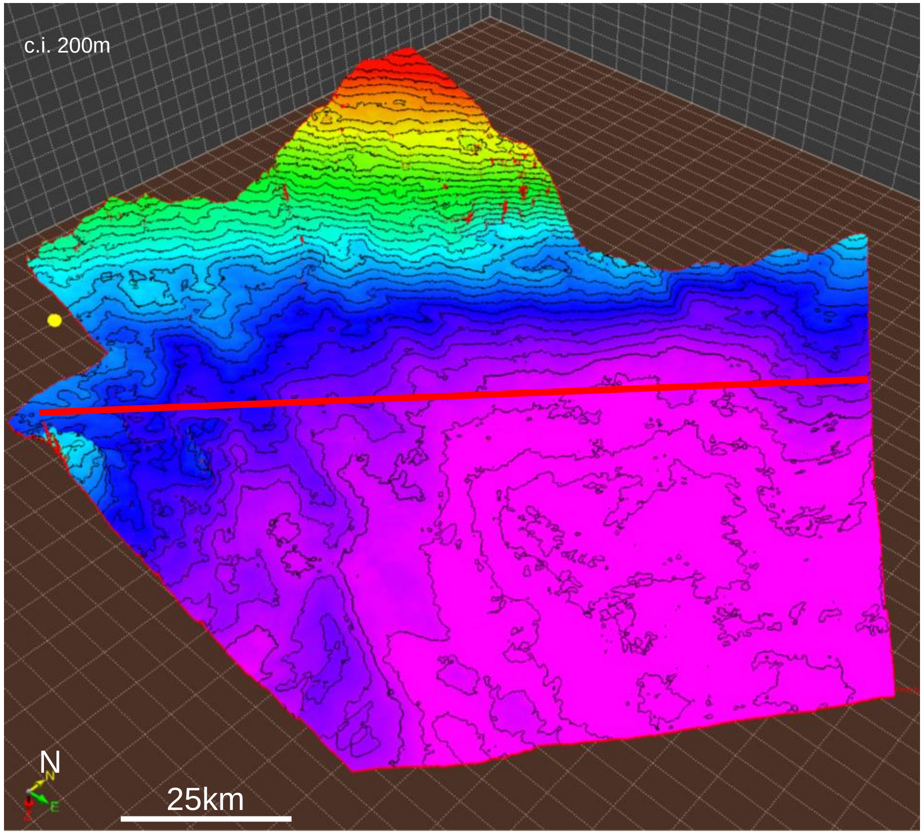
Offshore Uruguay – main sediment entry points

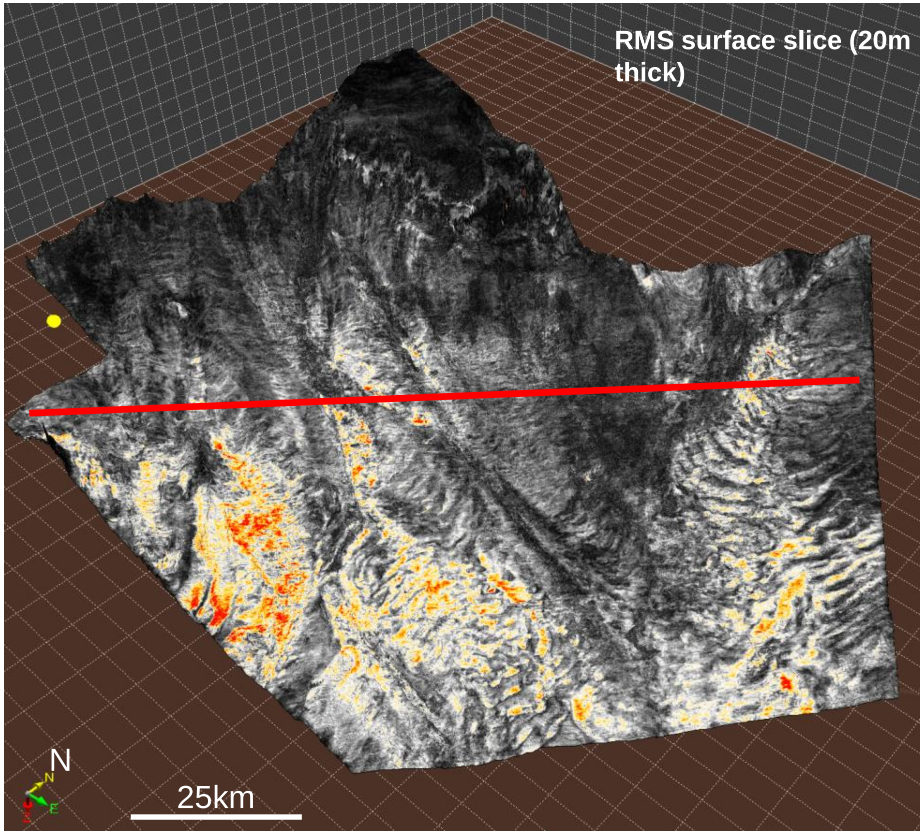


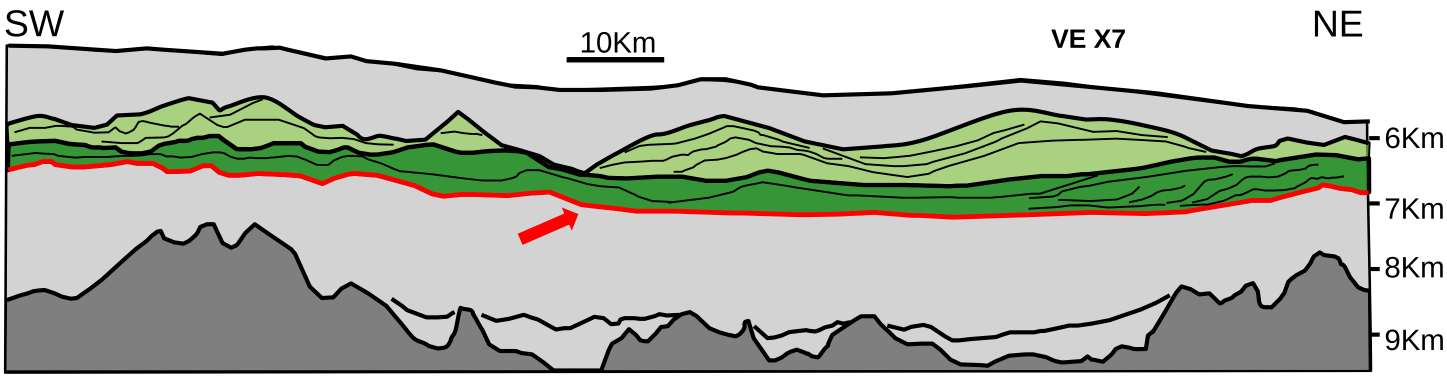
Offshore Uruguay – main sediment entry points



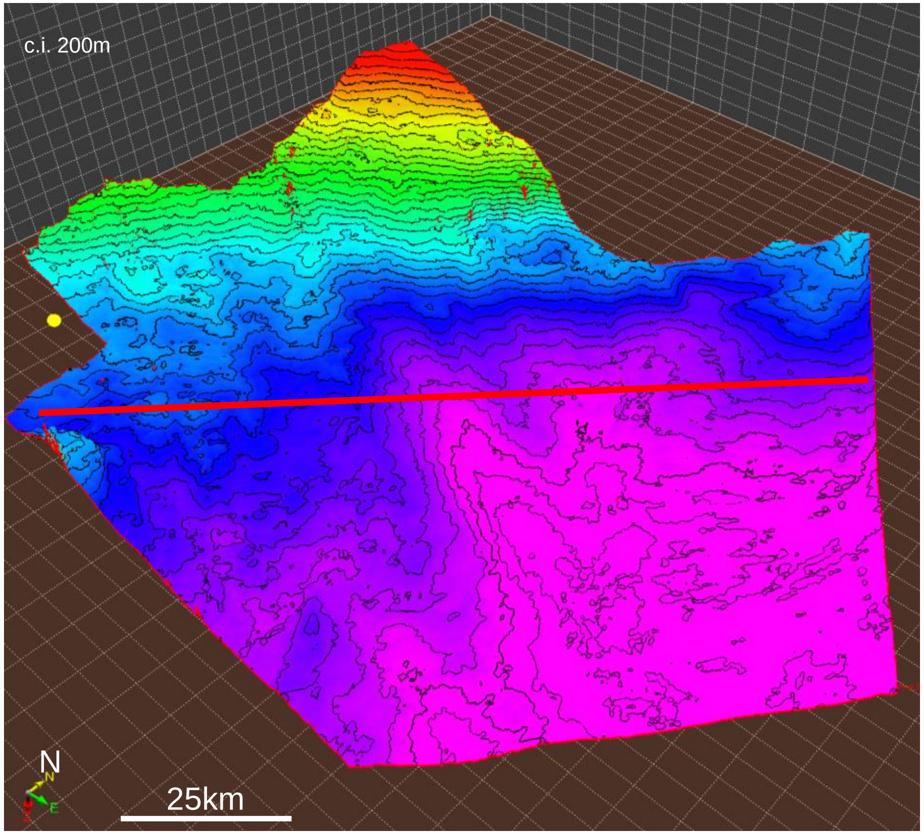
Basin evolution – slope fans and sediment waves (?)

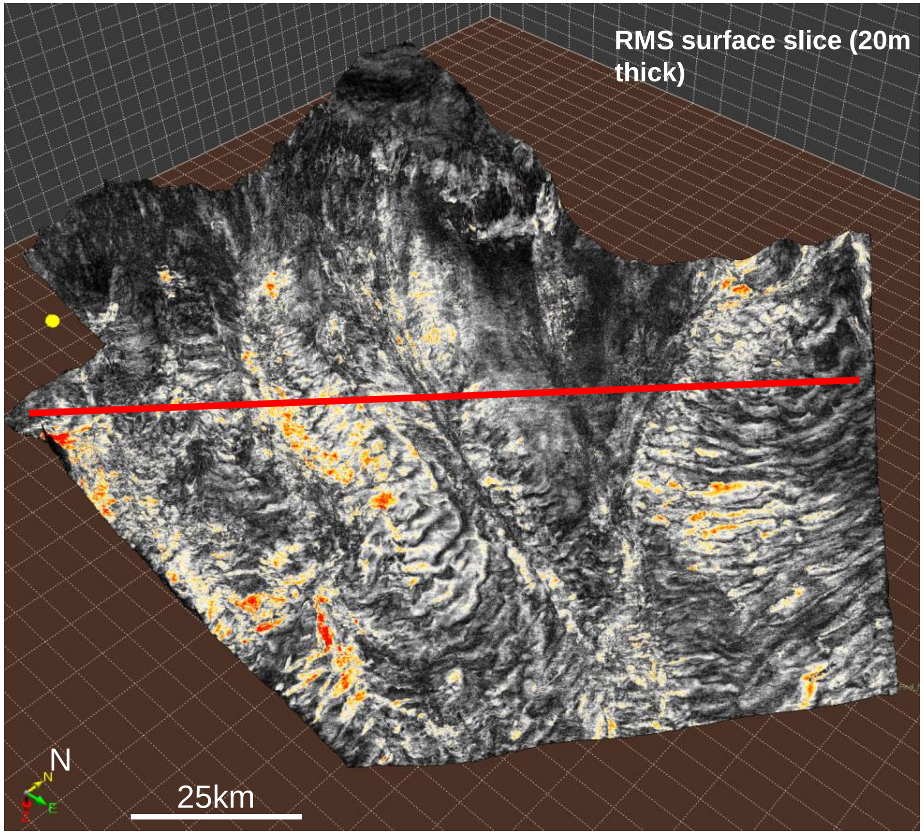


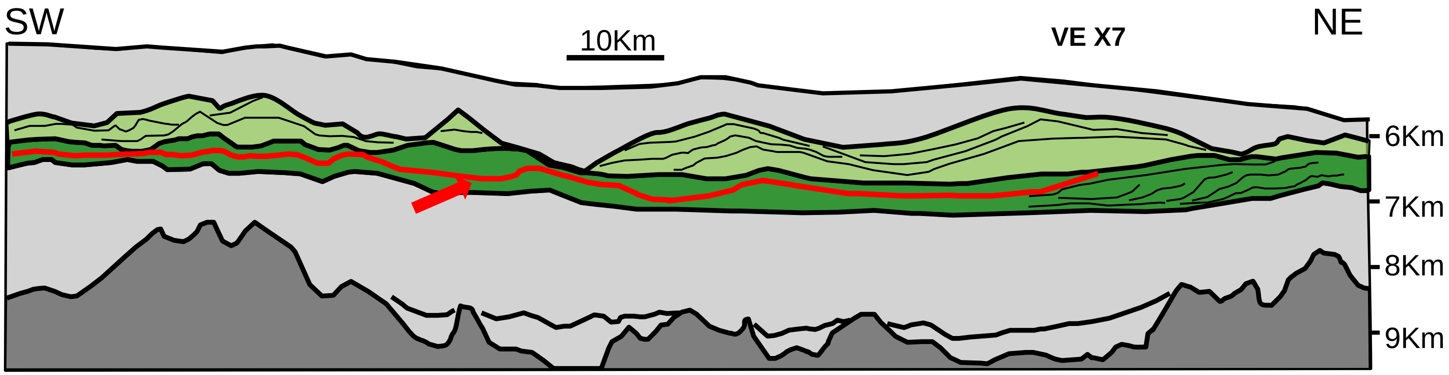




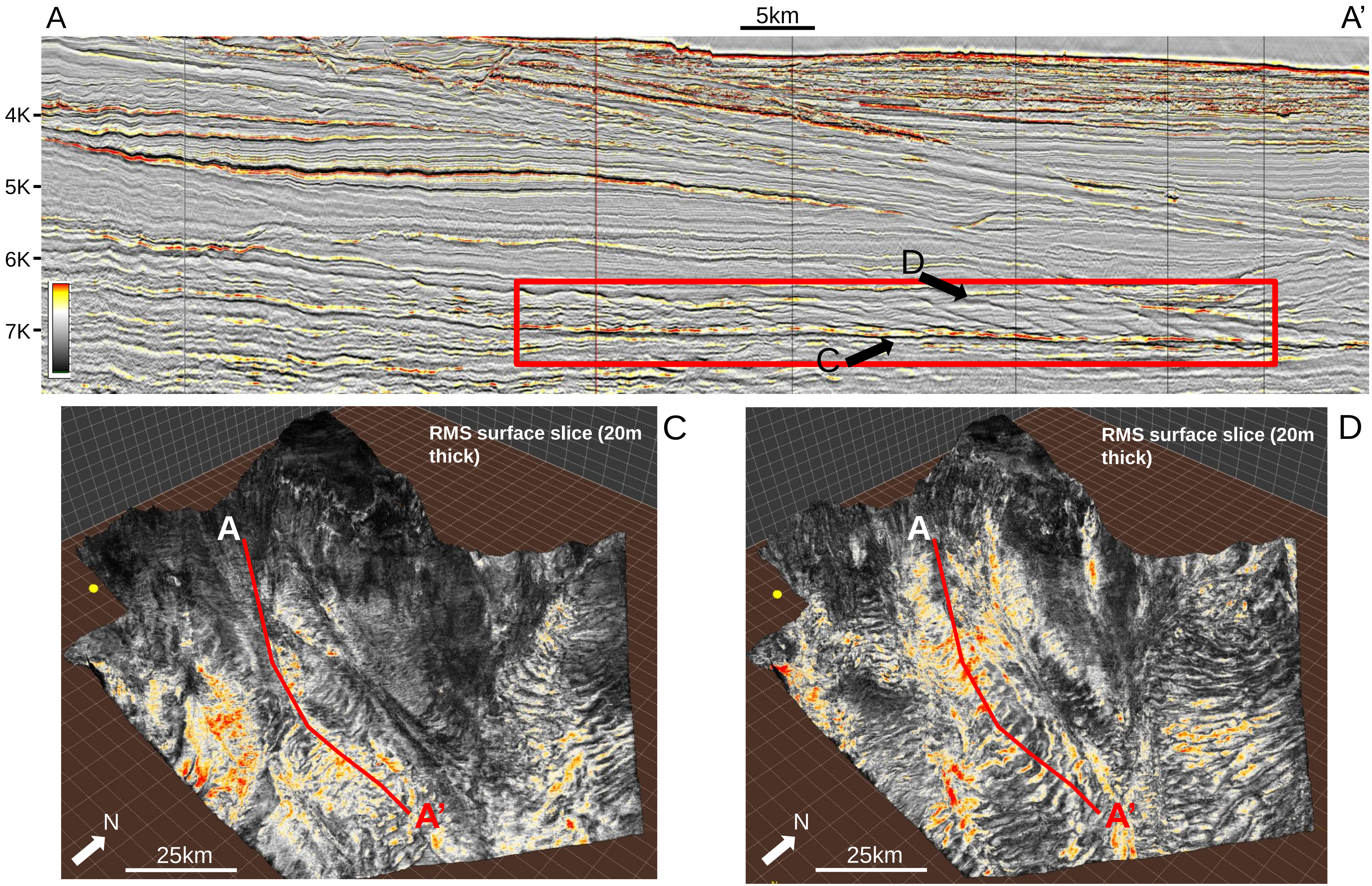
Basin evolution – sediment waves (?)



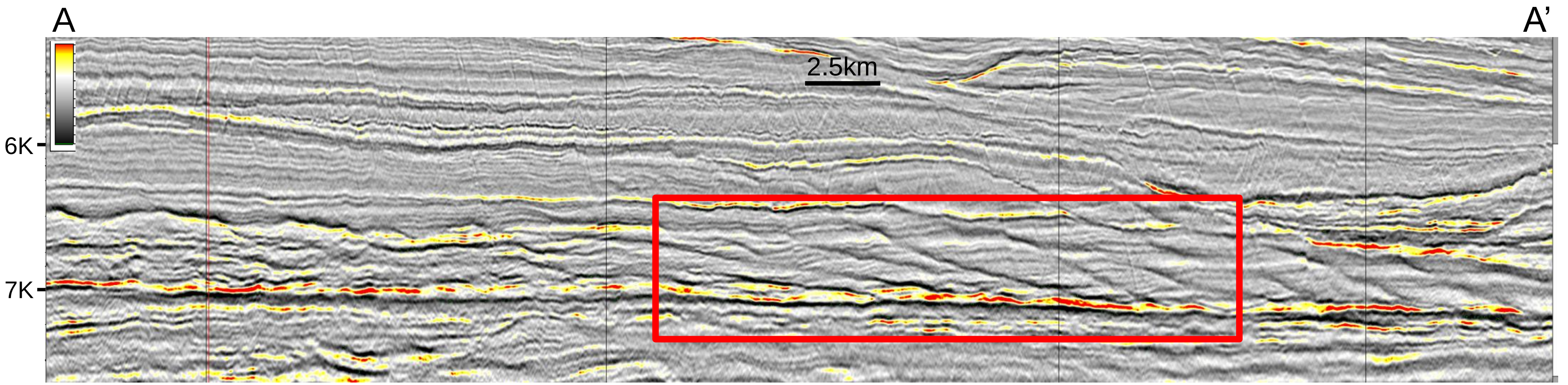




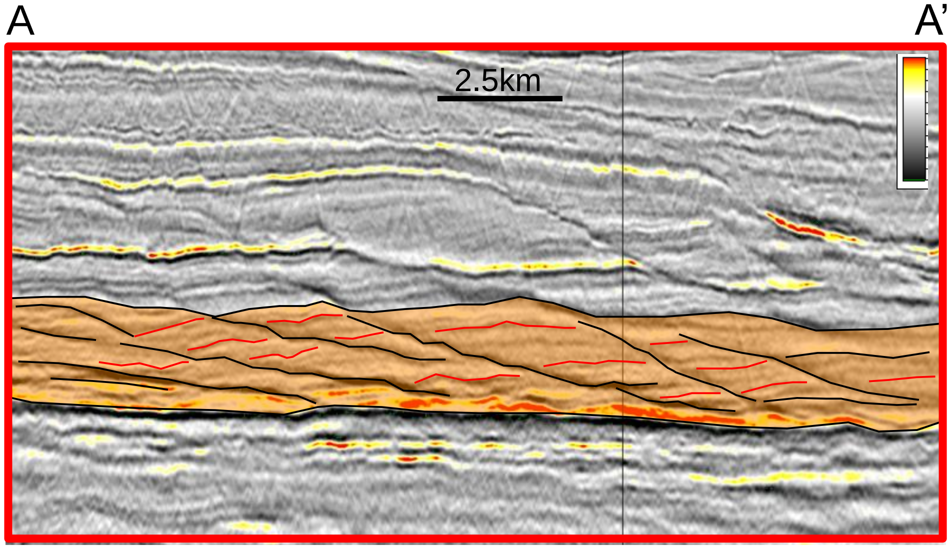
Slope fans, sediment waves (or slumps?)

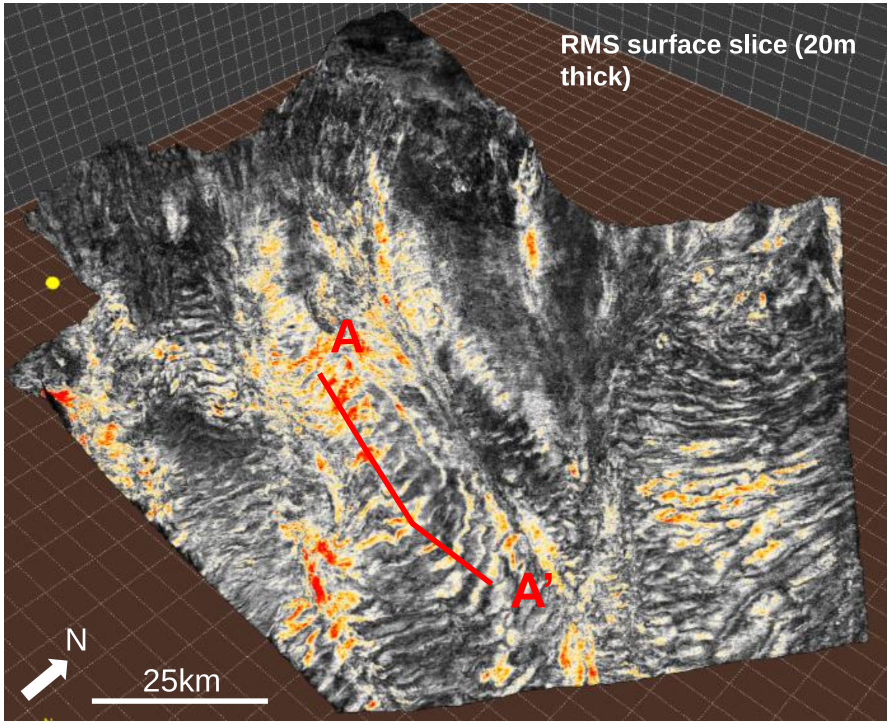


Sediment waves (or slumps?)

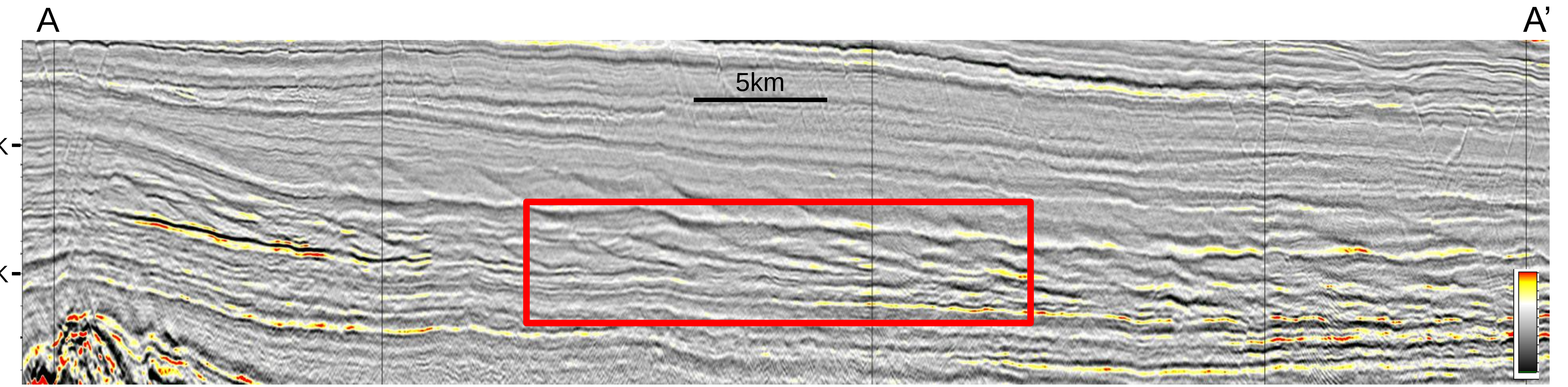


Sediment waves or slumps (or a combination of the two?)

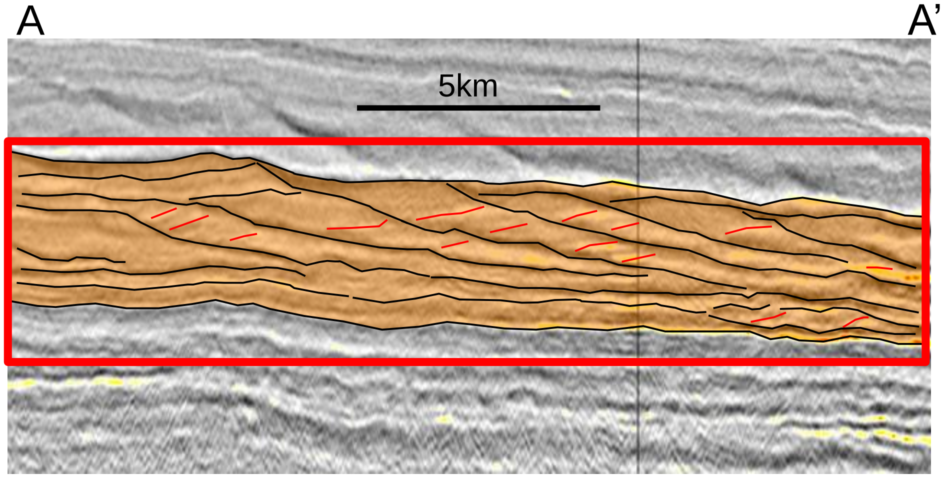


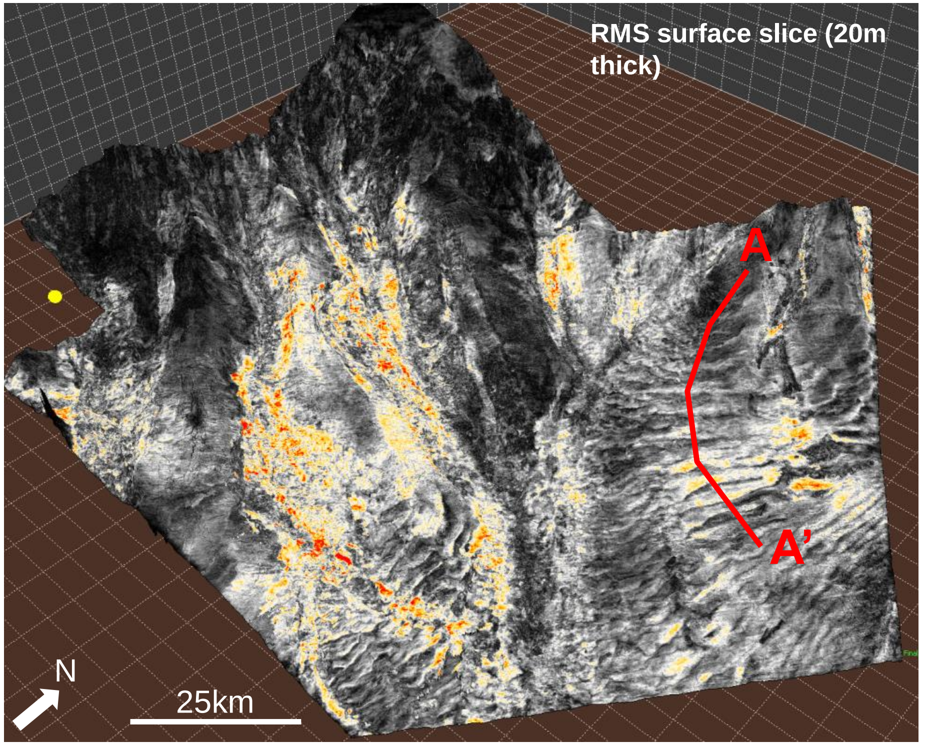


Sediment waves (or slumps?)

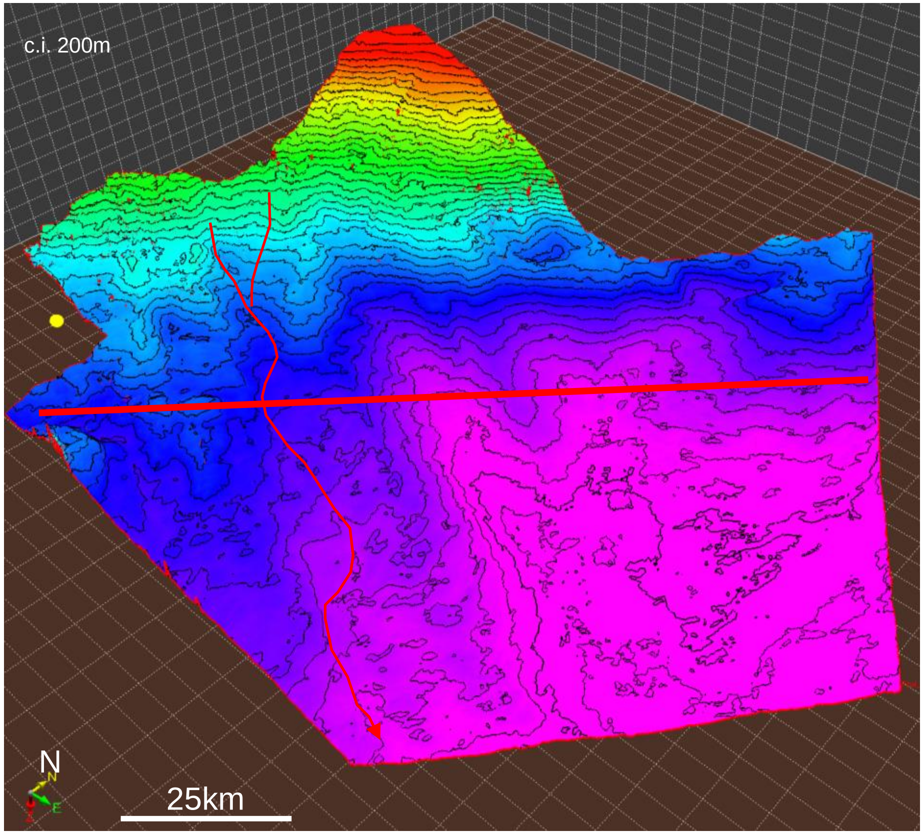


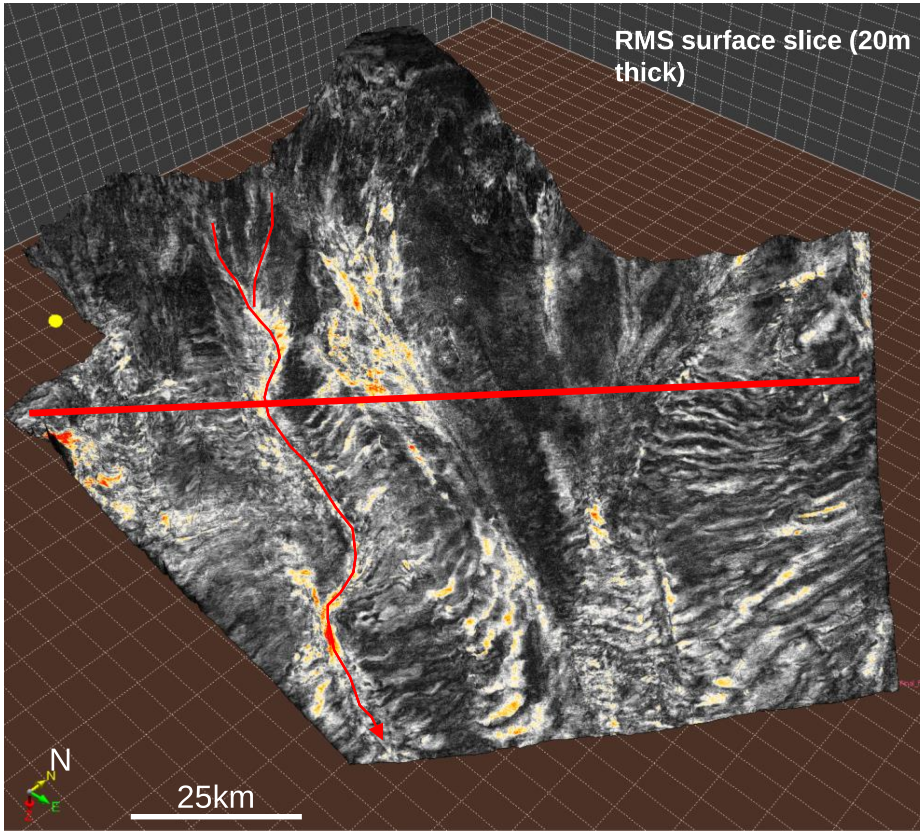
Sediment waves or slumps (or a combination of the two?)

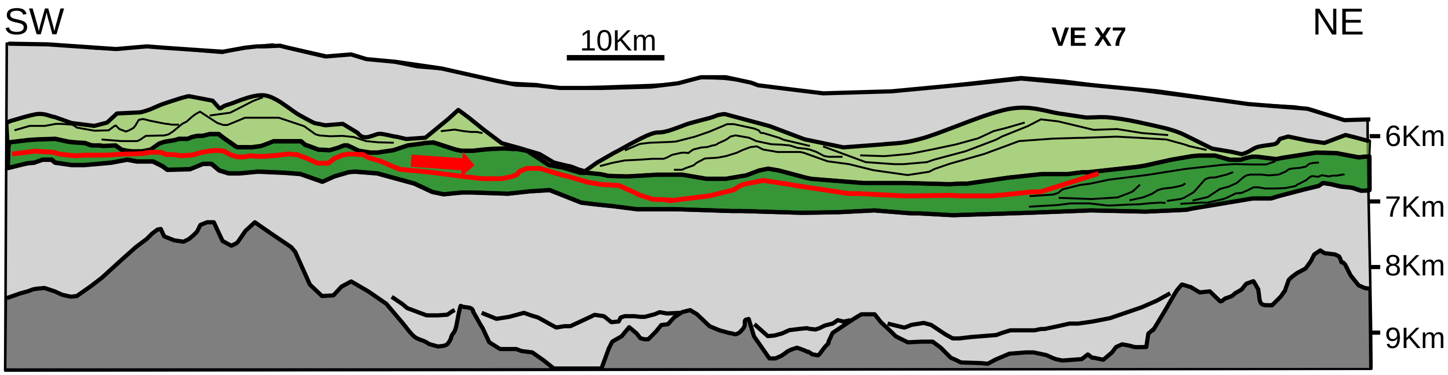




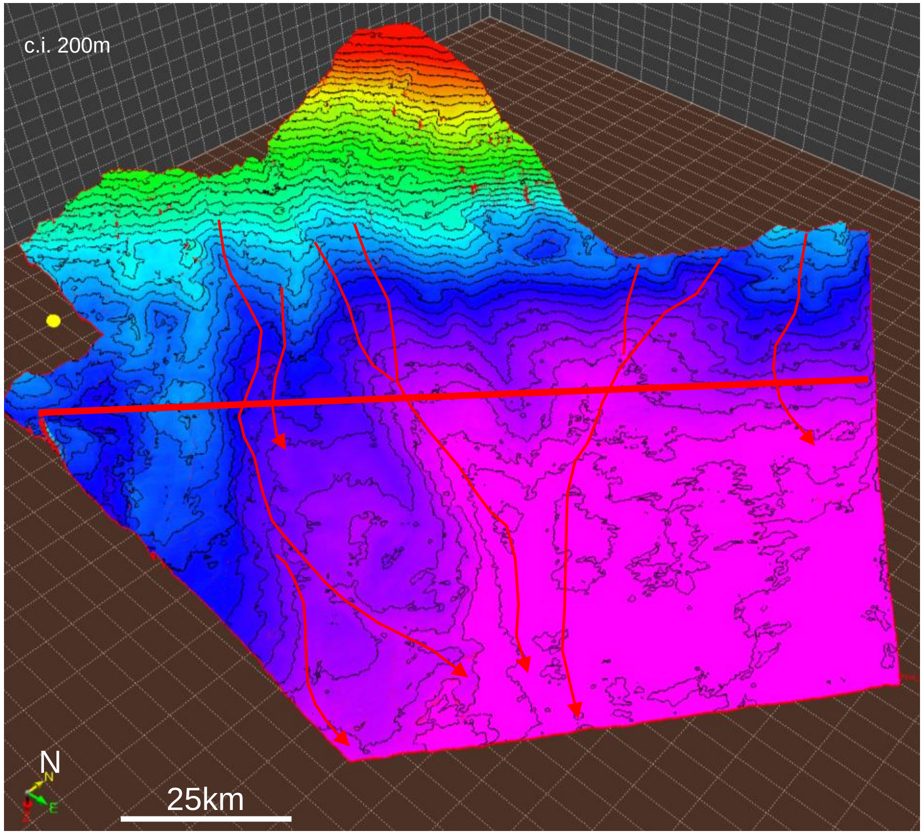
Basin evolution – hybrid system

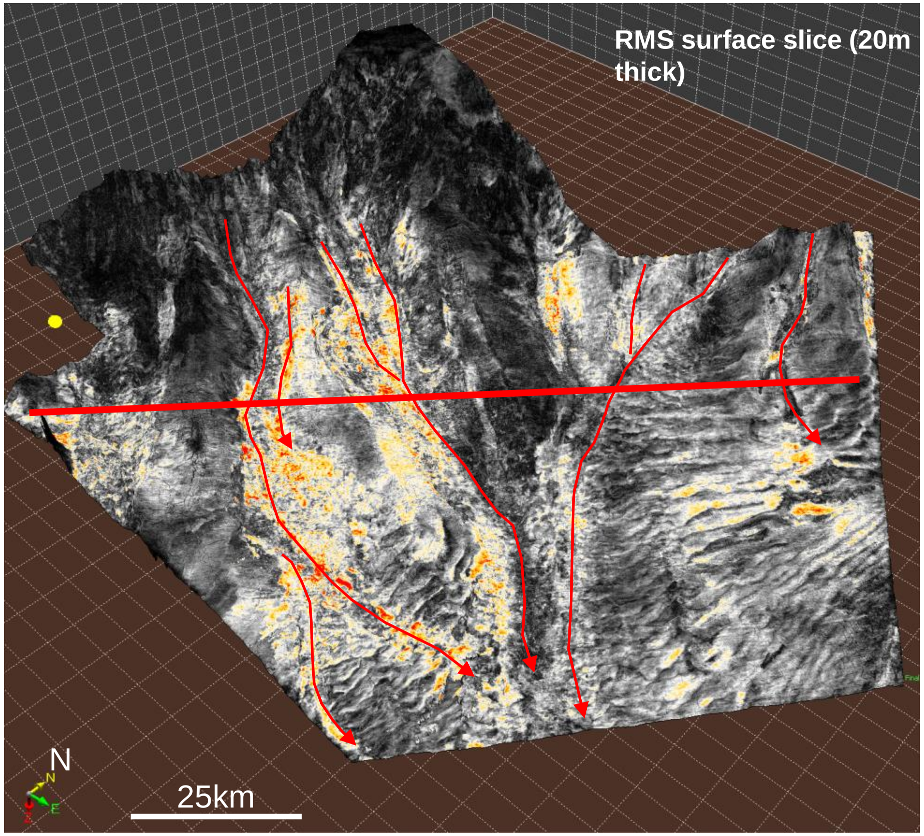


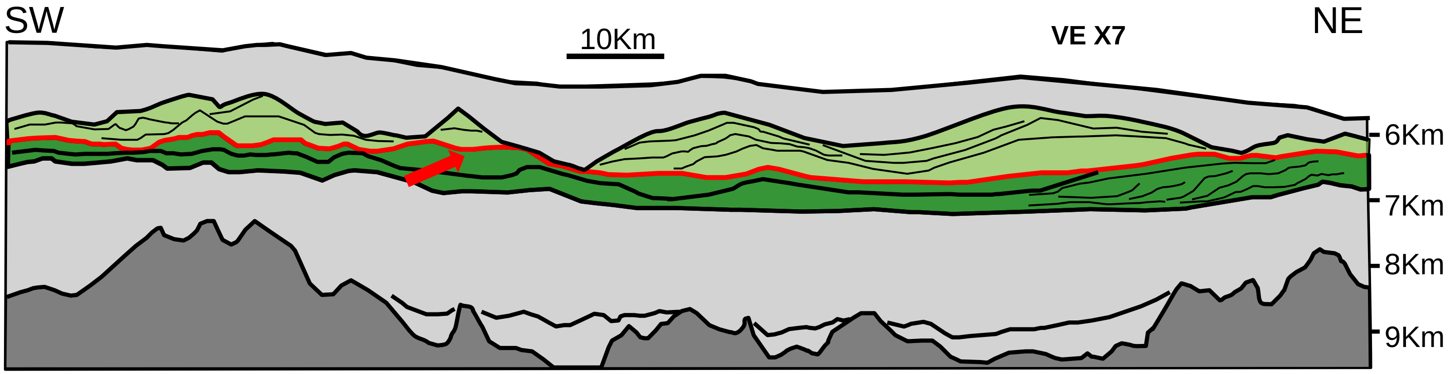




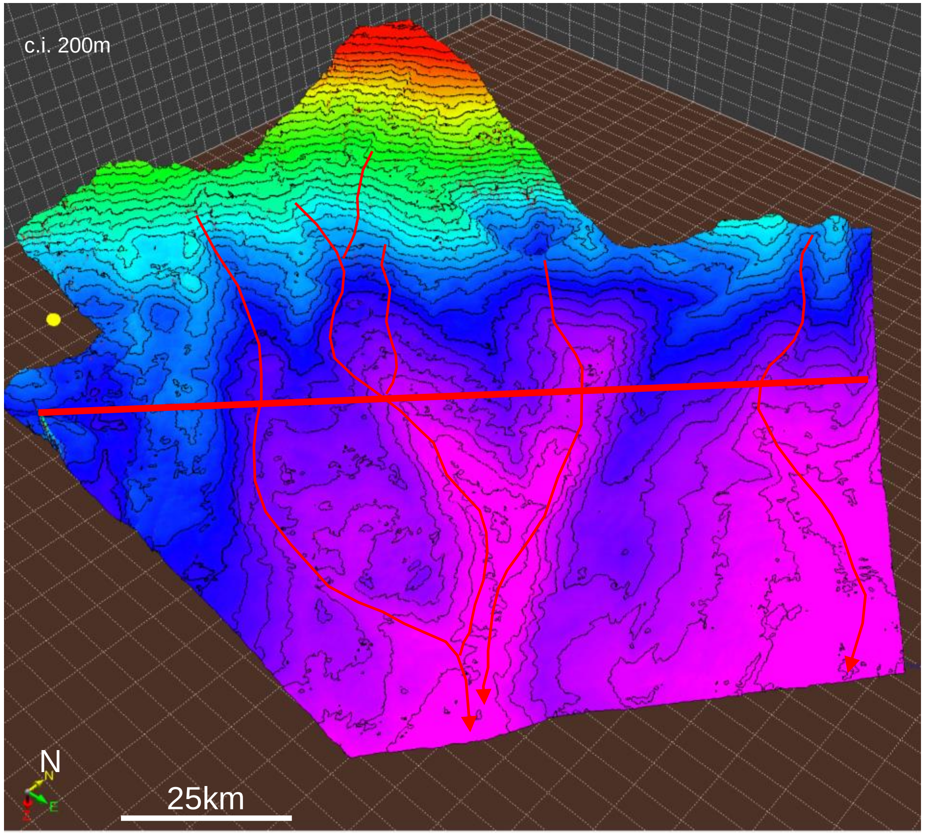
Basin evolution – hybrid system

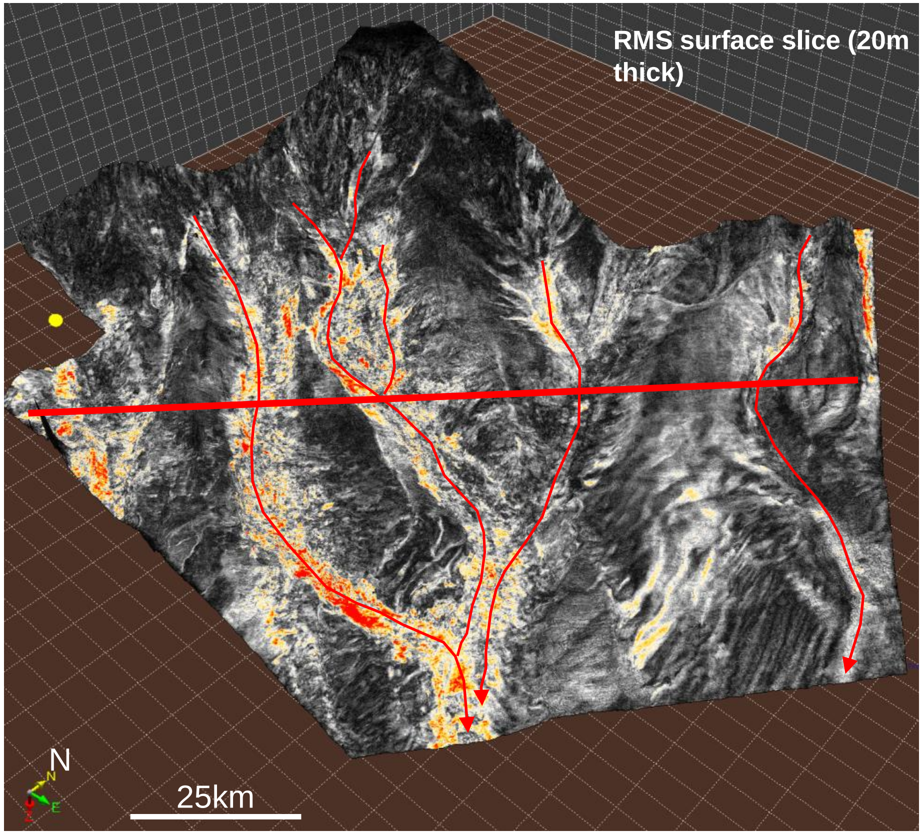


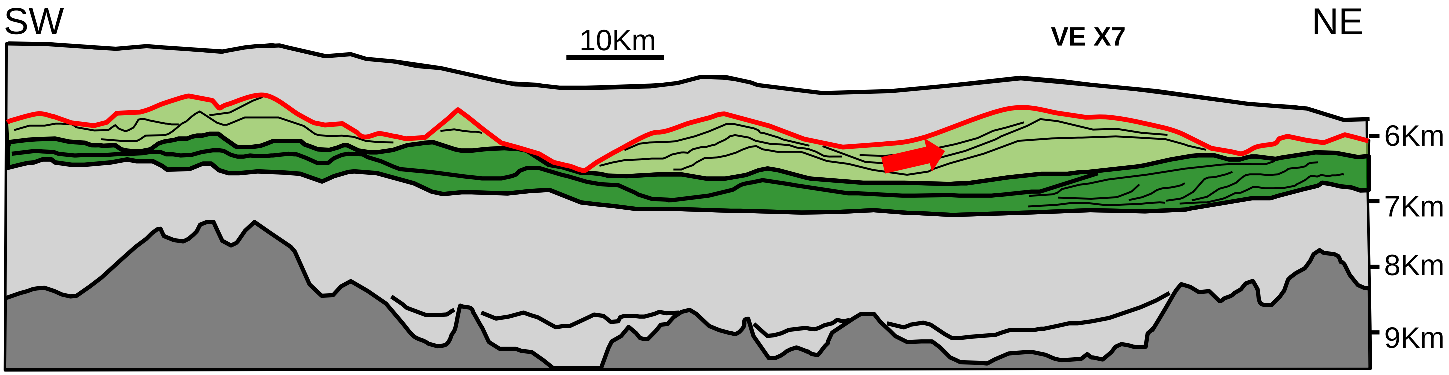




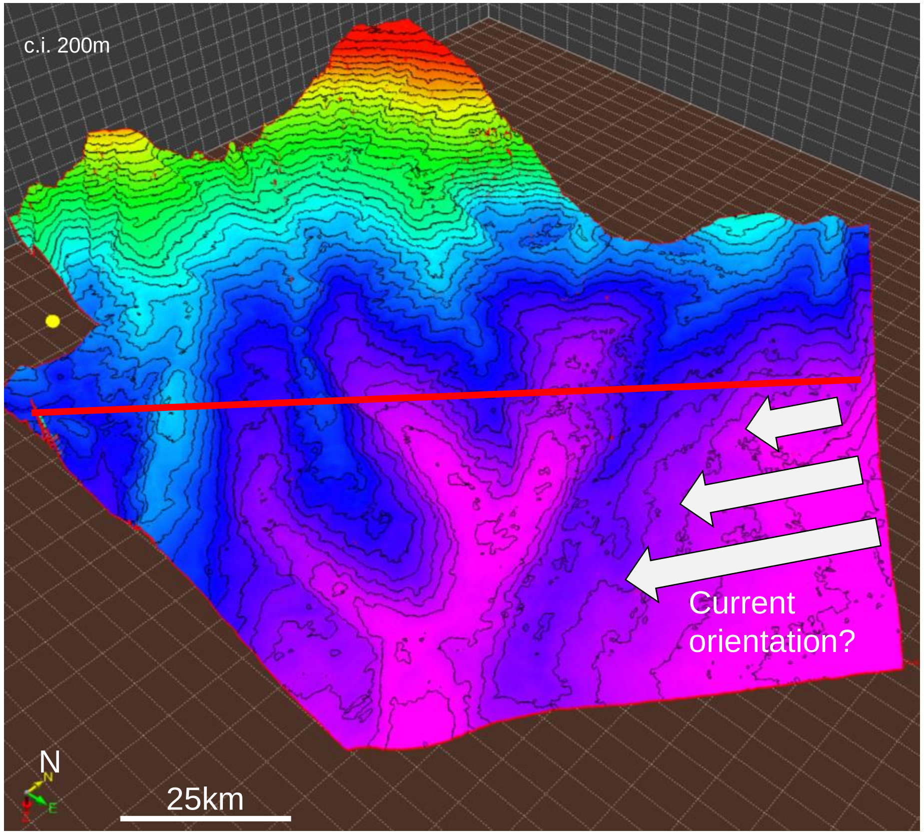
Basin evolution – drifts and hybrid system

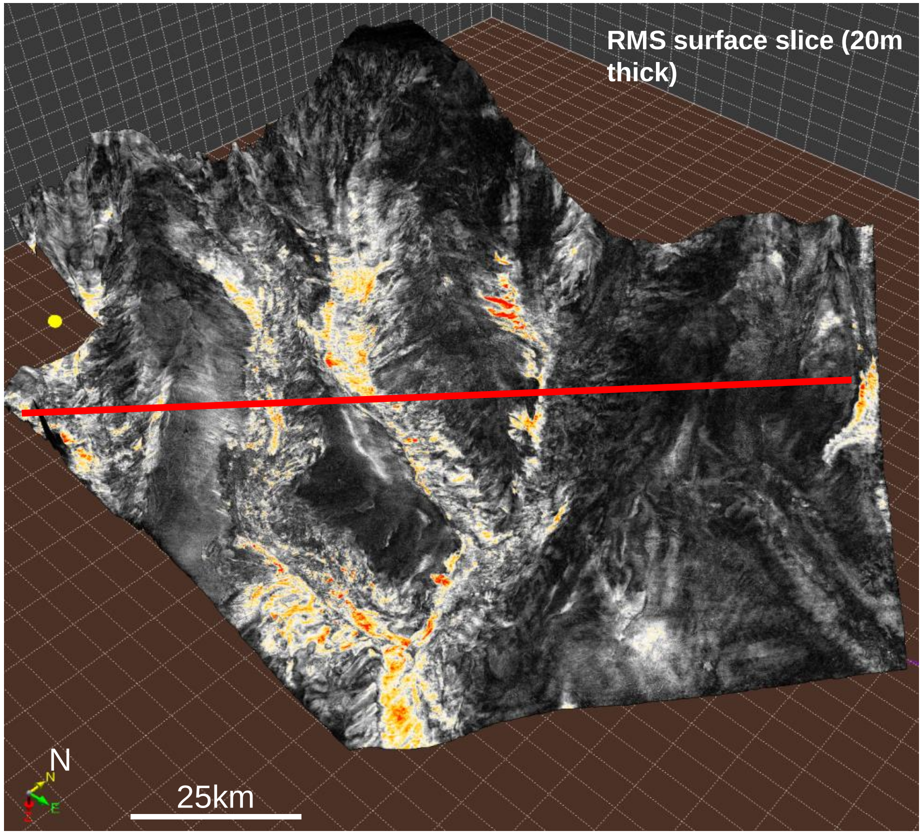




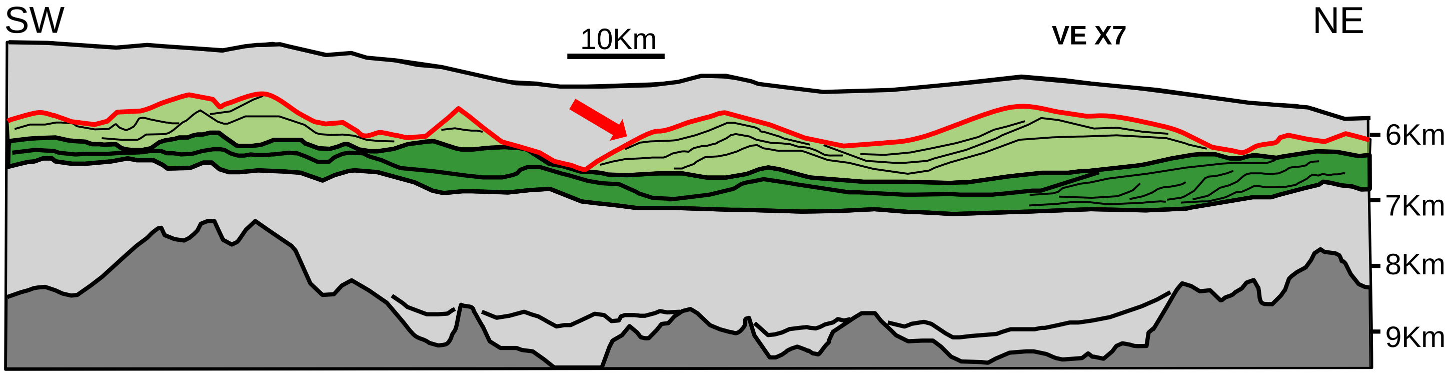


Basin evolution – drifts and hybrid system

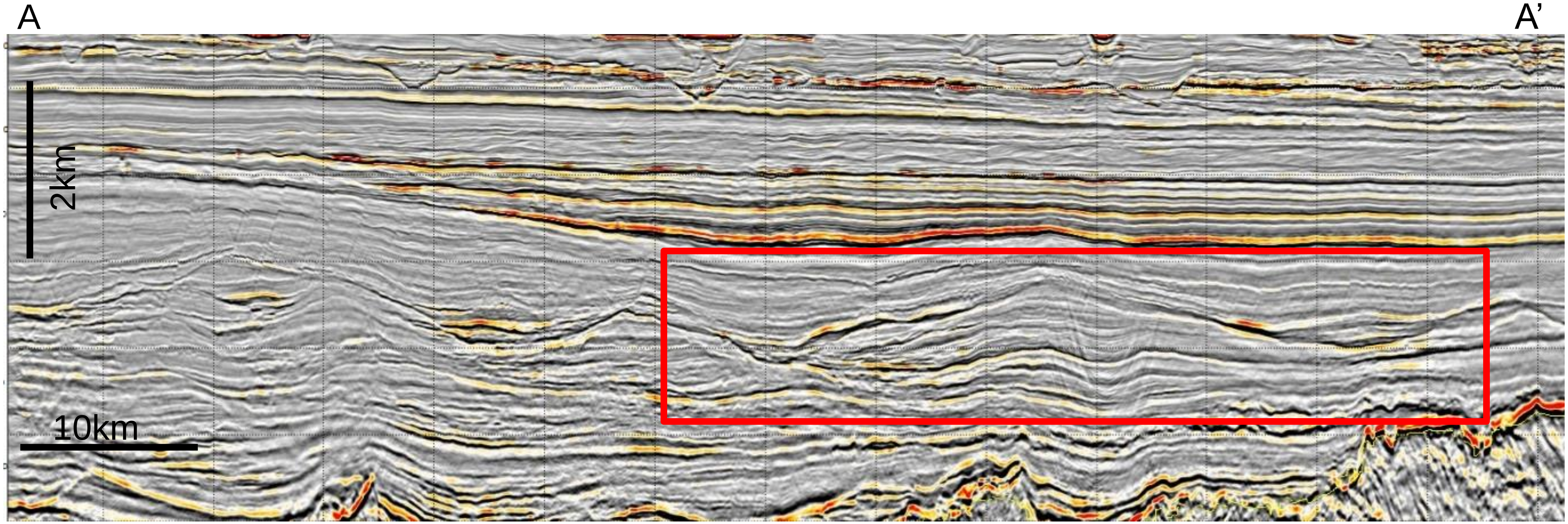


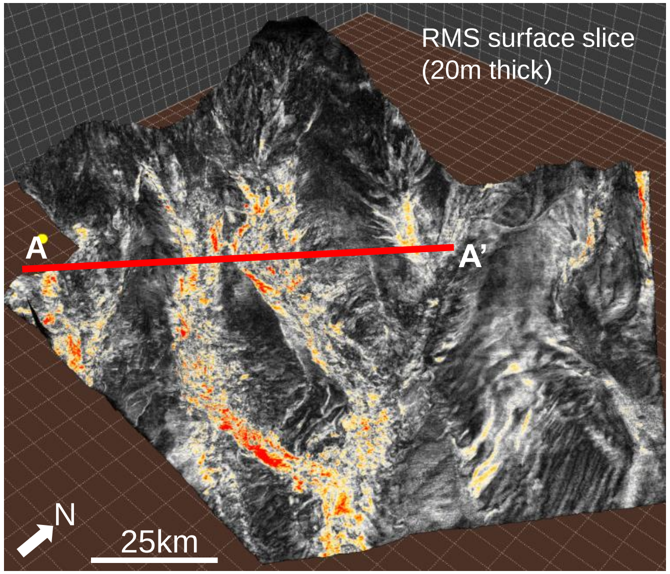


- Drifts orientated oblique (c.120º) or perpendicular to palaeo coastline
- Attached to upper slope region, run till basin floor

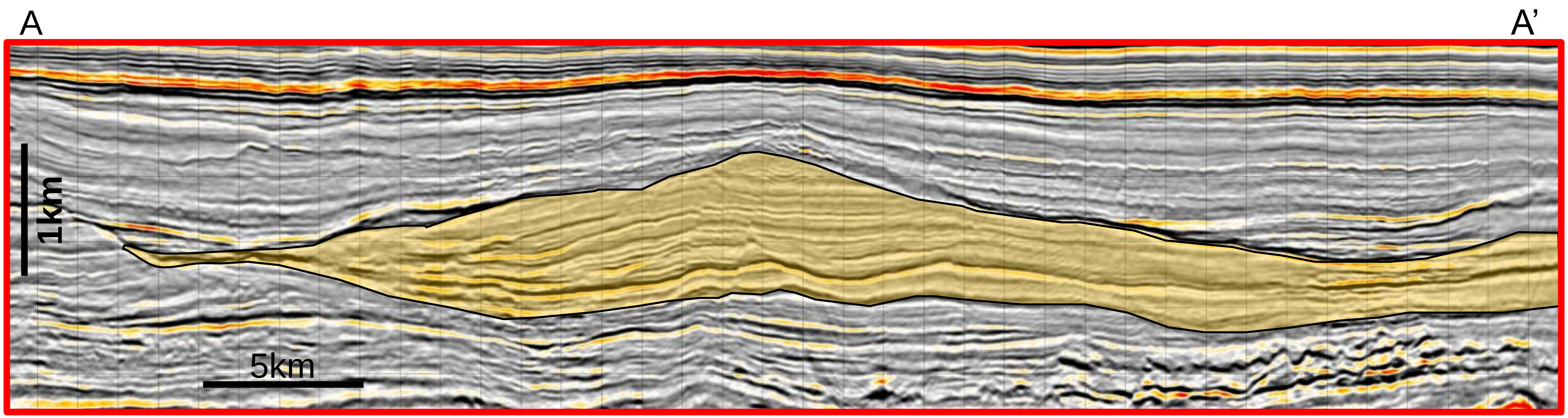


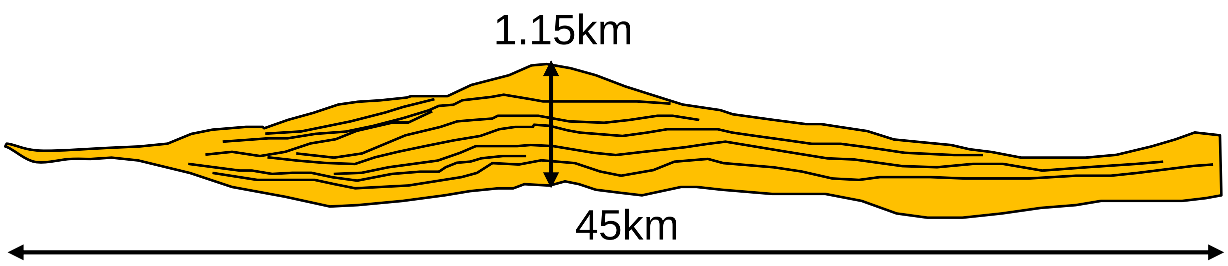
Drifts

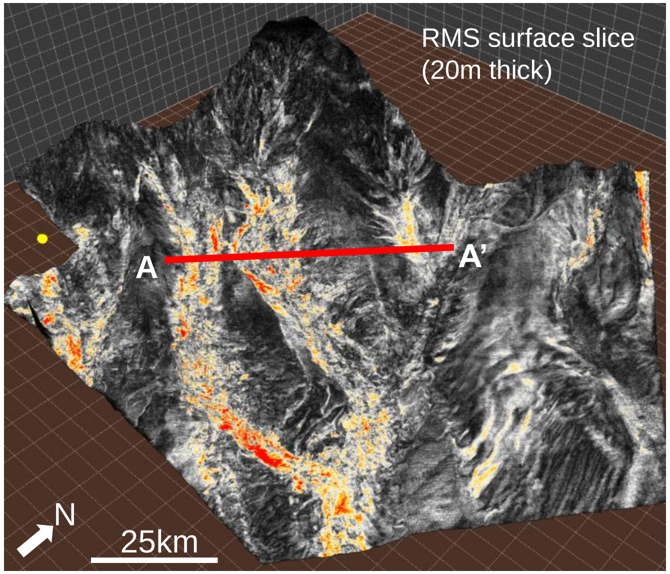




Drifts

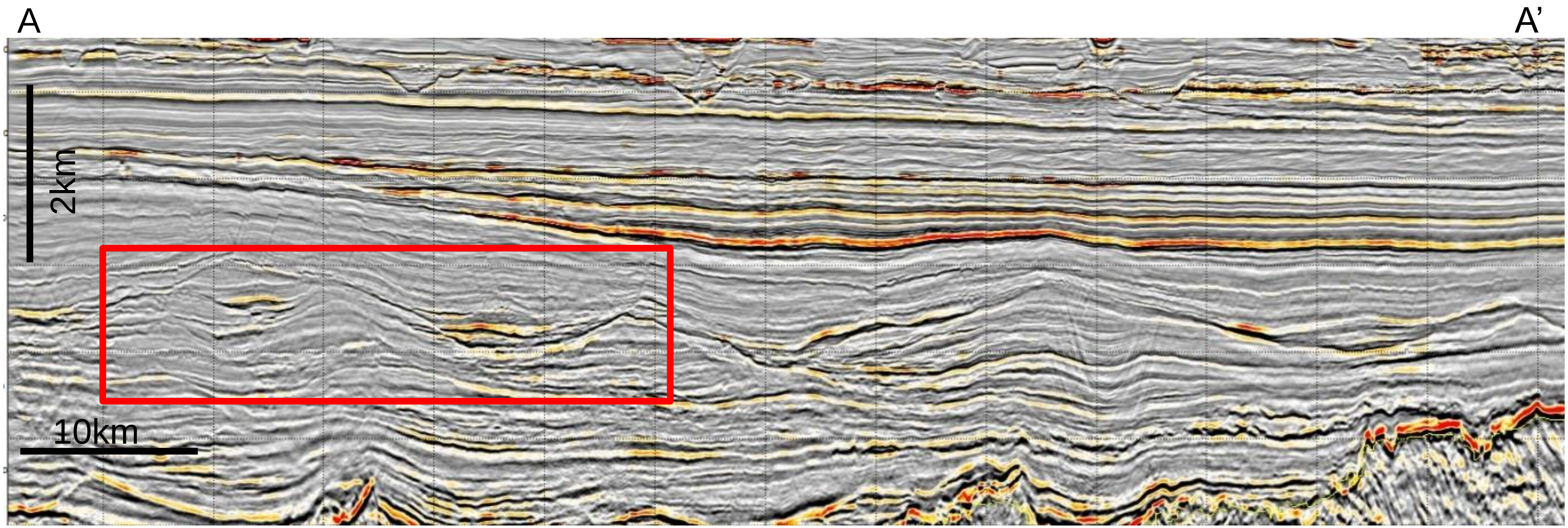


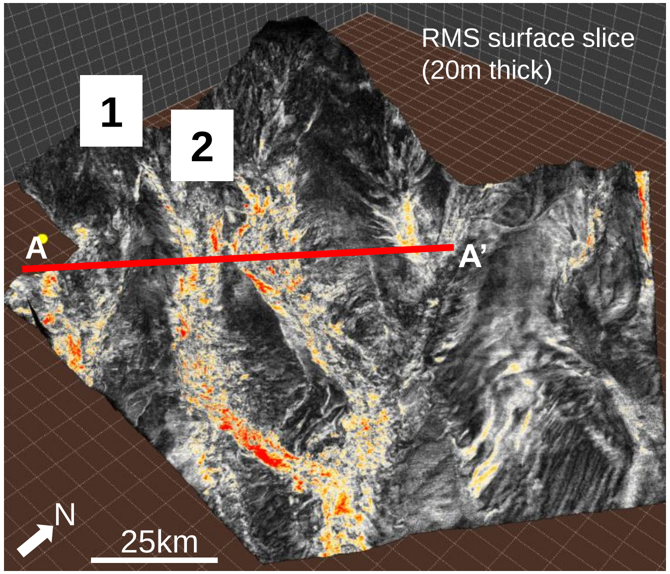




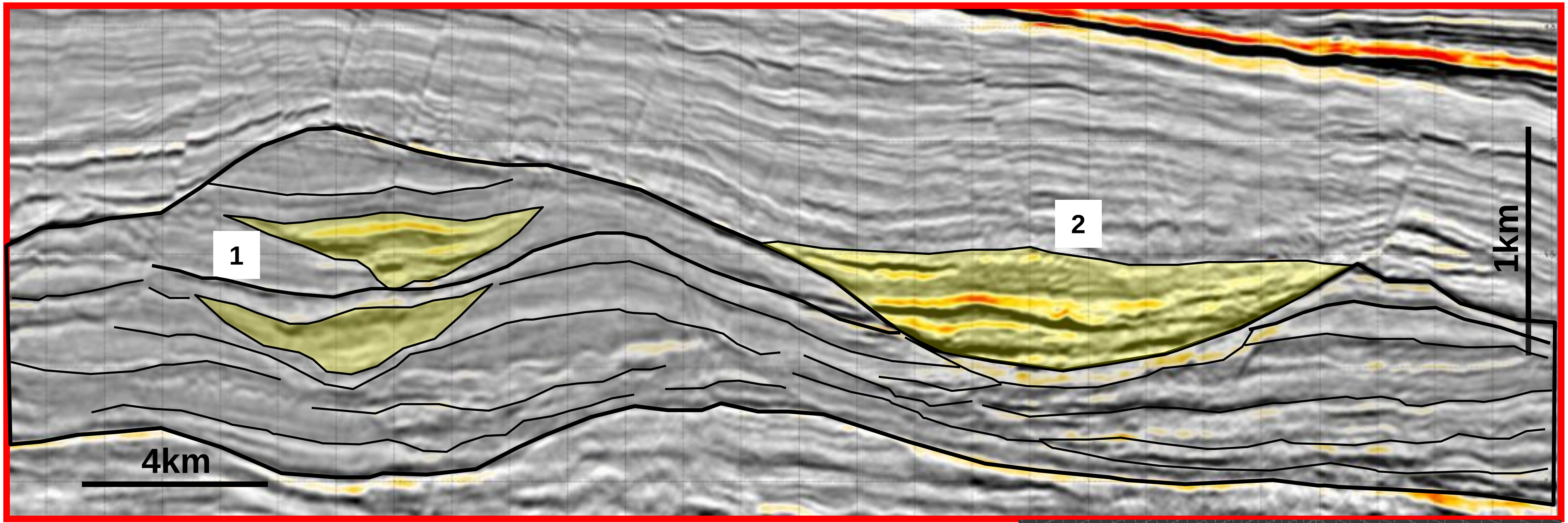
“Pinch and swell” morphology controlled by a combination of aggradation, lateral migration and erosion.

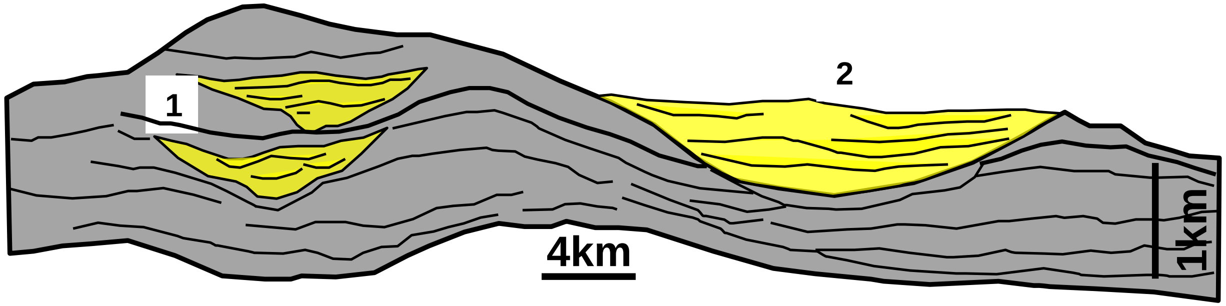
Cretaceous hybrid contouritic-turbiditic system

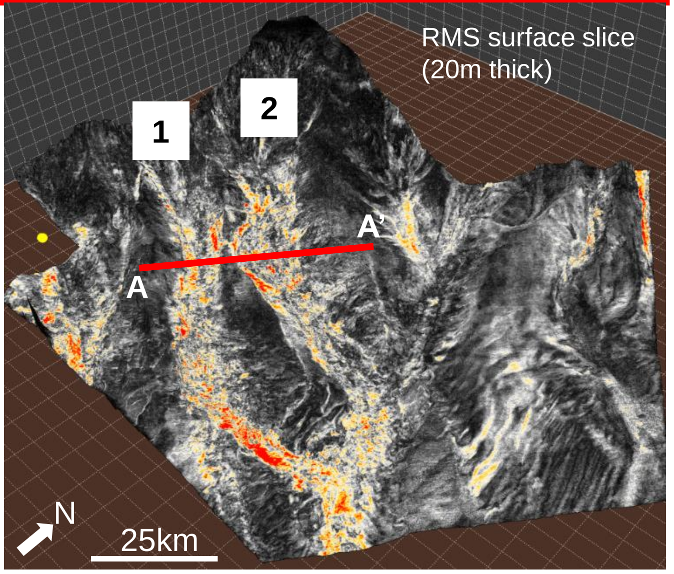




Cretaceous hybrid contouritic-turbiditic system

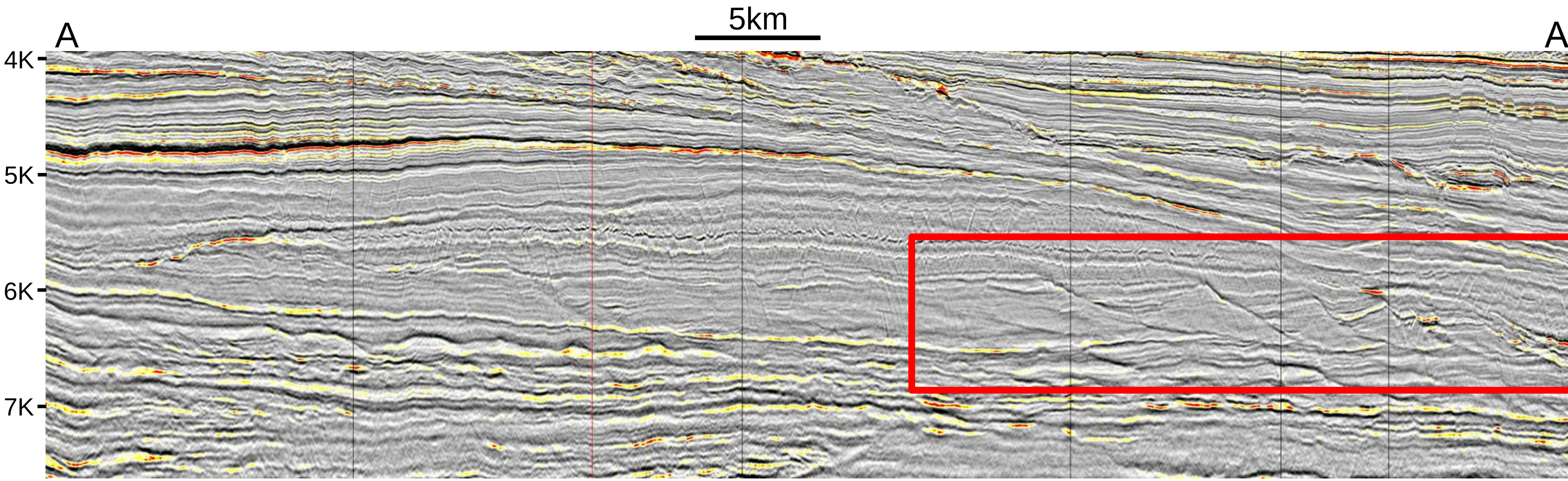




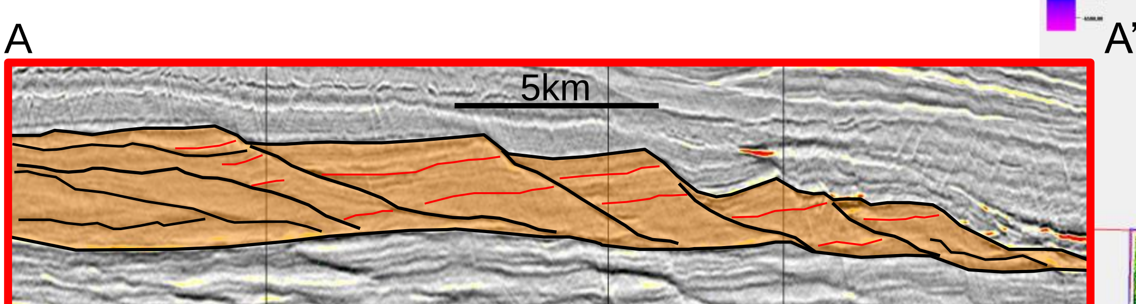


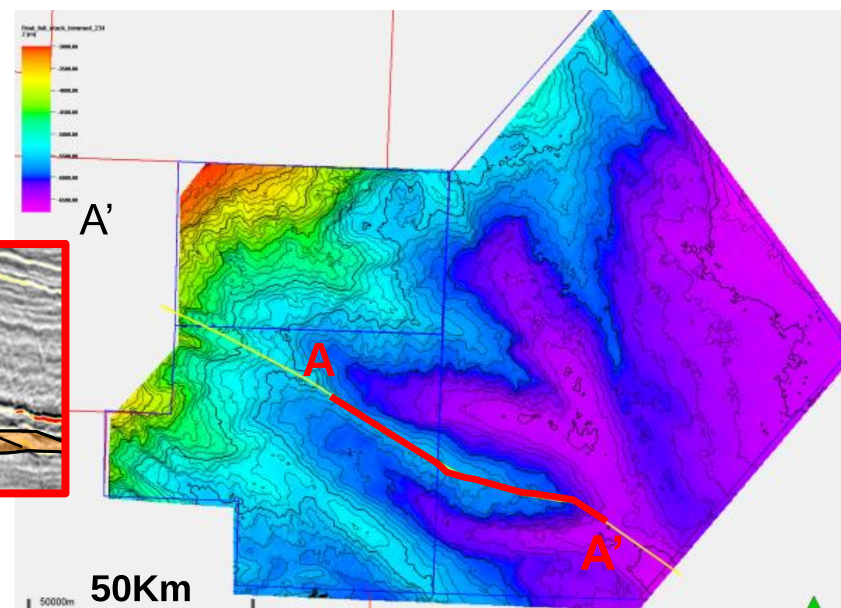
- 1: within main drift
- 2: postdates main drift

Drifts (slumped)

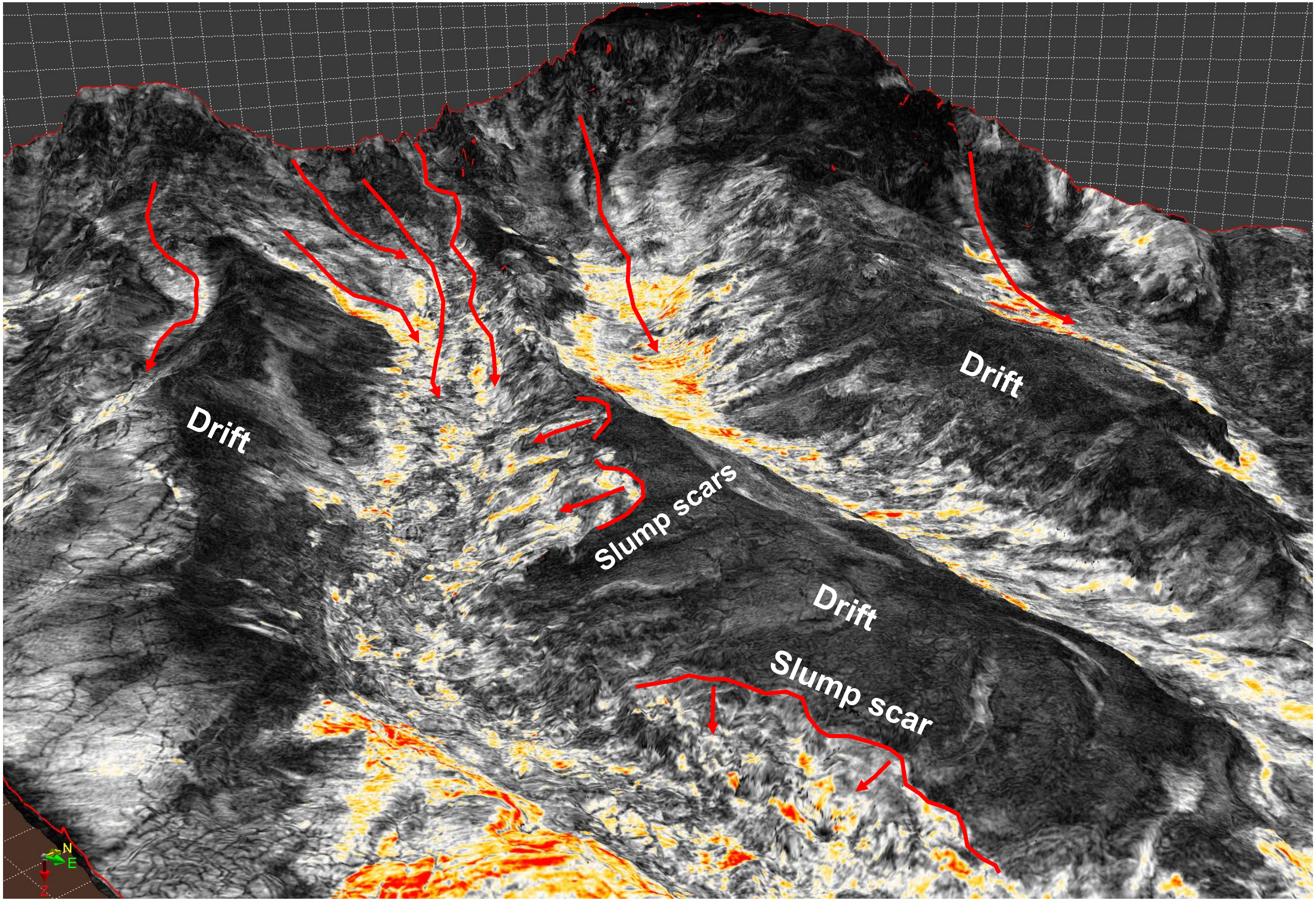


Drifts commonly affected by slumping

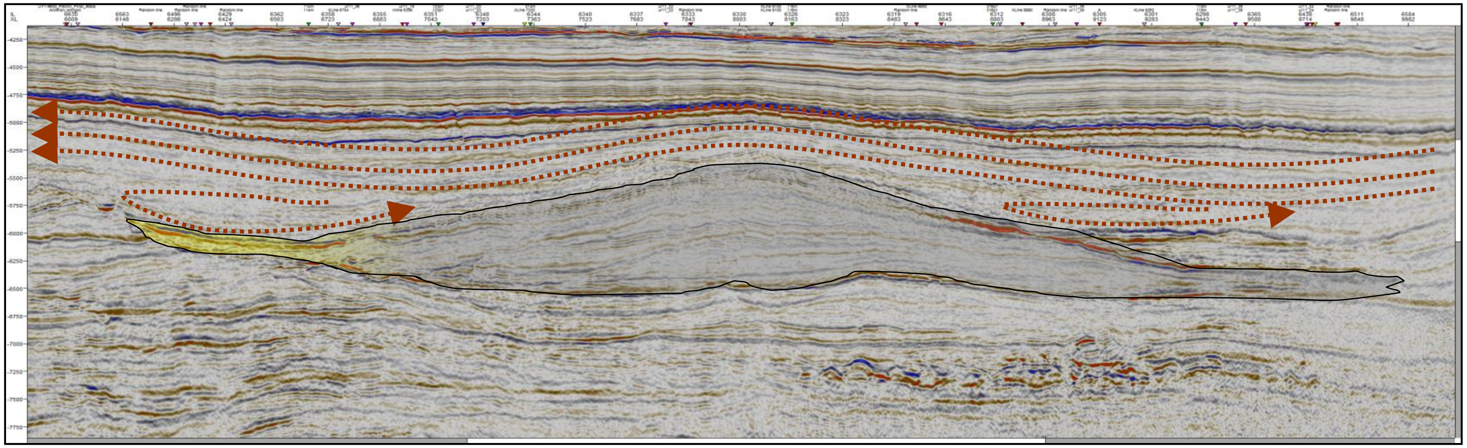




Cretaceous hybrid contouritic-turbiditic system

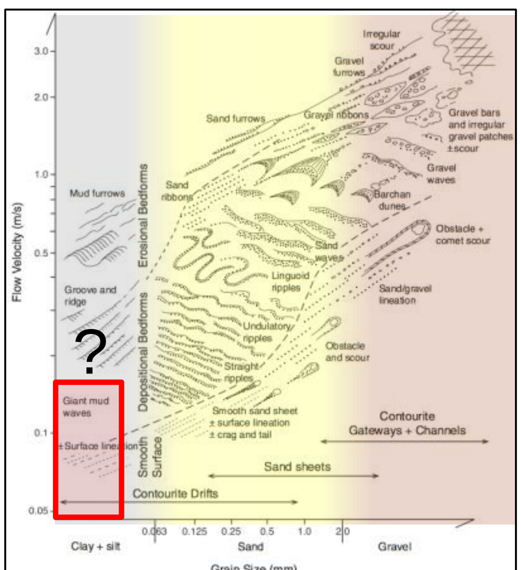


Cretaceous Drifts | Processes

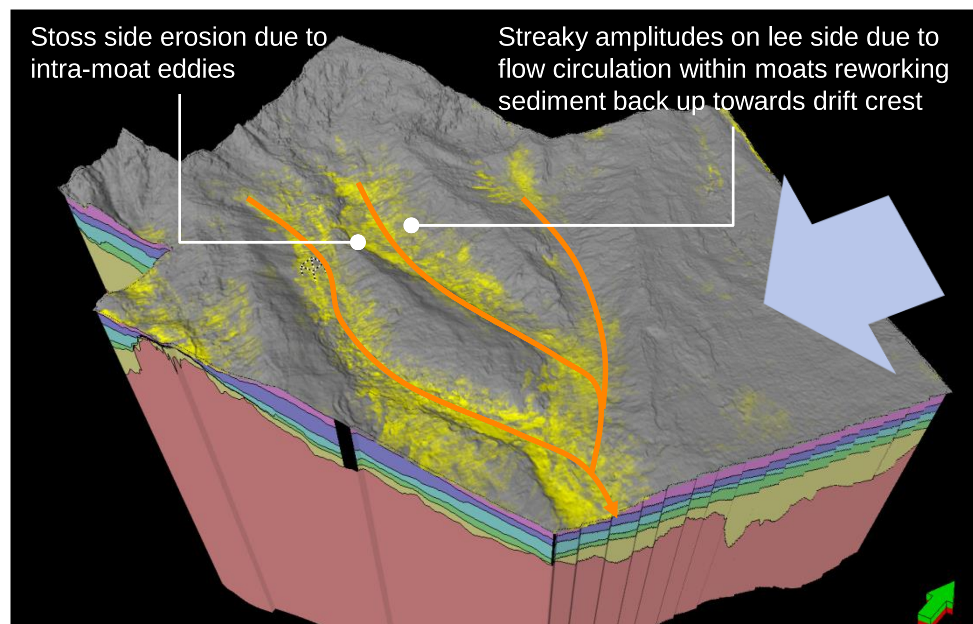


Drift development due to low velocity, low concentration currents interacting with basement topography – progradation and aggradation likely related to standing wave development (topographically high region in north of basin)

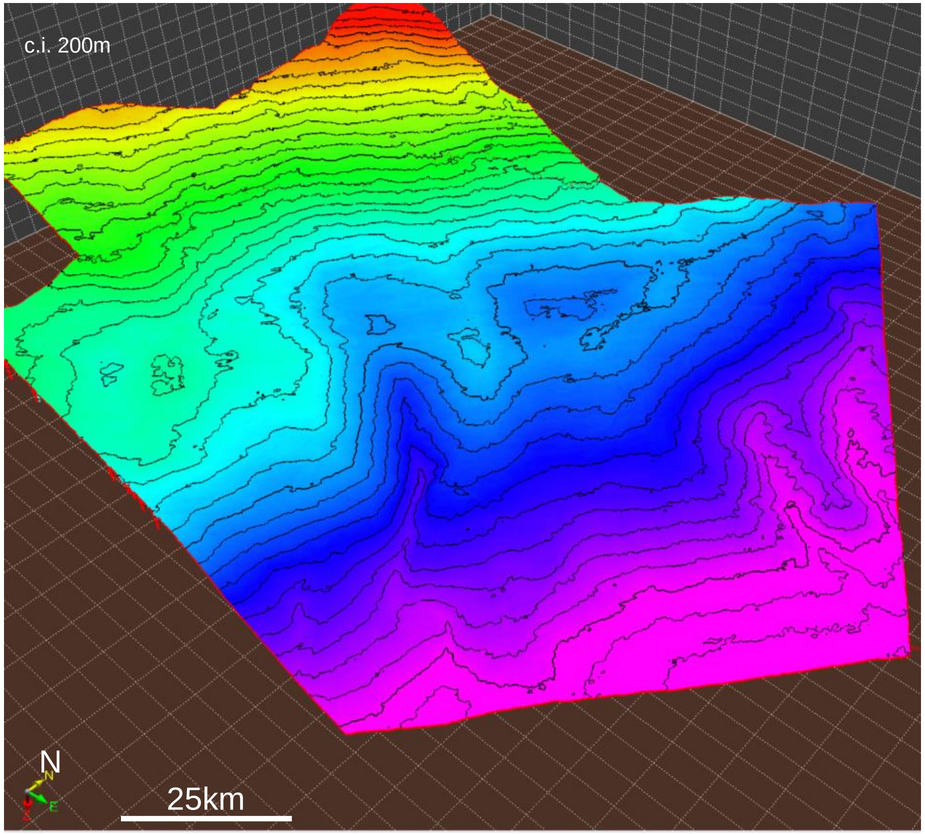
Moat regions capture downslope gravity currents and rework/ winnow sediment in-situ (erode stoss side and smear sediment up the lee side of the drift)



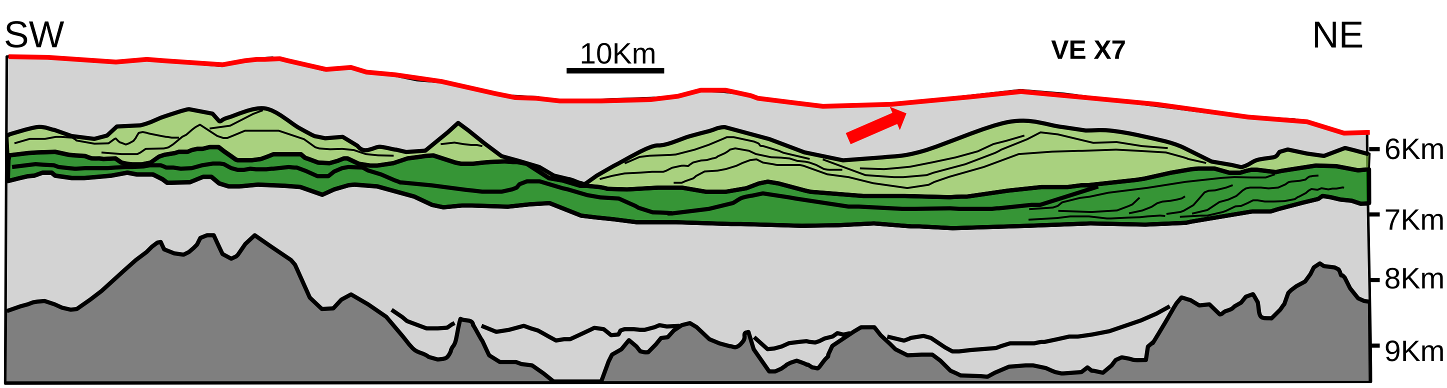
After Stow et al., 2009



Basin evolution – abandonment

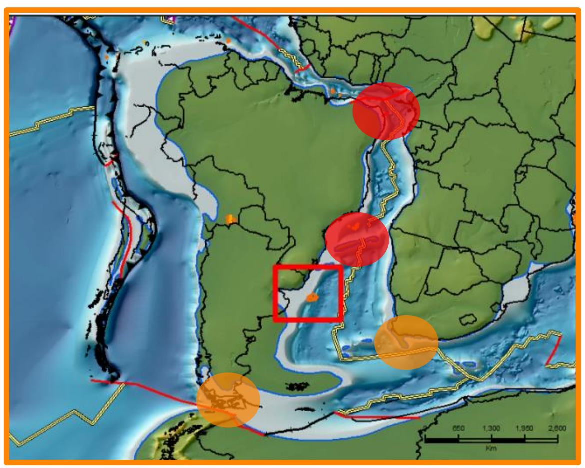
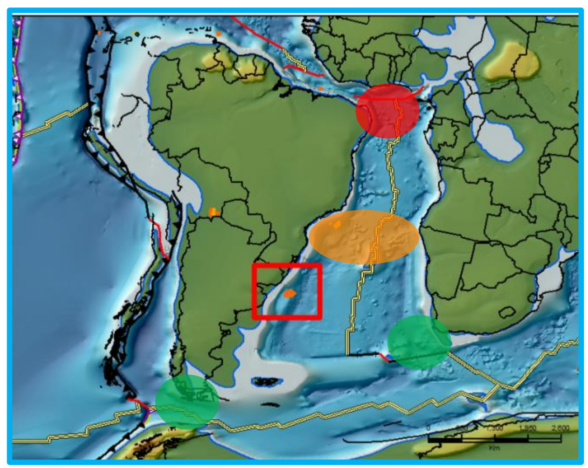
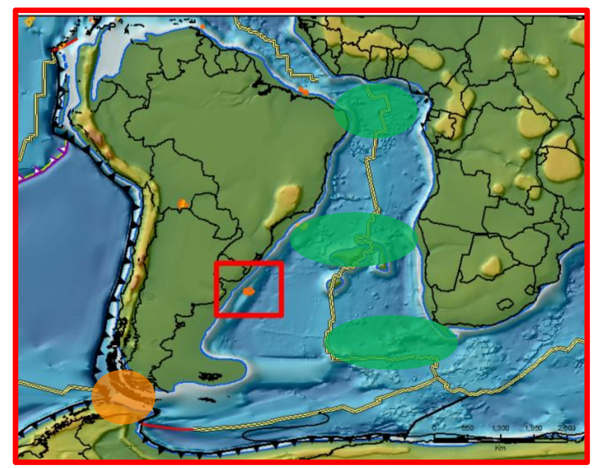


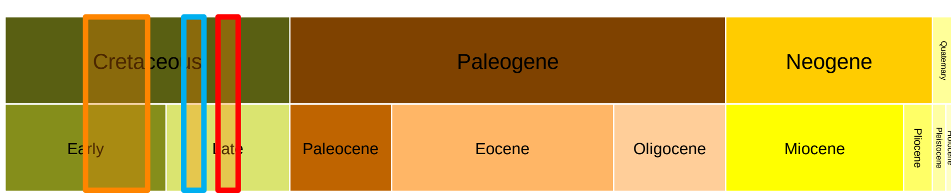
- Drift relief increases through time as a result of aggradation, slope instability and downslope incision
- Drifts (and moats) capped by predominantly fine-grained sediments that smooth pre-existing topography



Cretaceous Drifts – What's driving?

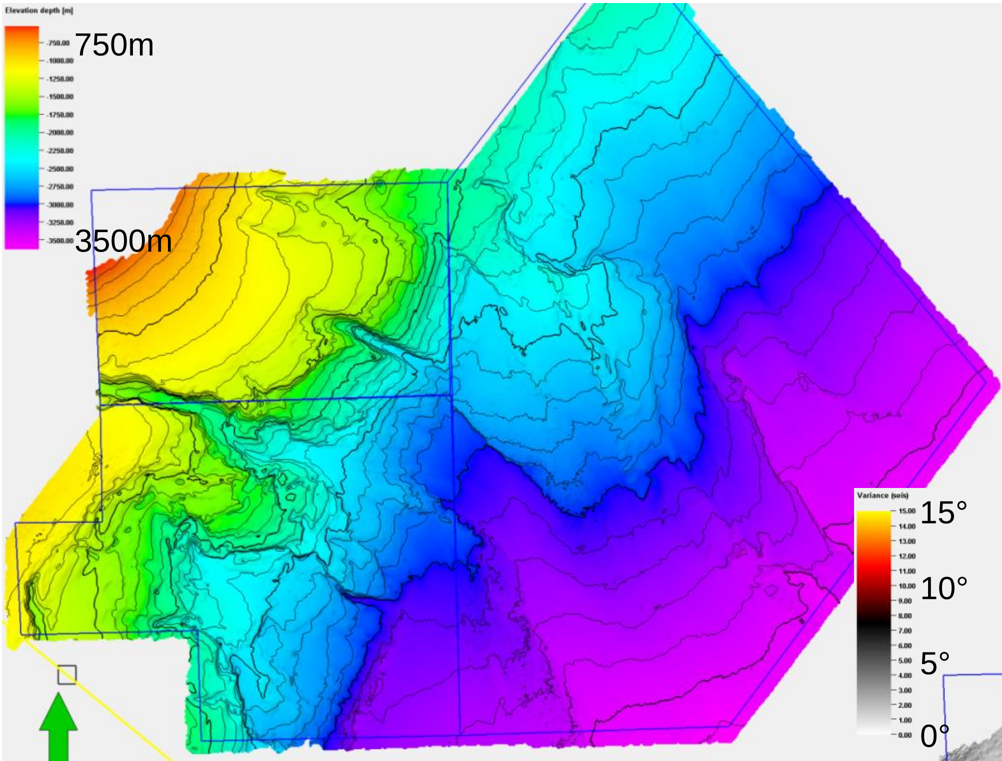
Albian	Turonian	Coniacian/Santonian
Marine conditions starting to develop Restricted circulation within Austral segment	Marine conditions Circulation within Austral segment	Marine conditions Circulation ceases within Austral segment
Equatorial gateway – closed Walvis/Rio Grande – closed Falklands/Agulhas – opening South America/ Antarctica – opening	Equatorial gateway – closed Walvis/Rio Grande – restricted Falklands/Agulhas – open South America/ Antarctica – open	Equatorial gateway – open Walvis/Rio Grande – open Falklands/Agulhas – open South America/ Antarctica – restricted



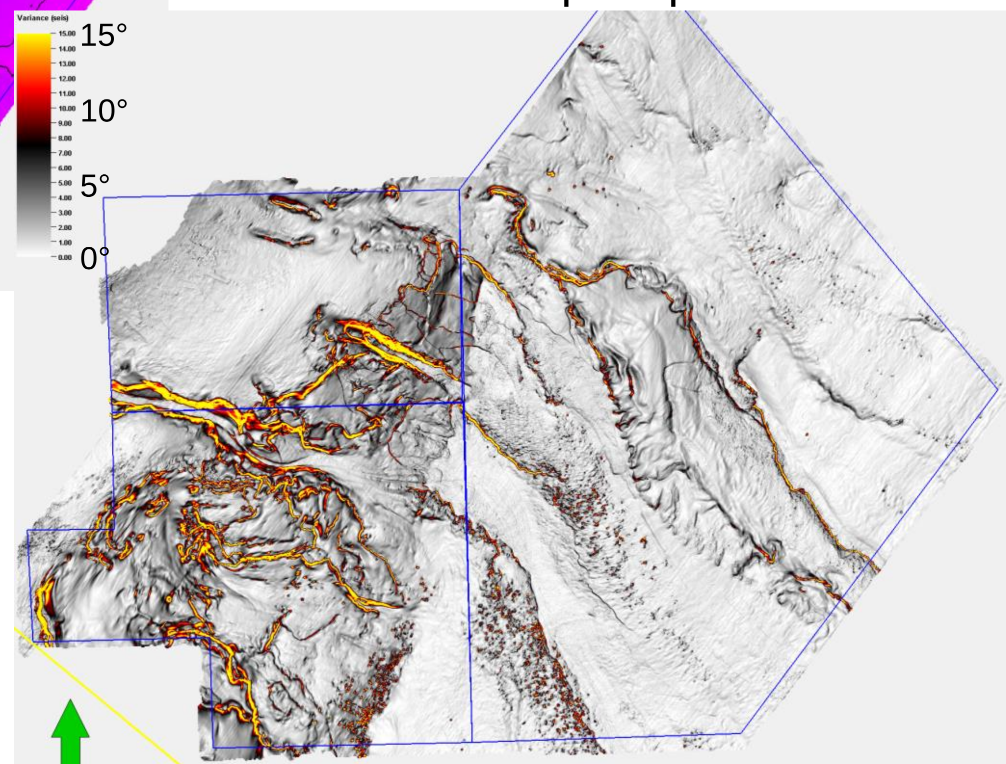
Seafloor Geomorphology

- Terraced profile, canyon, mass failures, pockmarks, scours (mostly at break of slope)



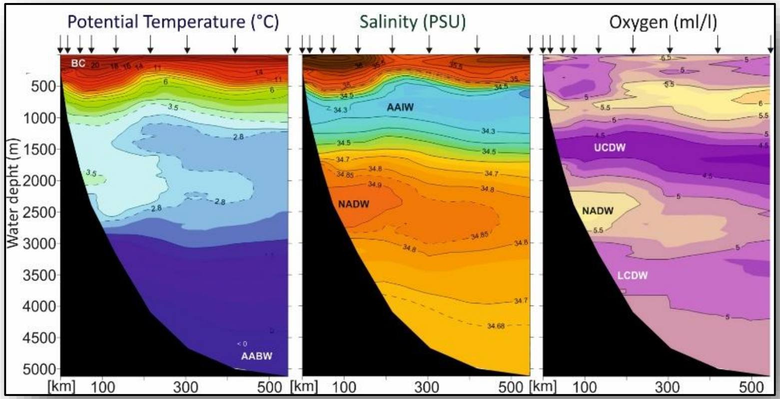
Seafloor depth map (c.i. 100m)

Seafloor dip map

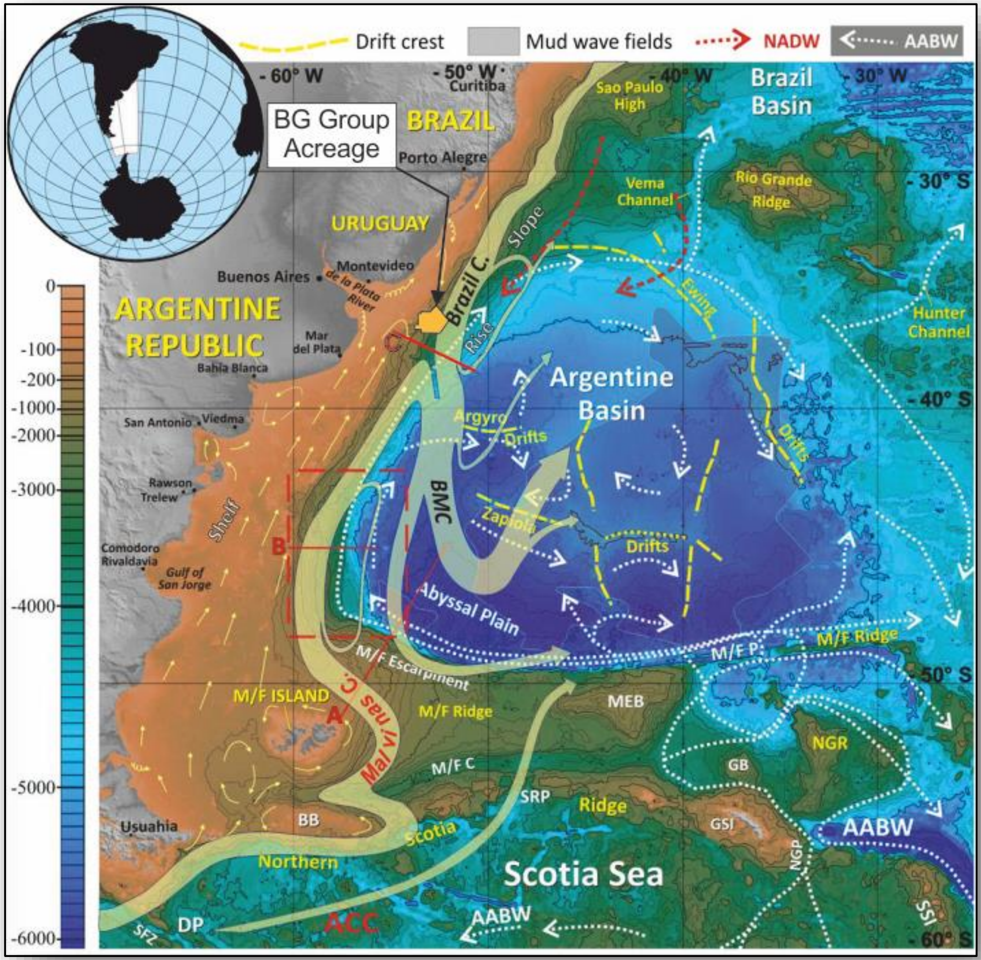


Modern Ocean Currents

- Area of complex ocean currents
  - Brazil Current
  - Malvinas Current
  - Brazil-Malvinas Confluence
  - + others…..

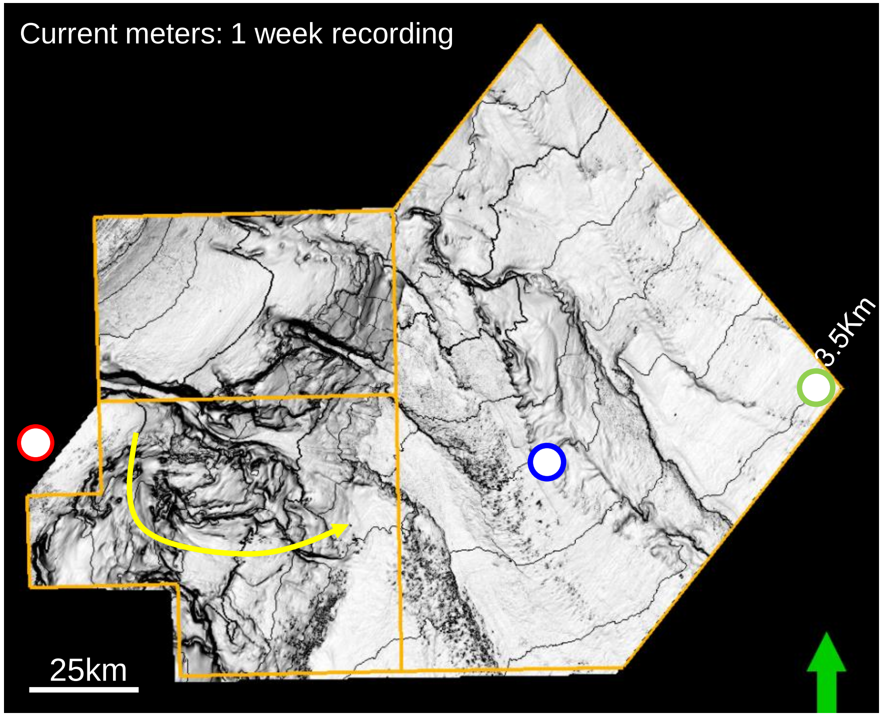


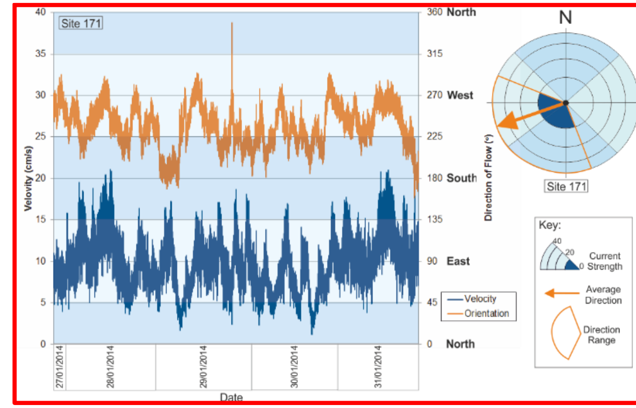
Hernandez-Molina et al (submitted)

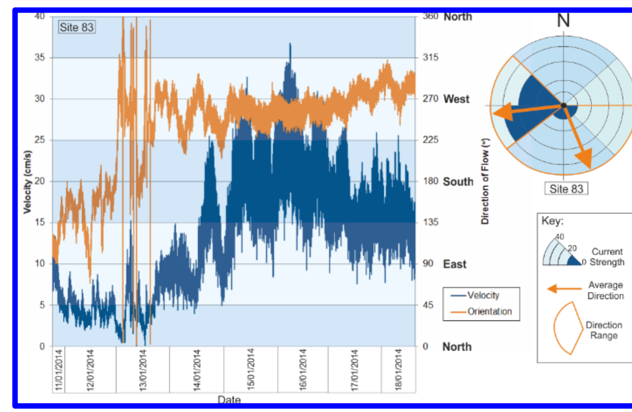


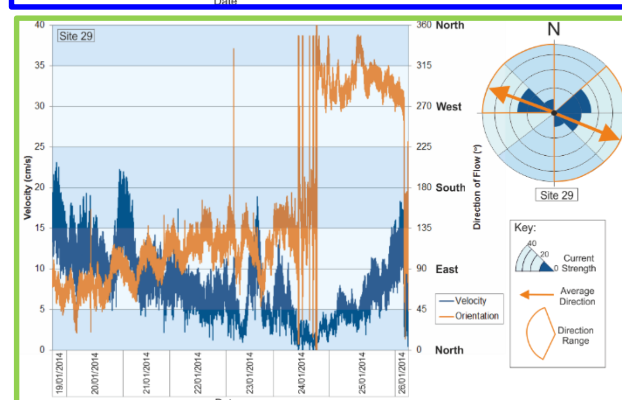
Hernandez-Molina et al (2009)

Current Velocities





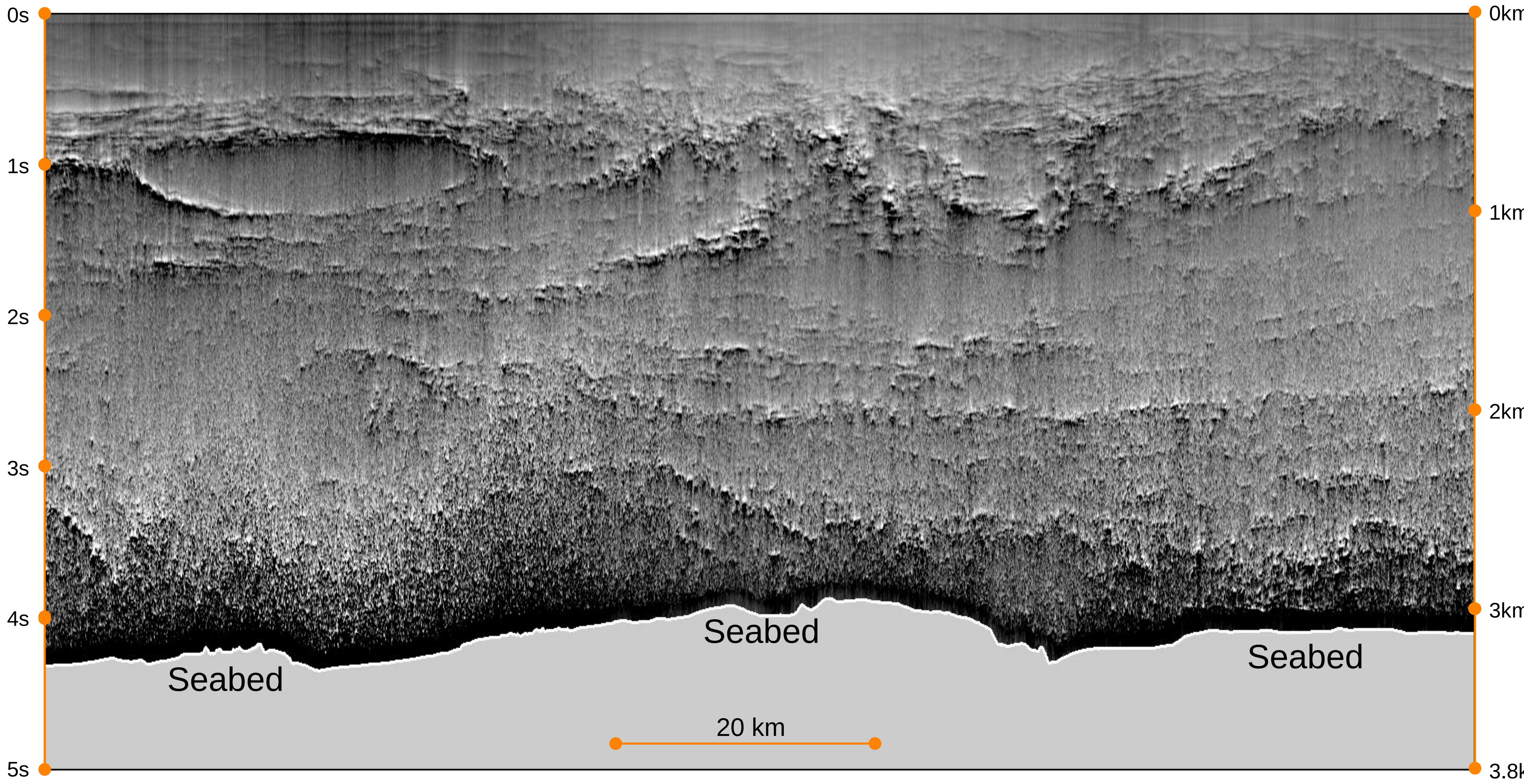




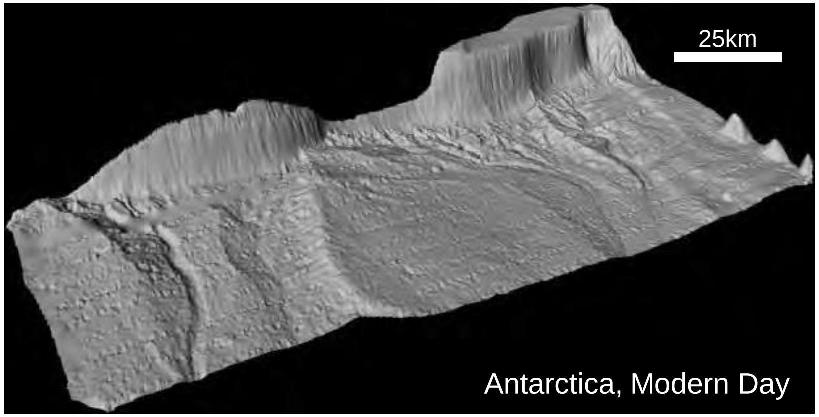
- Complexity on the basin floor – confluence (eddies?)
- Are modern features all fully representative of the modern current directions?
- Upper Slope – Brazil Current?
- Lower Slope/ Basin Floor – Antarctic Bottom Waters?
- Short term fluctuations: tidal influence
- Long term (monthly): phases of the moon (control flow velocity and direction)
- Current reversal

Water Column Imaging

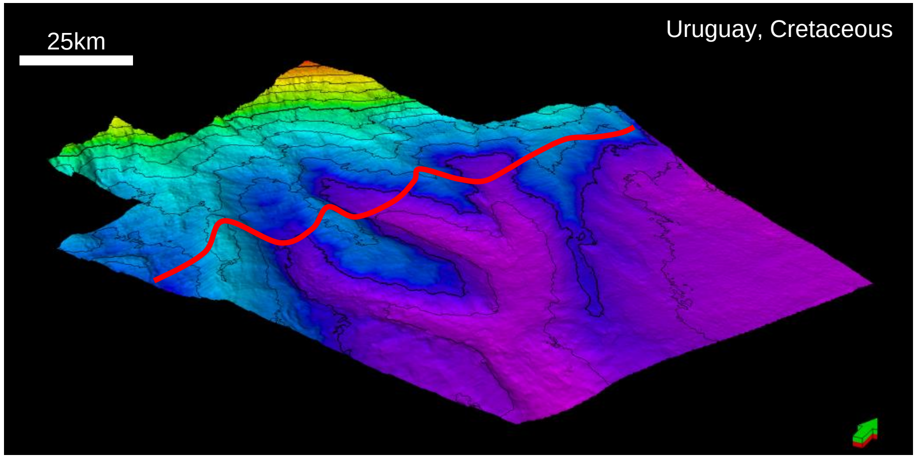
Water column seismic (-90º phase rotation of amplitude envelope)

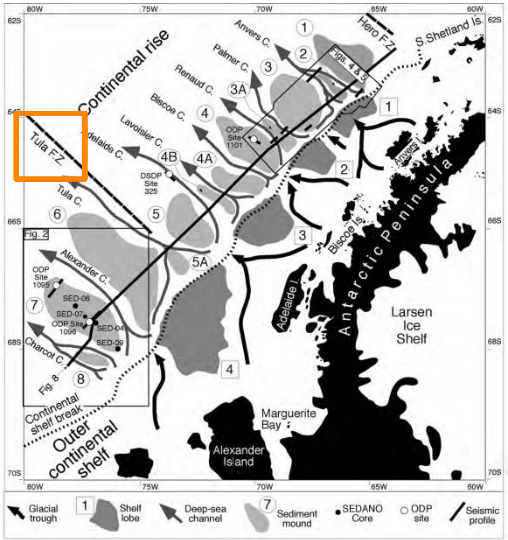


Cretaceous Drifts | Analogues

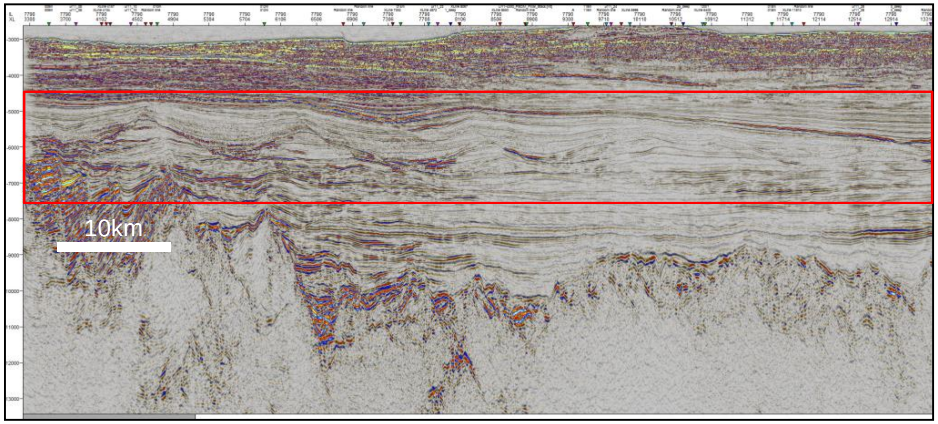


Rebesco et al., 2002





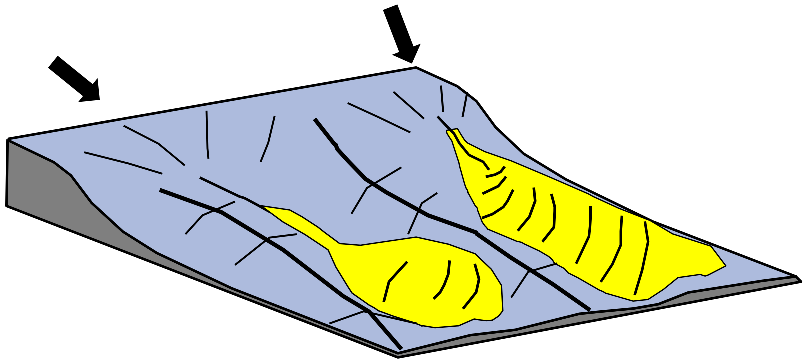
Rebesco et al., 2002

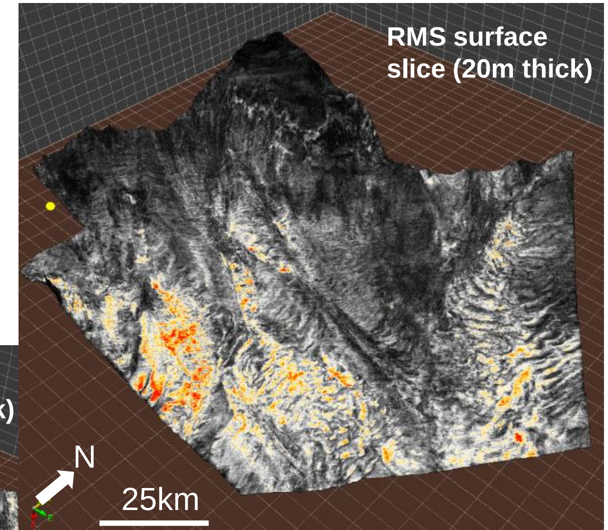


Are drifts somehow controlled/influenced by fracture zones/major structural elements?

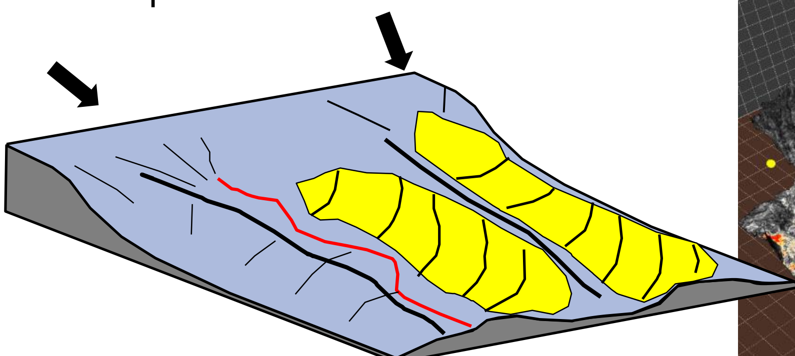
Basin evolution - summary

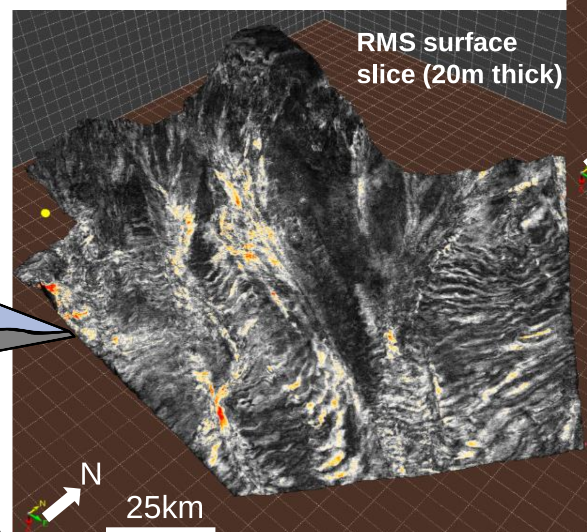
Sediment waves (affected by slope instability) and slope fans. First evidence of current reworking.



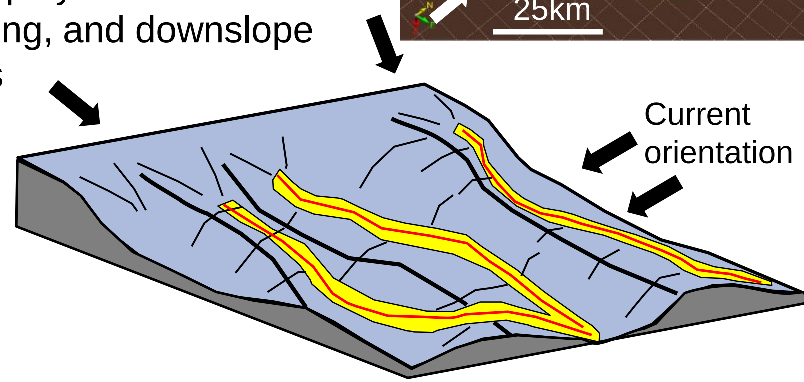


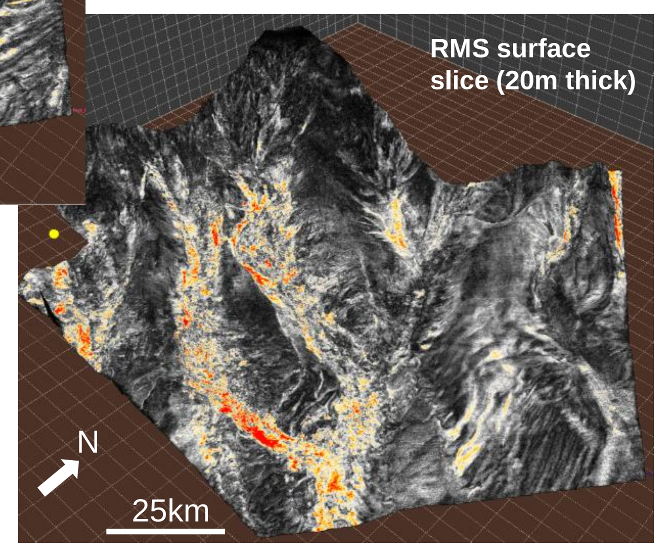
Sediment wave fields eroded by downslope channels





Hybrid system: interplay between drift aggradation, slumping, and downslope transport/processes





Summary & Conclusions

BG GROUP

- Cretaceous basin fill largely controlled by underlying rift-inherited topography
- Evidence of N→S ocean currents from Early Cretaceous (Tertiary and Present Day are different)
- Drift development due to a combination of topographic control on deposition, contour currents and down slope currents; location of drift features centred around rift axis
- Drift relief increases through time as a result of aggradation, slope instability and downslope incision
- Drift moats exploited by downslope processes
- Slumps and contour currents disrupt “channel” fills within moats
- Ability for contour currents to create submarine unconformities, lineations and giant scours on the basin floor