Channel-Levee Systems in a Tropical Carbonate Slope Environment and the Influence of Syn-Sedimentary Deformation, Browse Basin, Australian North-West Shelf*

Lucian Rinke-Hardekopf[1], Stefan Back[2], Lars Reuning[2], and Julien Bourget[3]

Search and Discovery Article #10901 (2016)**
Posted December 26, 2016

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

[1]Earth Science, Simon Fraser University, Burnaby, British Columbia, Canada (lrinkeha@sfu.ca)
[2]RWTH Aachen University, Aachen, Germany
[3]University of Western Australia, Crawley, Western Australia, Australia

Abstract

The Miocene succession of the Browse Basin, Australian North-West-Shelf hosts one of the largest Neogene tropical paleo-barrier reef systems. This barrier reef existed from the middle to late Miocene, and the growth architecture and development of the system is reasonably well understood. In this talk, we present a high-resolution 3D seismic investigation of the slope system coeval with the barrier reef. The study includes two overlapping 3D seismic surveys that cover an area 2,116 km^2 and have a lateral resolution of 14 or 20 m. While most turbidite studies focus on siliciclastic systems, the Miocene slope-succession of the Browse Basin reveals channel and channel-levee complexes on a carbonate-dominated slope. We present, to date one of the only detailed geomorphological descriptions of the development of channel systems in the carbonate environment. The channels develop from an early stage with < 3 km channel length and < 70 m incision, to a mature stage in which single tributaries have merged to form larger channel-systems with channel lengths of 12 km to > 20 km and 150 m to > 200 m incision depth. Additionally, we present a detailed description of a deep-water, 10 km long channel-levee complex with levee widths of up to 850 m. At the clinoform breakpoint, syn-sedimentary deformation structures are developed, which are attributed to differential compaction through the progradation and aggradation of the steep-sloped margin. This leads to shear-stress concentration and brittle normal faulting. In the Browse Basin, an extensive network of syn-sedimentary fractures and small faults with a throw of up to a few meters is located directly landward of the channel heads. We argue that these faults may initiate turbidity currents and directly relate the development of these faults to the initiation of channels. Further, channel fills and syn-sedimentary fractures potentially form conduits for fluid migration and hence are important for the understanding of hydrocarbon reservoirs in carbonate slope systems.

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LUCIAN RINKE-HARDEKOPF[1]

LARS REUNING[2], STEFAN BACK[2], JULIEN BOURGET[3]

[1]DEPARTMENT OF EARTH SCIENCES, SIMON FRASER UNIVERSITY, EMAIL: LRINKEHA@SFU.CA,

[2]RWTH AACHEN UNIVERSITY, [3]UNIVERSITY OF WESTERN AUSTRALIA

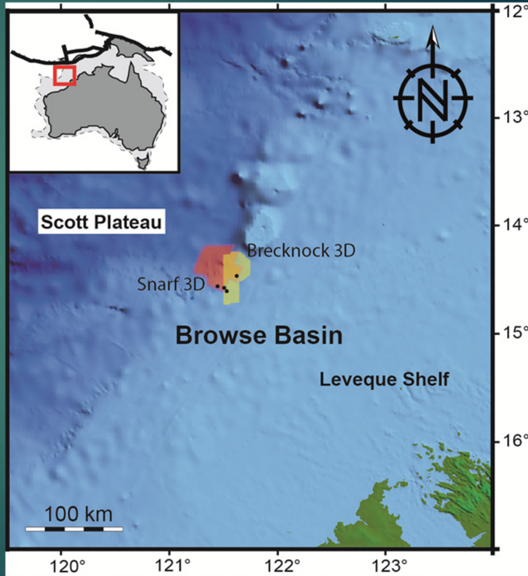
AAPG ACE 2016, THEME 2: MODELING OF CENOZOIC CARBONATE AND EVAPORITE SYSTEMS, JUNE 20, 2016

Outline

- 1. Introduction to the Australian North-West Shelf
- 2. Channel Initiation
  - Observations
  - Model
- 3. Channel Development
  - Observations
  - Model
- 4. Channel-Levee Development
- 5. Conclusions

1. Introduction to the Study Area

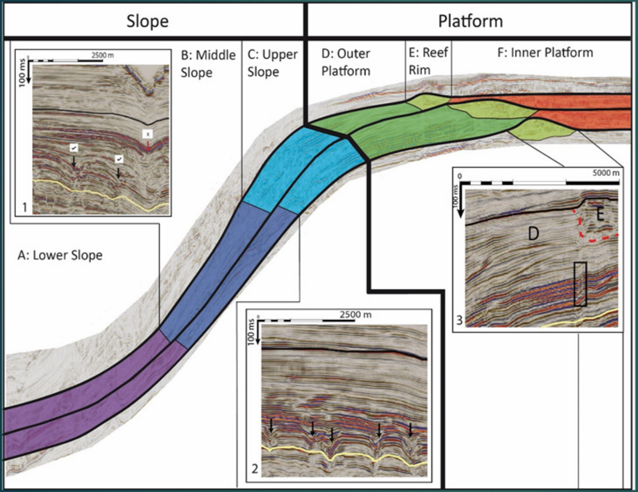
- Browse Basin on Australian NWS
  - Passive continental margin
  - Snarf and Brecknock 3D
- Miocene-aged tropical carbonate platform
  - Carbonate platform (Brecknock 3D)
  - Slope (Snarf 3D) development of coeval stratigraphy



Presenter's notes:

- Australian NWS ~ 21°S and 13°S latitude, presently constituting Australia's premier hydrocarbon province
- Passive continental margin, fault reactivation in the Tertiary through collision with the Banda (no effect on study area), 160000 sq km, 2118 sq km covered in partially overlapping surveys
- dominant frequency in the target interval varies between 40-50 Hz, resolution <20 m
- Since mid-Miocene climate optimum development of 3 barrier reefs on carbonate platform which ultimately drown in the Messinian due to low order sea level fluctation and far field tectonic effects
- Coeval slope systems shows the development of a wide-spread channel system → how is the influence on one another?

1. Introduction to the Study Area



- Coeval development of prograding barrier reef and channel systems
- Channels
  - Incisional morphology
  - First appearance on platform breakpoint
- Reliability of data

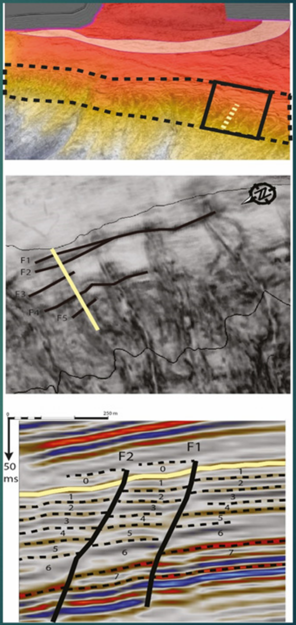
Presenter's notes: The Pre-Tertiary siliciclastics were covered by more than 3000 m of carbonate sediments. Three distinct barrier reef stages (approx. 8 km from prograding platform margin) → coevel development of channels. Why? How does the prograding platform influence or effect the development of these channels?

2.1. Channel Initiation

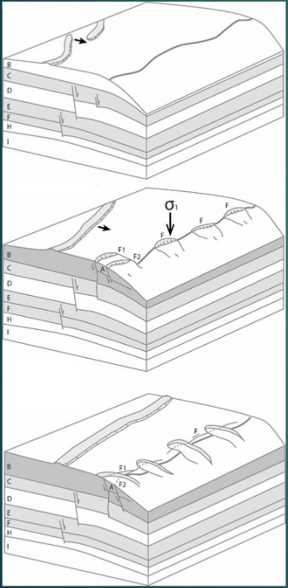
Observations

- Wide-spread network of faults at clinoform breakpoint
  - Arcuate – shaped
  - Located directly landward of channel-heads

- Origin of faults?
  - Tectonically un-active regime
  - Steep-sloped carbonate platform
  - Growth strata
  - Directional change



2.2. Channel Initiation



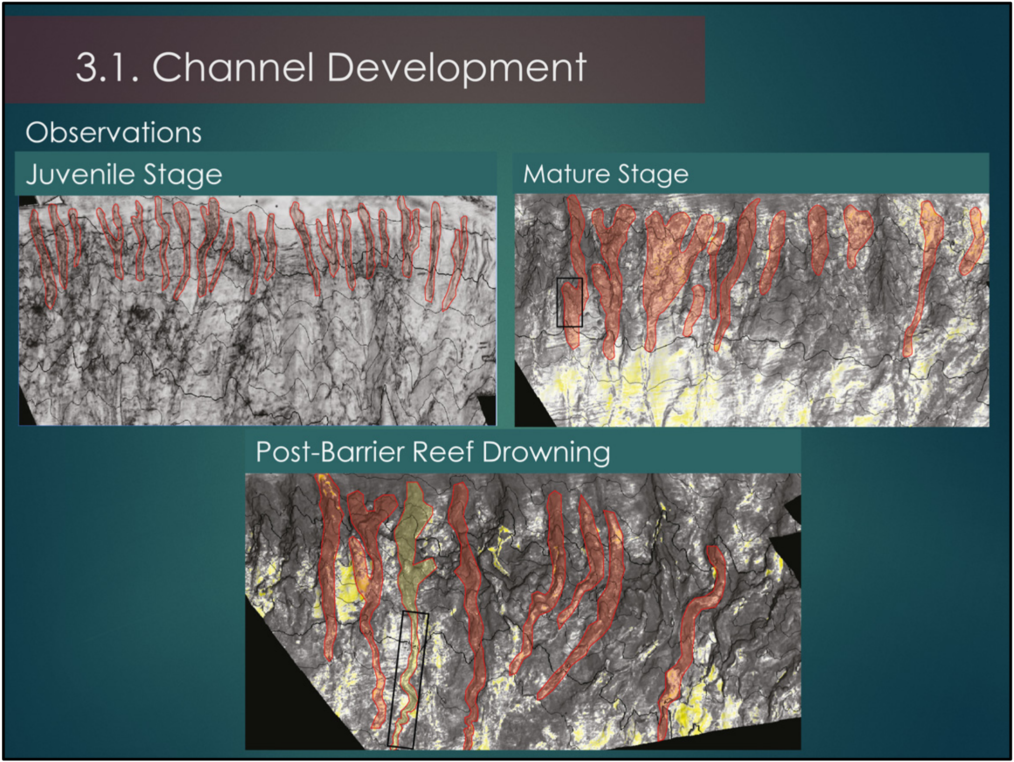
Model

- Initial Surface
  - Prograding carbonate margin

- First syn-sedimentary Deformation
  - Stress increase and concentration

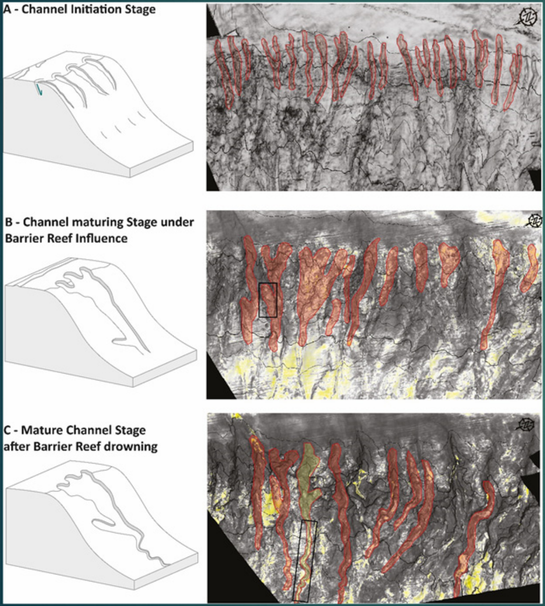
- Developing channel-heads
  - Weakness points
  - Event-based turbidity currents
  - Head-ward migration of initial small tributaries

Presenter's notes: Comparison to Puga-Bernabeu (2011, 2013) and Mulder et al. (2015)



Presenter's notes: Comparison to Puga-Bernabeu (2011, 2013) and Mulder et al. (2015)

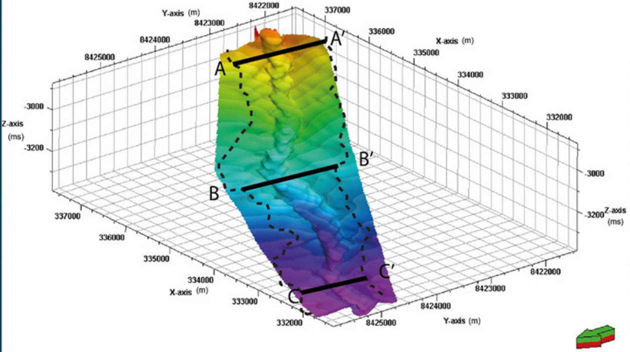
3.2. Channel Development



- Channels develop downslope from clinoform breakpoint (without mid-slope predecessors)
- After channel-initiation downslope development through erosion
  - Channel-head merging
  - Secondary channels
- After reef drowning
  - Extreme downslope development
  - Channel-levees on lower slope

Presenter’s notes: Comparison to Puga-Bernabeu (2011, 2013) and Mulder et al. (2015)

4.1. Channel-Levee Development



Key information:

(1) Extensive levees in front of systems 3 and 4

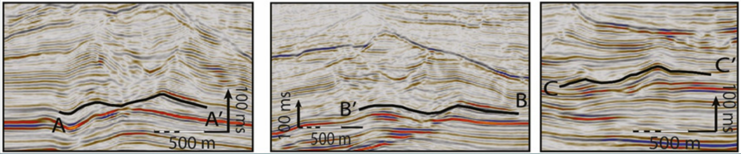
(2) Develop after reef drowning has taken place

(3) Levee mostly shows draped reflection patterns

Numerical information:

(1) Levee width up to 850 m

(2) Levee length 10 km



5. Conclusions

- Channel-system development in front of a coeval barrier-reef system
- Channel initiation is related to the progradation of the carbonate platform causing syn-sedimentary deformation
- Channel development is shown in three different stages
- Channel-levee systems develop after reef-drowning has taken place
  - Barrier reef also blocking mechanism besides contribution
- Channel-levee systems may be more common within deep-sea carbonate regimes, enhancing their reservoir bearing potential

Presenter’s notes: A submarine channel-system initiated in front of a reef in the Browse Basin slightly before the mid-Miocene climate optimum, which is contemporaneous with the occurrence of a clinoform breakpoint parallel barrier reef.
Channel initiation was possibly directly linked to the progradation and aggradation of the carbonate platform, which leads to stress concentration on the clinoform breakpoint causing brittle deformation. The detected normal faults are possibly weaknesses on the platform to slope transition and act as predecessors for later developing channel-systems. Additionally, syn-sedimentary faulting may lead to the development of event-based turbidity flows that can cause initial channel lengthening through erosion.
A three-stage channel development model for this study area was developed including channel initiation stage, a channel maturing stage under barrier reef influence and mature channel stage after barrier reef drowning. The channel development after initiation takes place through auto-cyclic mechanisms such as downslope lengthening through erosional activity of the channel-systems, as well as channel merging, as long as sediment supply is significant. Influencing factors for this are sediment input and erosion, as well as changes in the eustatic sea level. Successively, channel lengthening becomes amplified after reef drowning takes place.
Channel-development suggests that the main sediment contributor to the system is the barrier reef and the outer platform area. The barrier reef in this study may not highly contribute to the sediment input due to its distance from the clinoform breakpoint, but may act as a sediment blocker.
A channel-levee complex developed in the lower slope area after the barrier reef has drowned. The most important controls on the distribution of overbank sediments likely were the slope angle and the presence of the Indonesian Throughflow. The occurrence of channel-levee complexes in other carbonate slope systems can greatly enhance the reservoir bearing potential of carbonate environments.

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Q & A

Thank you for your attention.

Questions?

Feel free to talk to me after the presentation regarding questions that could not be answered in the Q & A session!