Seismic Stratigraphy of the Deep-Water Area in the Northern Orange Basin, Offshore South Africa*

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Abstract

The petroleum potential off South Africa's west coast margin has been widely studied in recent years, but has largely focused on the shelfal areas where most of the acquired data exists. These studies led to a comprehensive understanding of the shallower water depositional history and systems which in turn aided the identification of several petroleum plays along the margin. With the focus of petroleum exploration shifting more and more to deep-water areas in recent years, it becomes pivotal to expand our knowledge of these depositional systems with the focus on source and reservoir facies. With the proven success of seismic stratigraphy methods in the identification of regional scale plays, it provides a key input for the development of leads to drillable prospects.

This research presents the seismic stratigraphy of the sedimentary succession of the deep-water areas in the northern parts of the Orange Basin, off the west coast of South Africa. The seismic data used for this study includes a set of good quality PSTM 2D lines located within water depths of between 1000 m and 3500 m combined with well data from the nearest wells. The workflow is based on the classic approach of delineating subsurface stratigraphy through the interpretation of reflection seismic data and the integration of well-log and core data.

Several basin-wide sequence boundaries previously mapped on the shelf were correlated well into the deep-water areas. The westward-thinning, post-rift sedimentary wedge can be subdivided into several seismic units. These comprise mappable sequences of Late Hauterivian, Barremian to Aptian and Cenomanian to Turonian claystones with source potential, complimented by several submarine basin floor systems at different stratigraphic levels. The potential for stratigraphic and/or combination hydrocarbon plays is high throughout the study area. The results of this study provide a strong basis for correlating the well-known shelfal areas with the relatively under-explored deep-water areas of the northern Orange Basin, in terms of the identification and prediction of the location of reservoir, source and seal facies. The study results also allow for the integration of the nearly resolved depositional history of the western parts of the basin with that of the shallower parts in the east.

Reference

Jungslager, E.A., 1999, Petroleum habitats of the Atlantic margin of South Africa, *in* V.S. Clure, N.R. Cameron, and R.H. Bate (eds.), The Oil and Gas Habitats of the South Atlantic: Geological Society of London Special Publication 153, p. 153-168.

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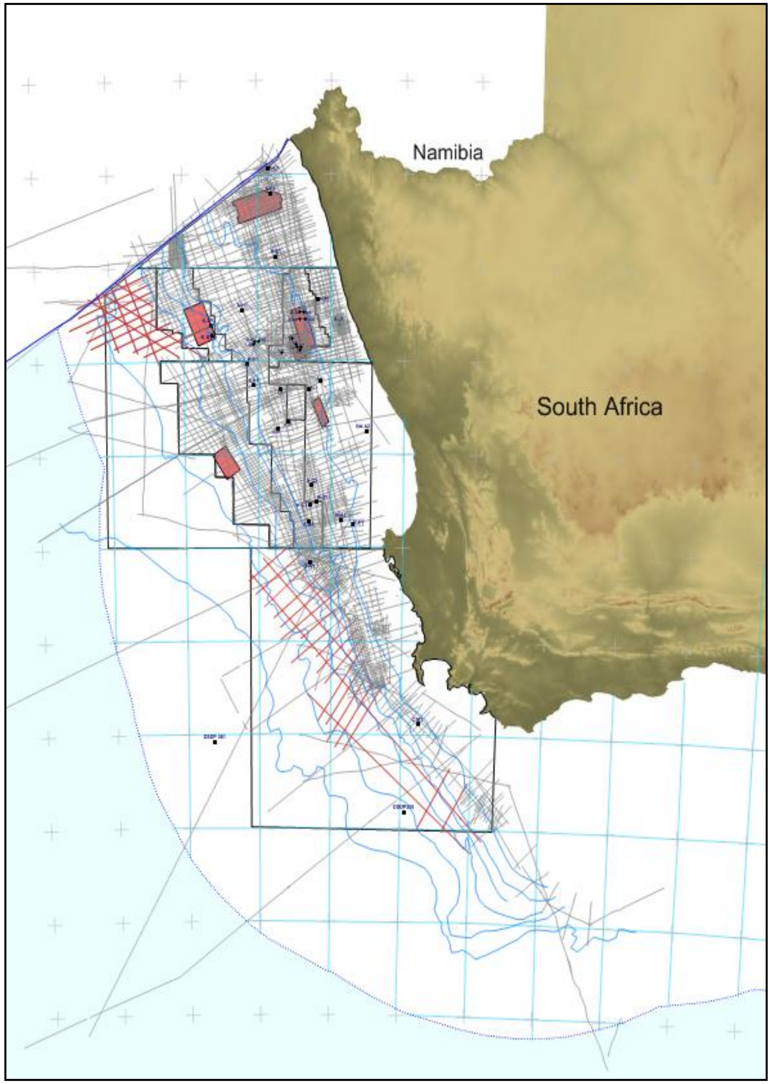
Petroleum Agency SA

Contents

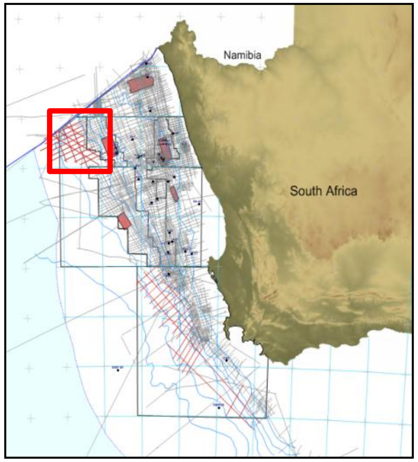
Introduction

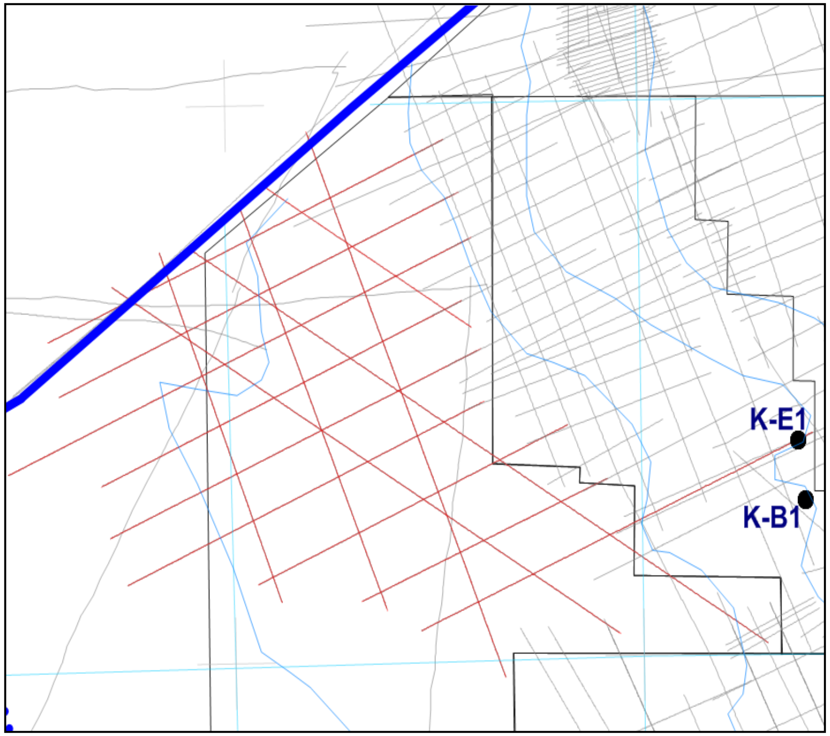
- West coast shelf extensively studied
- The well understood shelf needs to be correlated to the deep-water areas.
- This study aims to use the limited data currently existing in the deep-water to:
  - **Establish a basis for correlating the shelf with the deeper offshore**
  - **To aid with understanding, identification and prediction of petroleum related facies**



Introduction

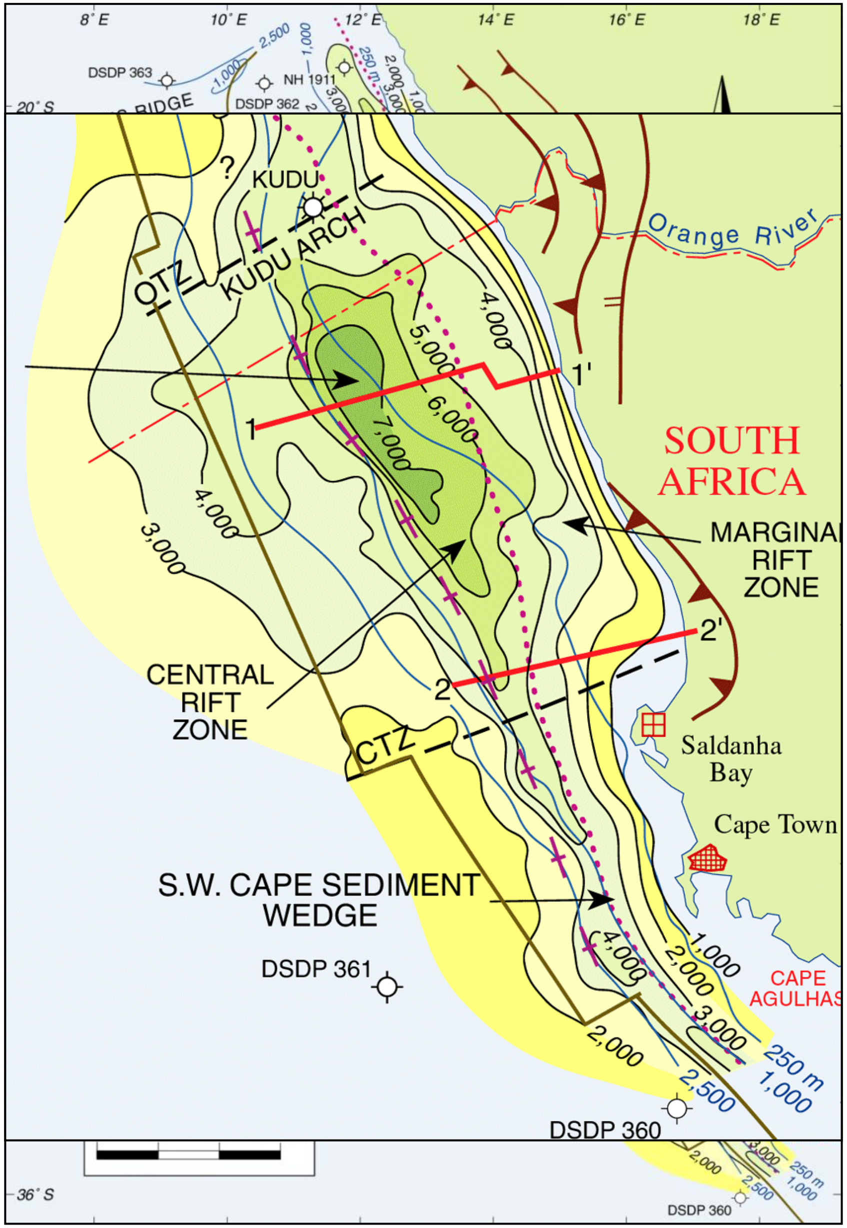
- The study area is located in a deep water area of the northern parts of the Orange Basin
- Water depths are between 1000m and 3500m
- The seismic data used for this study are a set of good quality PSTM 2D lines acquired by PGS in 2002
- The two closest wells, K-B1 and K-E1 were drilled in 1979 and 1981 respectively.





Structural Setting

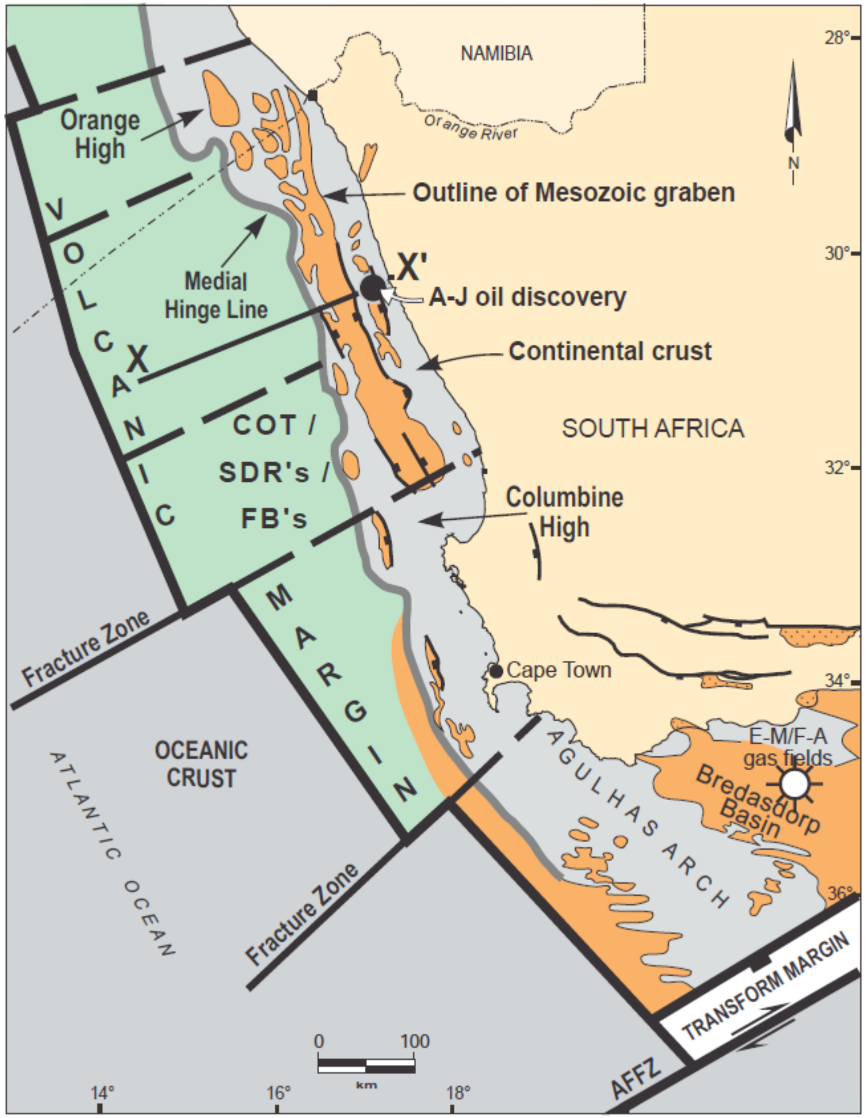
- The Orange Basin is a sub-basin of the larger Southwest African Coastal Basin.
- Three depocentres: the Walvis, Lüderitz and Orange sub-basins.
- The larger Orange Basin covers an area of 160 000 km^2 to the 2000m isobath.
- Defined by its post-rift sediments rather than its structure.



Basin Evolution

- Formed in response to the fragmentation of Western Gondwanaland and the opening of the South Atlantic
- The geological succession displays a typical two-fold subdivision: an older synrift unit, overlain by a younger post-rift unit
- Rifted plate margin that is underlain by pre-rift and synrift grabens, covered by post-rift sediments.
- Four main tectono-stratigraphic sequences represent the major phases:

  Synrift
  Post-Rift (Transitional)
  Drift
  Post-Drift (Cretaceous and Tertiary)

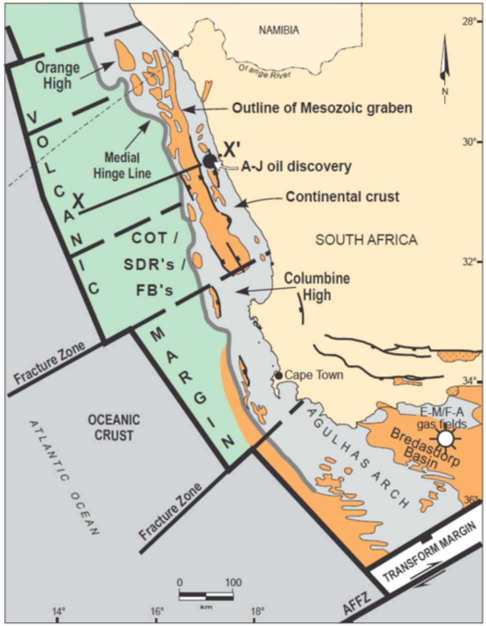


(after Jungslager, 1999)

Basin Evolution

SYNRIFT

- Extensional stress regime caused formation of NS trending graben systems
- These graben systems are separated laterally from an outbound synrift wedge the Medial Hinge.
- The grabens are filled by Lower Cretaceous siliclastics (fluvio-lacustrine sediments & continental clastics) and volcanics



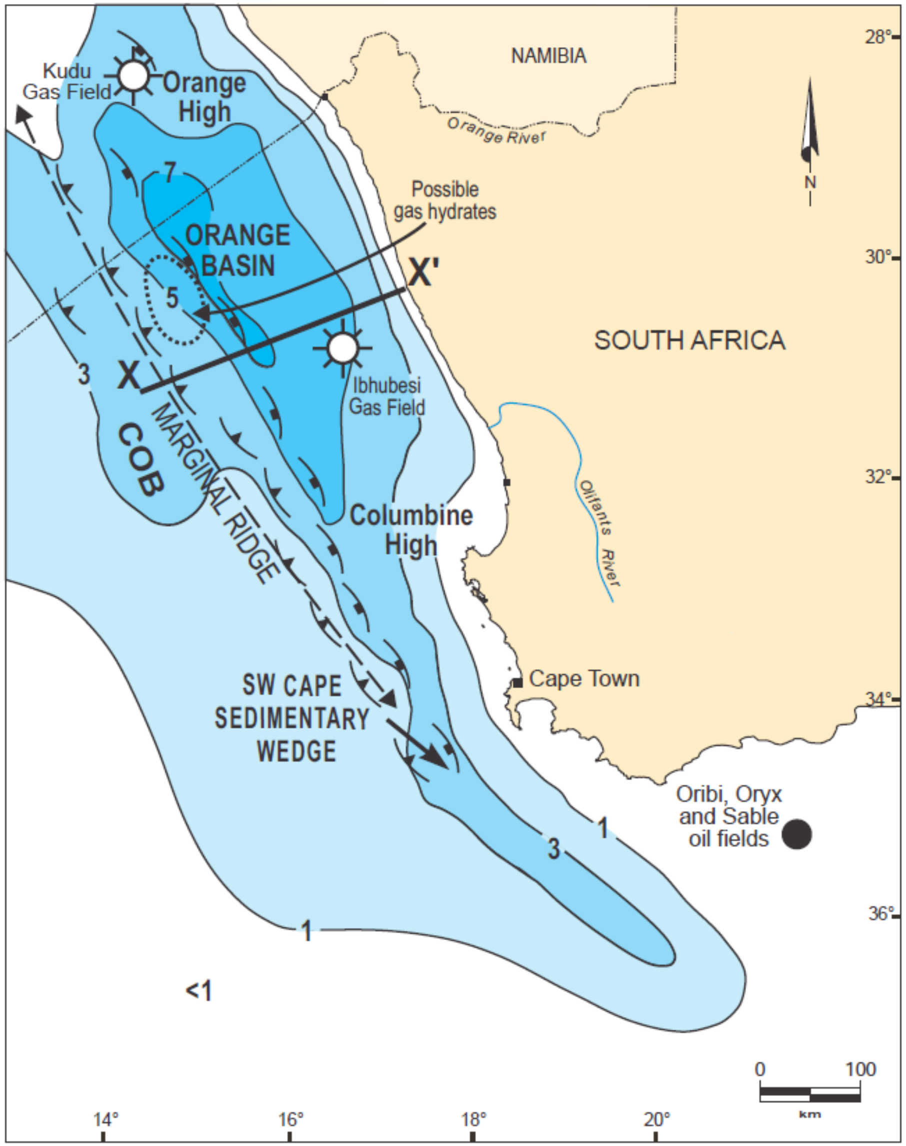
(after Jungslager, 1999)

Presenter's notes: During the Middle to Late Jurassic, the extentional stress associated with the breakup, caused the formation of a series of coast-parallel graben systems. These grabens systems are seperated laterally from an outbound synrift wedge by a flexural high which is known as the Medial Hinge. The graben-fill comprises Lower Cretaceous siliclastics and volcanics, the former including fluvio-lacustrine sediments and coarse continental clastics.

Basin Evolution

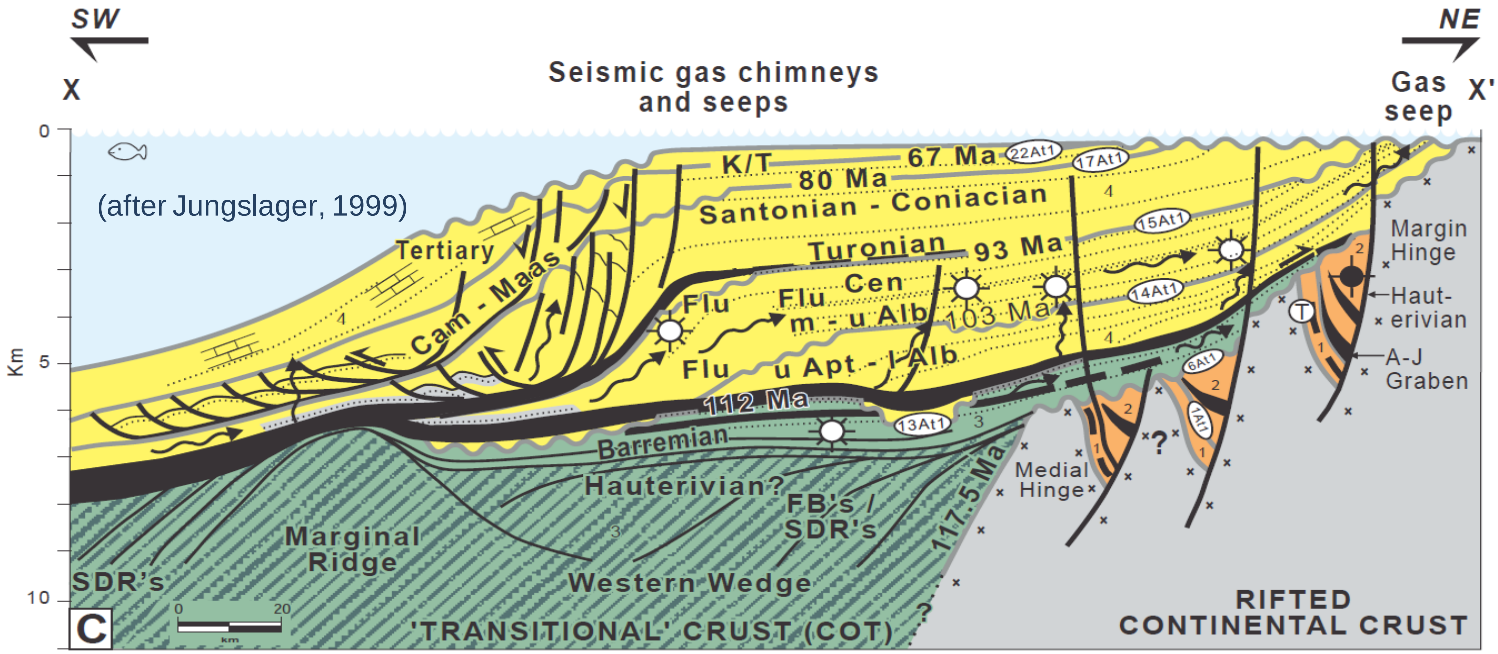
POST-RIFT/DRIFT

- A thick post-rift seaward and landward thinning sedimentary wedge overlies the rift basins.
- This sediment volume was mainly supplied by the Orange and Olifants rivers.
- Flanking basement highs represent the depocenter in a strike sense.



(after Jungslager, 1999)

Basin Evolution



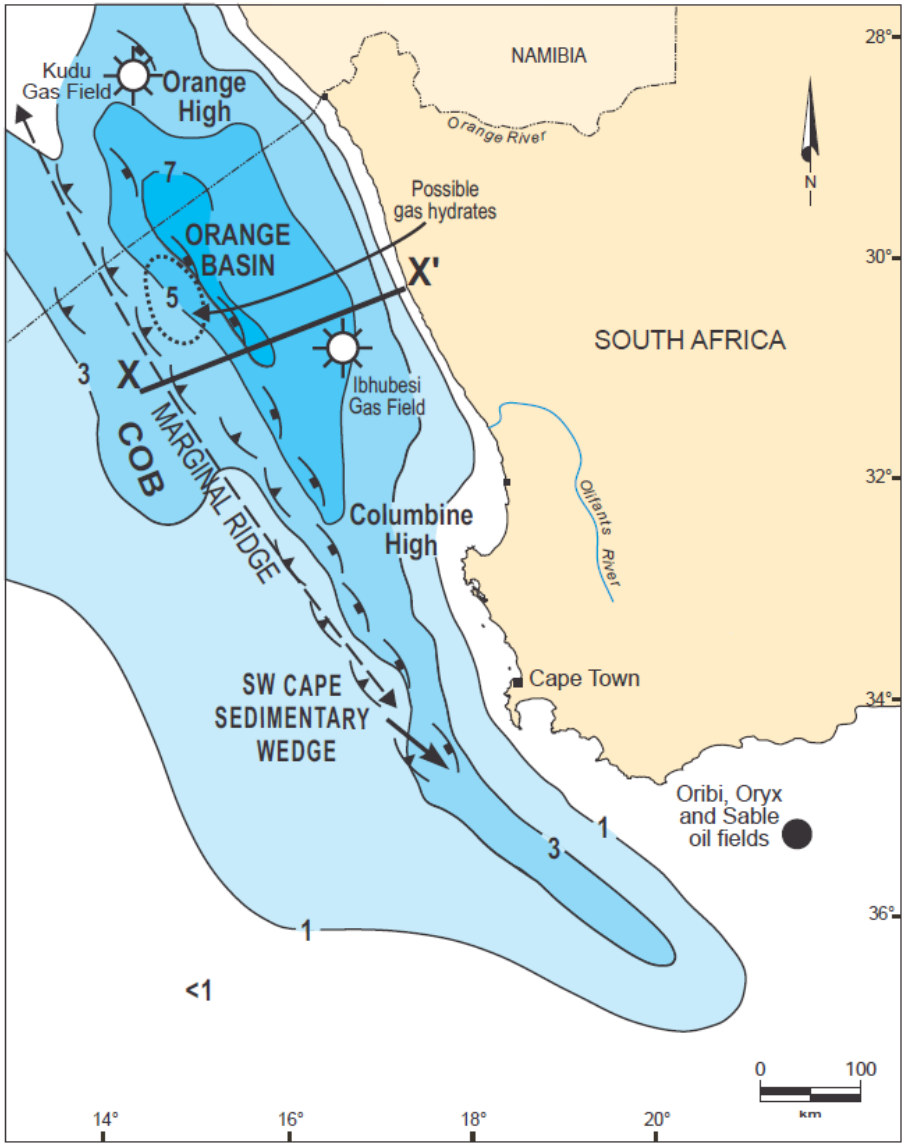
CRETACEOUS

- Termination of rifting and onset of drift at ~117.5 Ma - permanent marine influence
- 5 major super-sequences bounded by major sequence boundaries
- Shallow and restricted margin during the initial phase- transitional. Poorly developed ramp-like shelf/slope. Restricted marine, deltaic and coastal plain settings
- Major marine flooding were established at 112Ma marking onset of passive margin drifting and subsidence - mainly deltaic to shelfal
- Sediment input prolonged during the Mid-to late Cretaceous in the north – explains the position of the main depocenter

Basin Evolution

TERTIARY

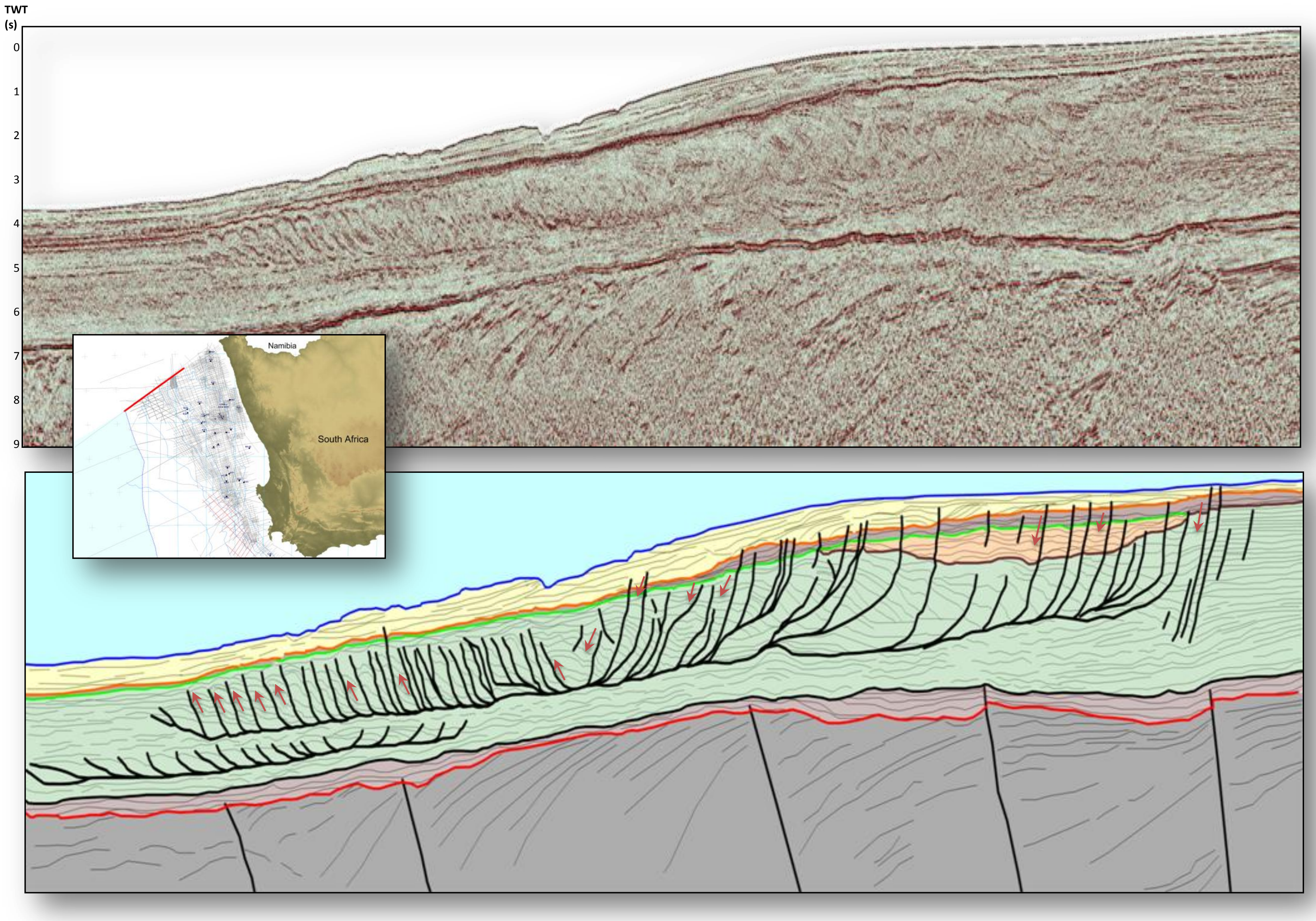
- Subsidence rates reduced by the onset of the Tertiary – causing a stable underlying Cretaceous platform
- Depocenters shift basinward – slope setting sedimentation
- Vertical slope stacking during aggradation causing spectacular gravity faulting



(after Jungslager, 1999)

Interpretation and Results

- Seismic stratigraphy and facies analysis concepts (Vail and others, 1977) been applied to the present study in order to characterize the internal geometry of the seismic sequences
- The 2D Seismic sections are subdivided into seismic sequences separated by unconformities
- Unconformities represent regional events off the Orange Basin
- Display high amplitude and/or erosional truncation
- Commonly associated with significant tectonic events and sea level changes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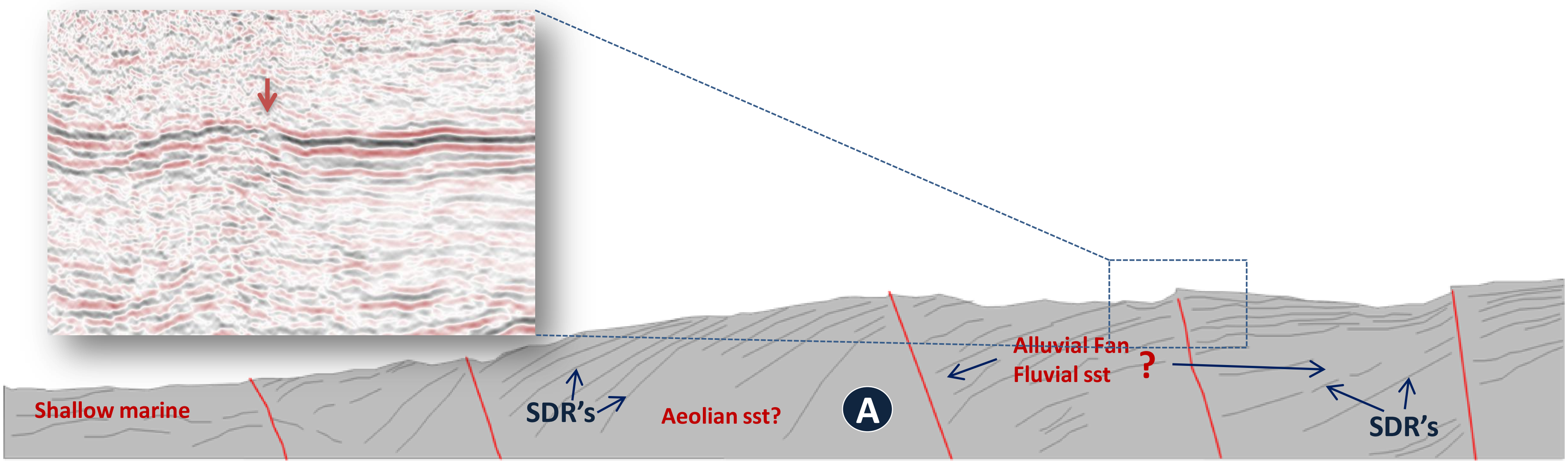
Namibia
South Africa

A SYNRIFT

(LATE JURASSIC TO EARLY HAUTERIVIAN (150 – 130Ma)

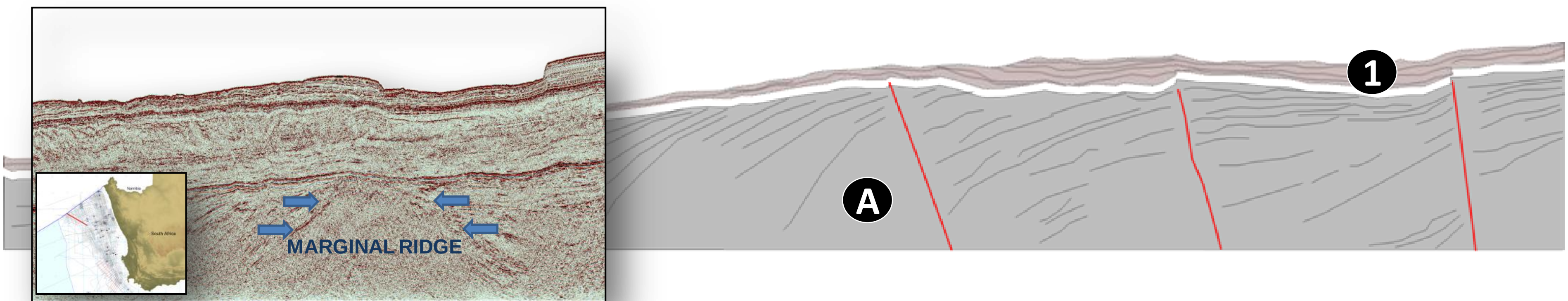
- SDR's are discontinuous to continuous, high amplitude, divergent and westerly dipping
- Syn-tectonic continental sedimentary sequences interbedded with SDR's (typical of volcanic rifted margins)
- Some of the synrift extensional faults show small reverse offsets of reflectors



1 POST-RIFT 1

EARLY HAUTERIVIAN TO MID APTIAN (130 – 112 Ma)

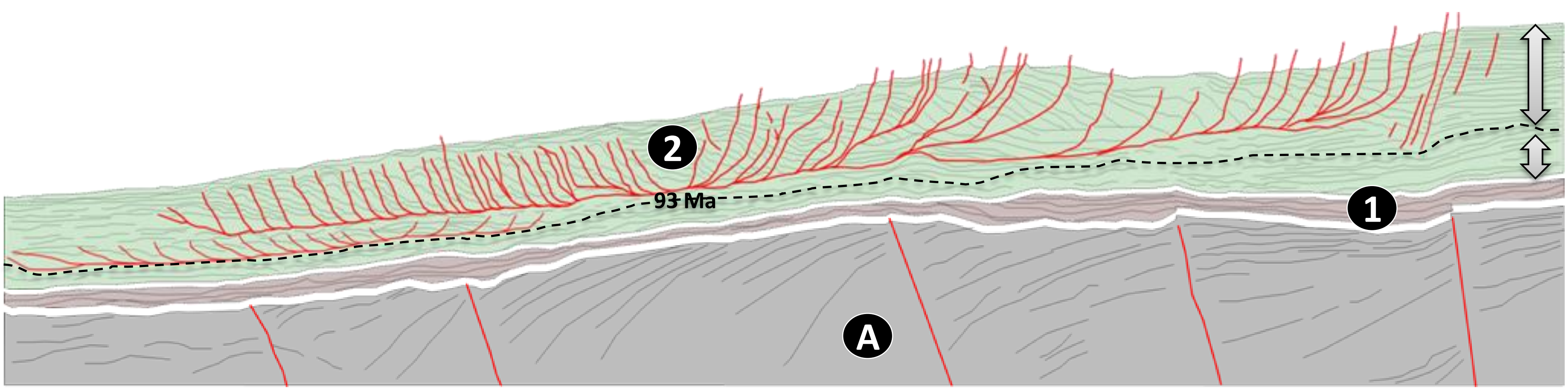
- Bounded by the Hauterivian rift-drift unconformity the mid-Aptian unconformity.
- Represents transitional phase from true rifting to post-rift
- Deposition influenced by the presence of a marginal ridge
- Reflections are parallel/divergent, alternating high/low amplitude with good to moderate continuity.
- Deposition under conditions where the subsidence and sedimentation rates are of similar magnitude.
- East of the ridge – low amplitude chaotic reflections – fluvial sediments
- West of the ridge – divergent, more uniform higher amplitude – transition from fluvial-deltaic to marine facies

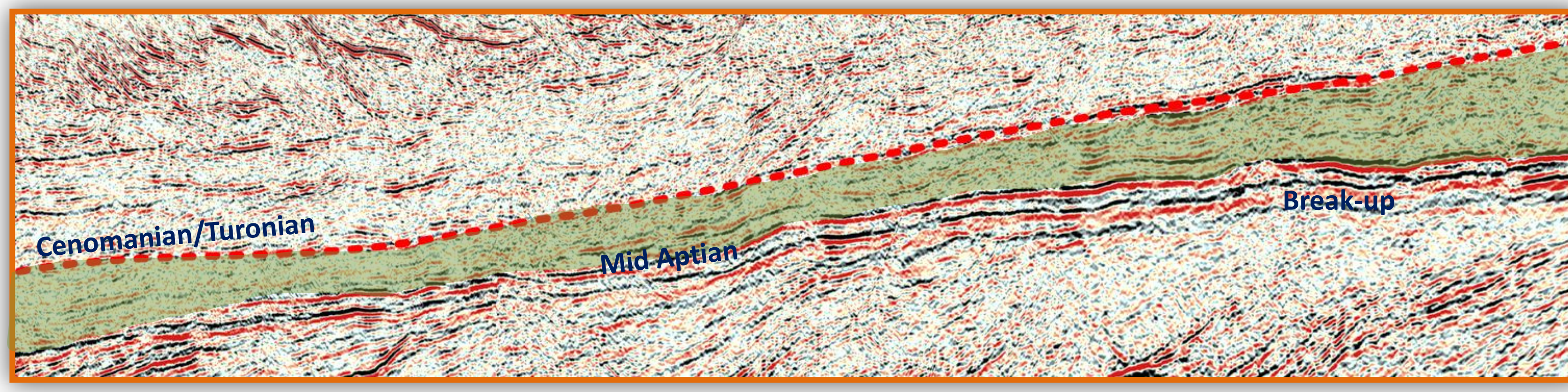


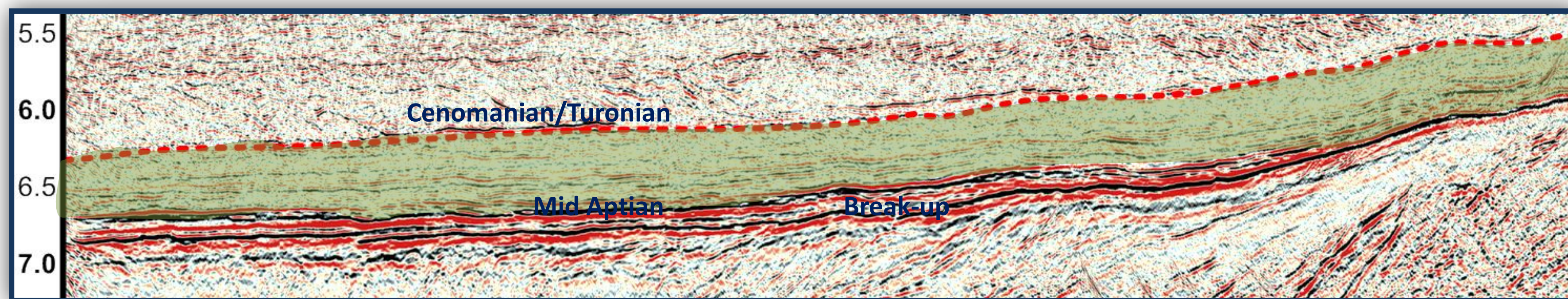
2 POST-RIFT 2

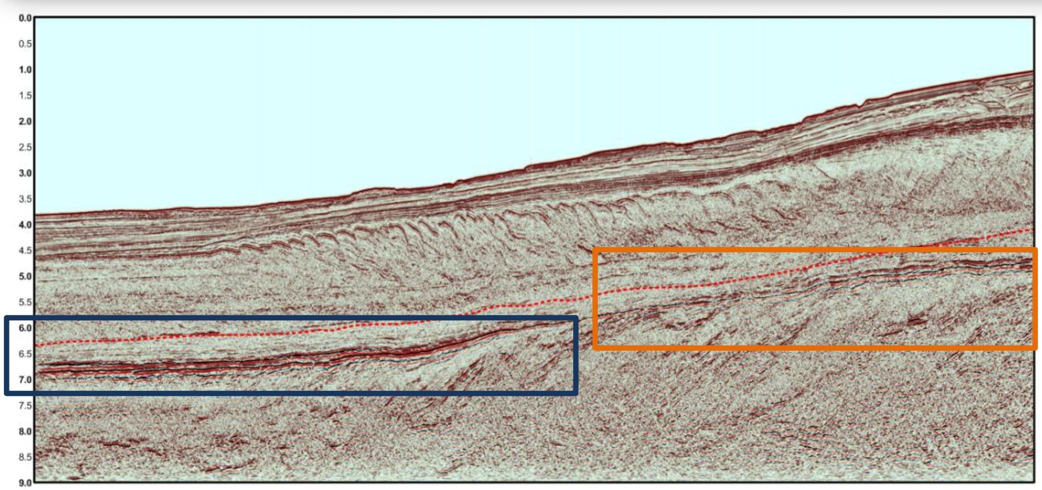
EARLY APTIAN TO MAASTRICHTIAN (112 – 67Ma)

- Bounded at the base by an Aptian unconformity and at the top by a Maastrichtian unconformity
- The base of this sequence marks the initiation of a major marine flooding event – anoxic black shale deposition
- This sequence can be divided into a lower and upper seismic sequence – separated by a Cenomanian/Turonian (93Ma) unconformity
- The upper sequence in contrast to the lower sequence is characterized by major gravity related tectonics and deposition









Low to high amplitude, variable frequency/continuity reflection, their presence with respect to the paleoslope and blanket like geometry

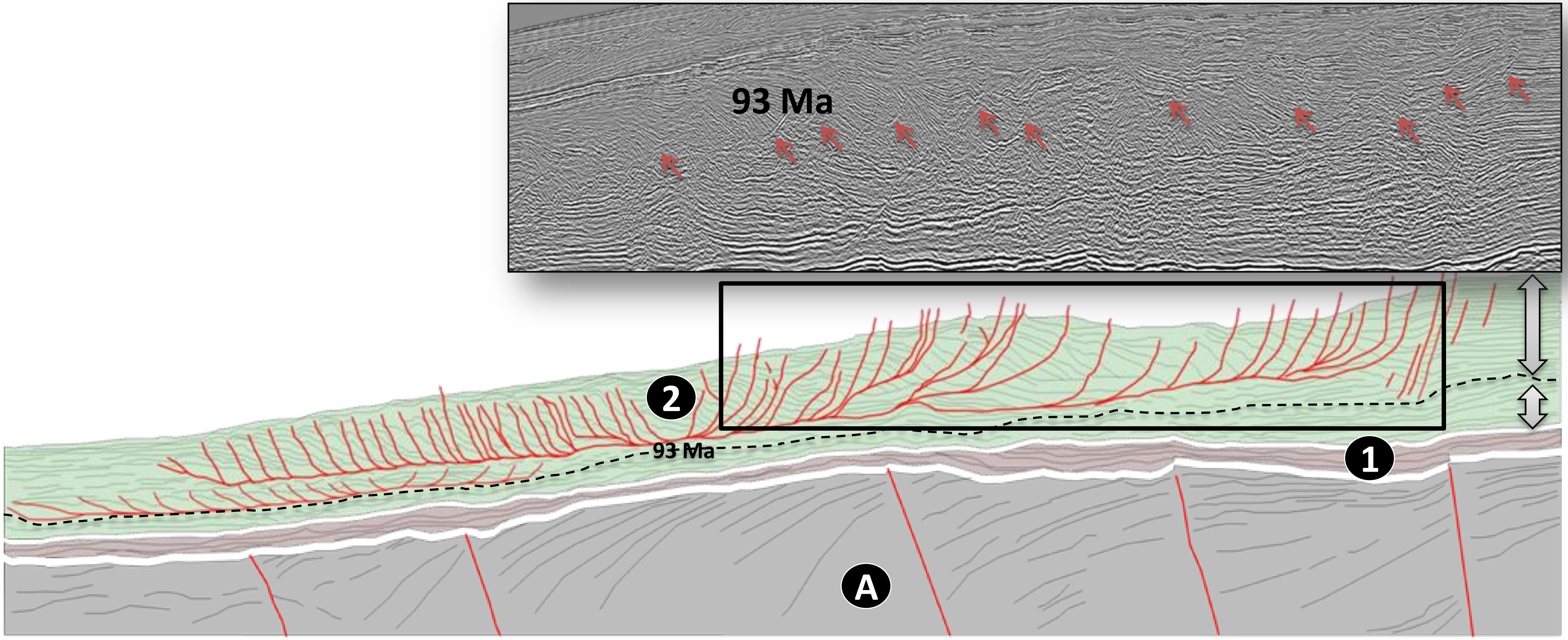
Deep-water, low energy depositional environment probably with a fine-grained lithology

2 POST-RIFT 2

EARLY APTIAN TO MAASTRICHTIAN (112 – 67Ma)

Extensional, seaward-dipping rotational listric growth faults, detached above decollements

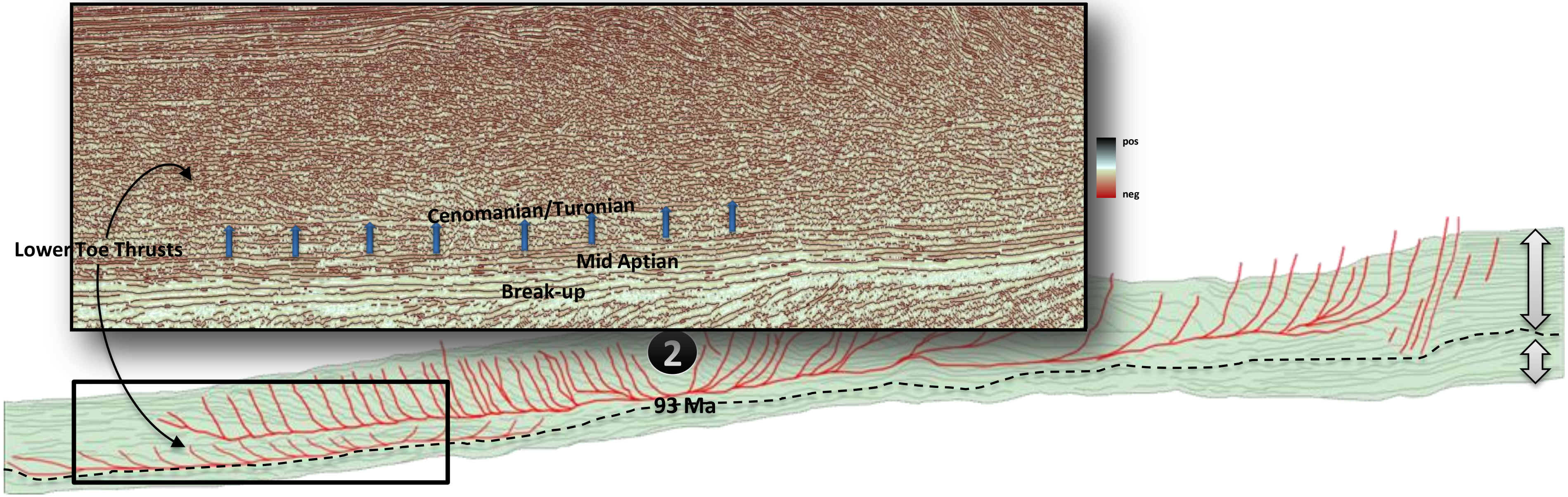
Seaward movement transferred and balanced by imbricated thrusting in the lower slope area



2 POST-RIFT 2

EARLY APTIAN TO MAASTRICHTIAN (112 – 67Ma)

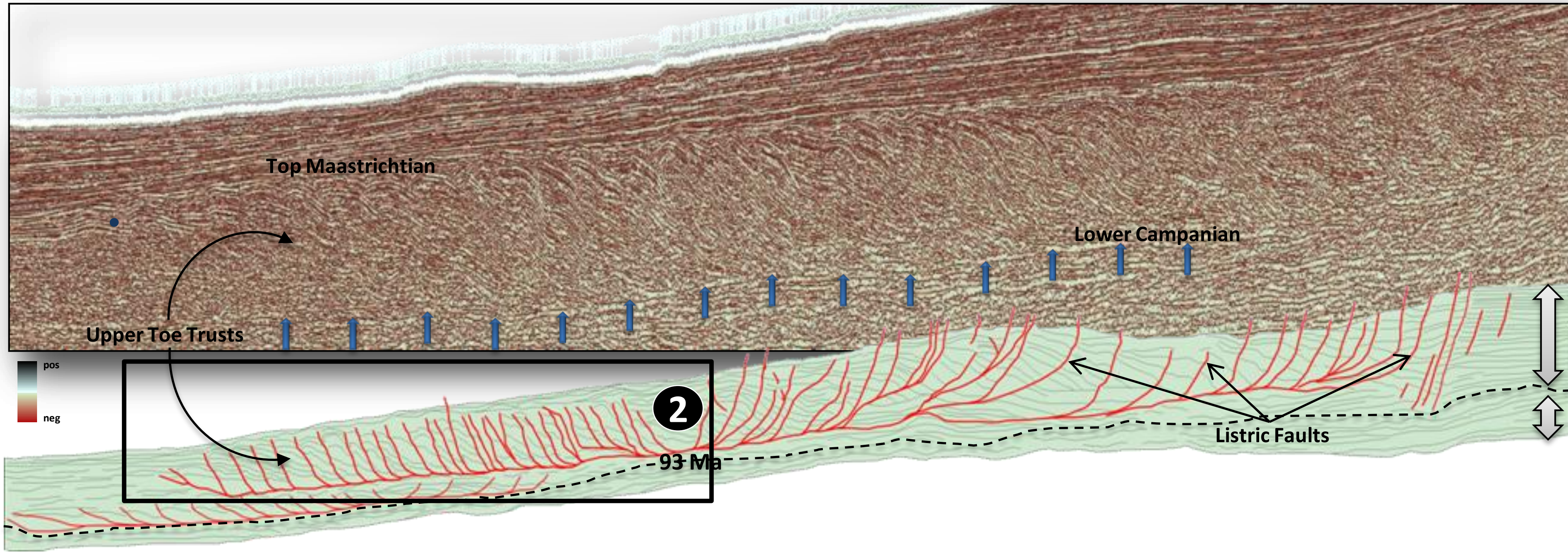
- At least 2 major decollement surfaces can be mapped in the upper sequence over a large area
- These developed and correspond to stratigraphic shale intervals within the sequence
- The lowermost decollement corresponds to the Cenomanian/Turonian transition at the lowermost parts of the slope, and mostly at the basin floor



2 POST-RIFT 2

EARLY APTIAN TO MAASTRICHTIAN (112 – 67Ma)

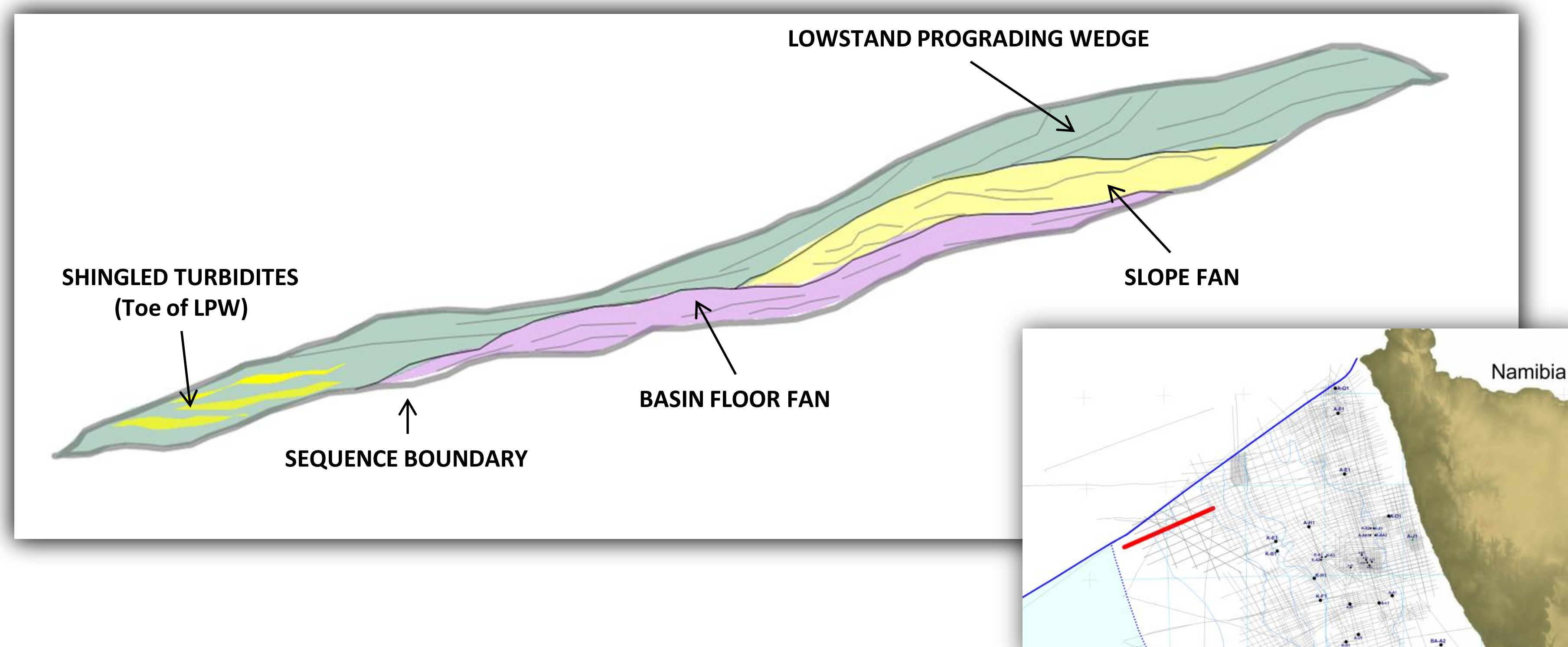
- The second and main decollement surface occurs in the lower Campanian
- Listric extensional faults developed only above dipping decollements i.e. in the paleoslopes
- The prominent Aptian anoxic shale interval, almost horizontal, did not act as a decollement



2 POST-RIFT 2

EARLY APTIAN TO MAASTRICHTIAN (112 – 67Ma)

- Lowstand systems tracts can be interpreted on the lower, less deformed parts of the sequence above the mid Aptian unconformity
- A basin floor fan, slope fan and a lowstand prograding wedge components can be interpreted

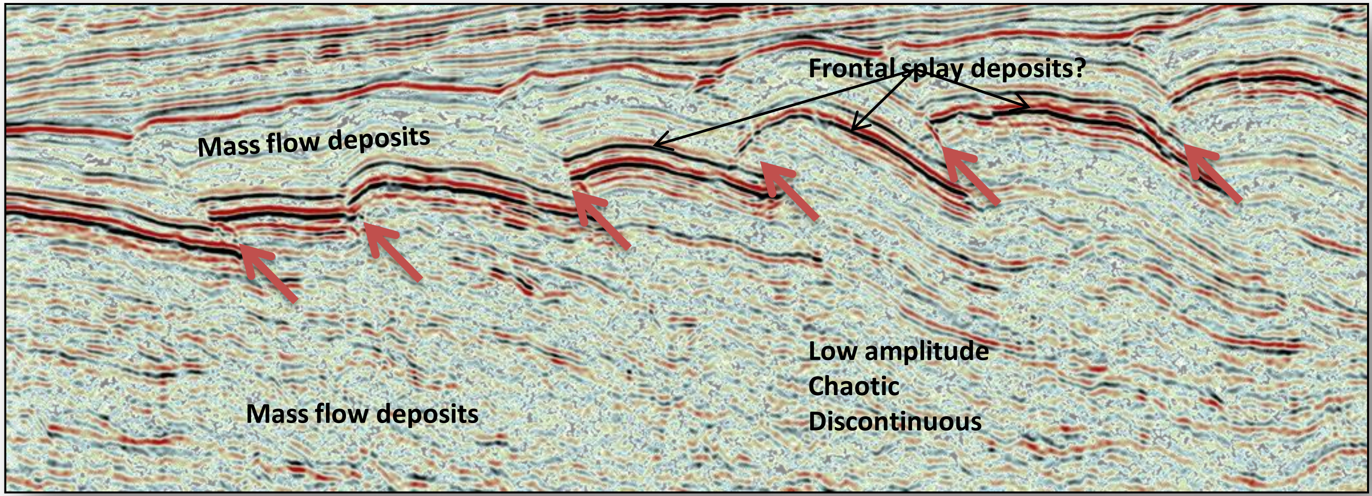


2 POST-RIFT 2

EARLY APTIAN TO MAASTRICHTIAN (112 – 67Ma)

- The internal reflections of the toe-thrust structures in the north are low amplitude, discontinuous and chaotic in character and can be interpreted as mass flow deposits.

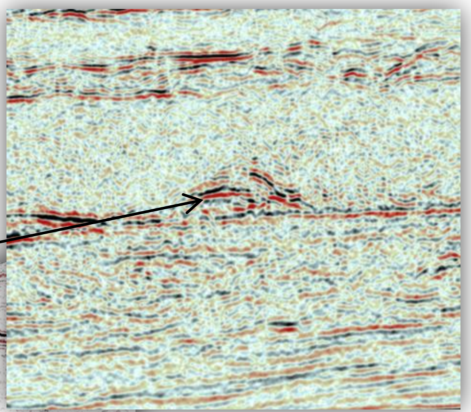
- Mass-transport deposits are overlain by high amplitude turbidite deposits, possibly the frontal splay.

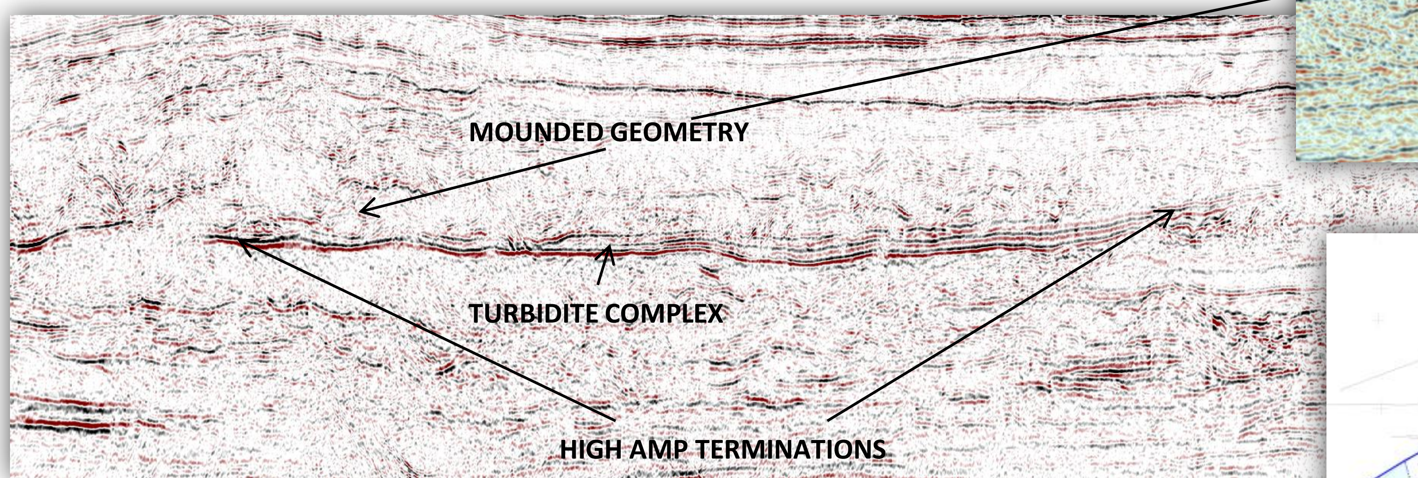


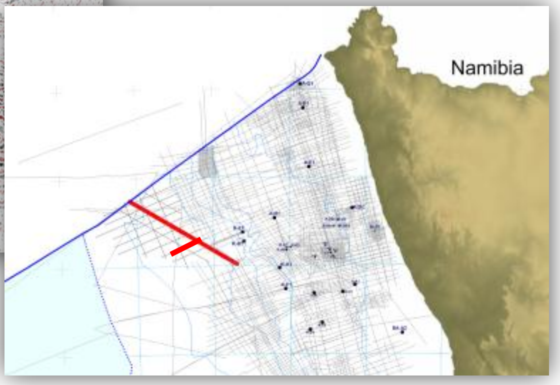
2 POST-RIFT 2

EARLY APTIAN TO MAASTRICHTIAN (112 – 67Ma)

- High amplitude turbidite complex pinches out towards the edges
- Terminating high amplitude internal reflections
- Mounded external geometry



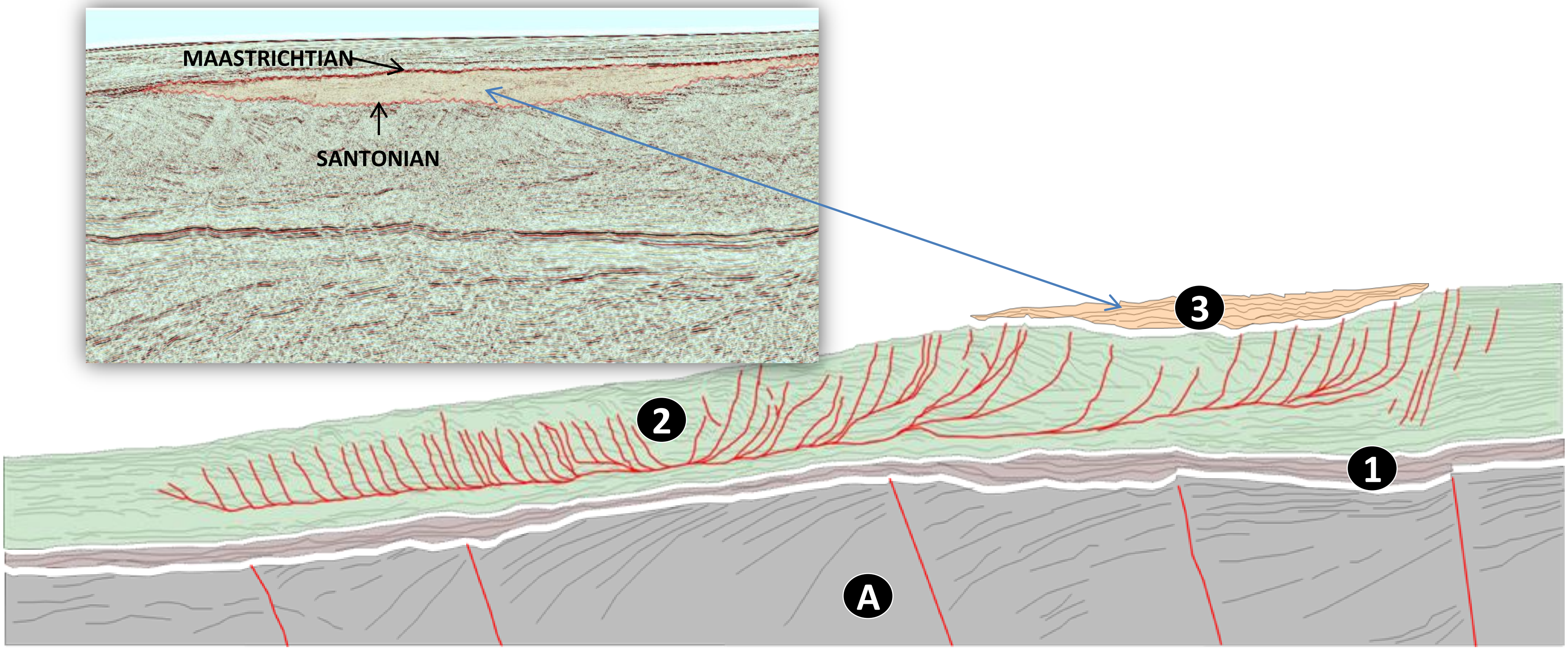




3 POST-RIFT 3

SANTONIAN TO MAASTRICHTIAN (80 – 67Ma)

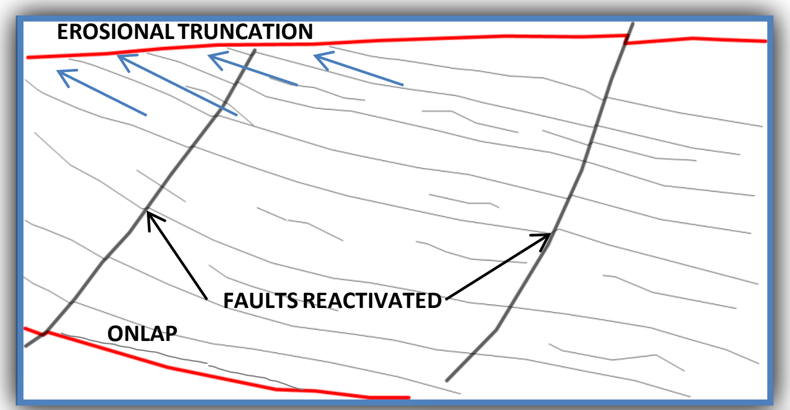
- Confined to the northern parts of the study area
- Internal seismic character distinctly different to the sequences above and below

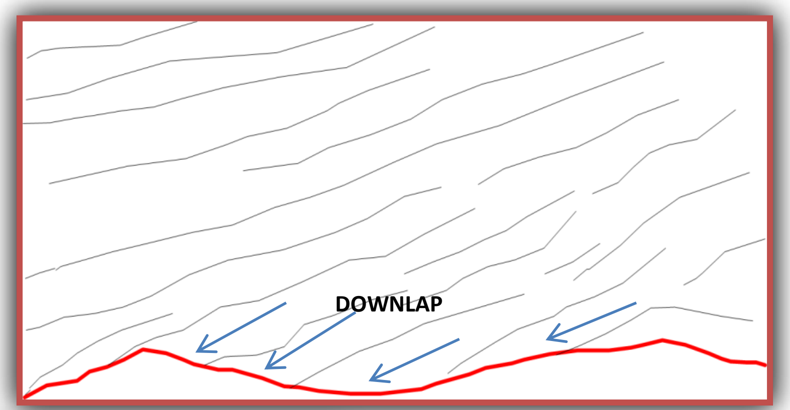


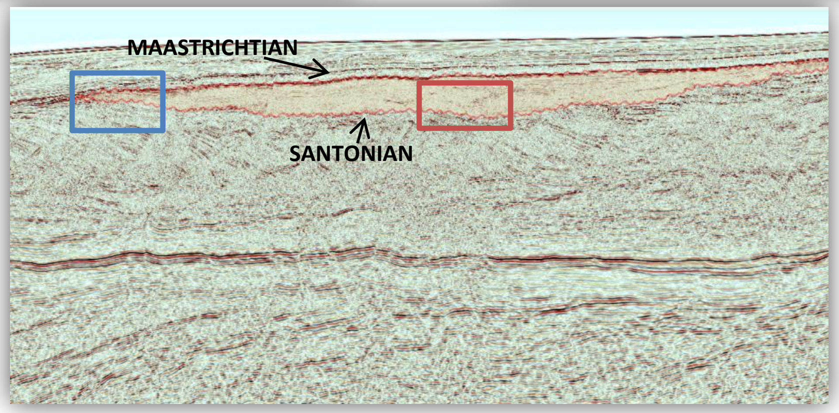
3 POST-RIFT 3

SANTONIAN TO LATE MAASTRICHTIAN (80 – 67Ma)

- Low amplitude, fairly continuous with erosional truncation, onlap to the SW and downlapping reflections to the NE
- Prograding wedge with relatively steeply dipping clinoforms, with oblique parallel geometry
- Coincides with the initiation of an accelerated sea level fall



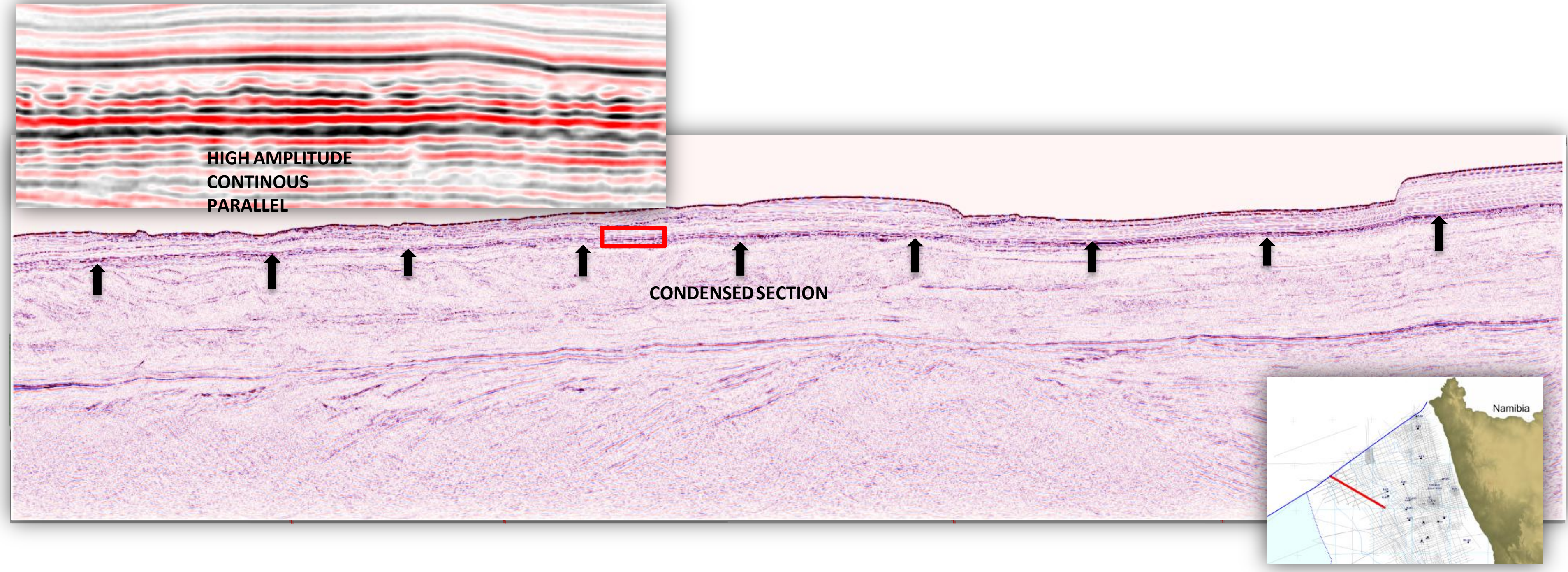




4 POST-RIFT 4

LATE MAASTRICHTIAN TO BASE PALEOCENE (67 – 64Ma)

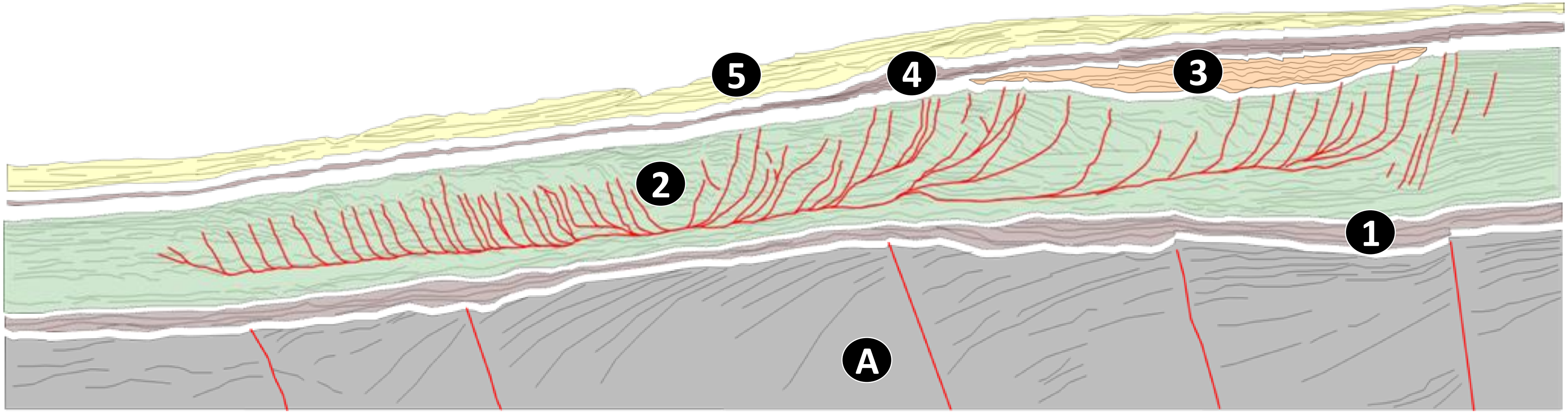
- This interval is bounded at the base by the major Late Maastrichtian unconformity and at the top by the base of the Paleocene/Tertiary
- Seismic reflections west of the shelf break are very high in amplitude, continuous and parallel
- This interval is interpreted as a marine condensed section and can be mapped over the entire study area in the deep water areas
- The sediments are likely to be hemipelagic and pelagic sediments, starved of indigenous materials especially towards the base of slope and on the abyssal plain



5 POST-RIFT 5

BASE PALEOCENE TO RECENT (64 – 0 Ma)

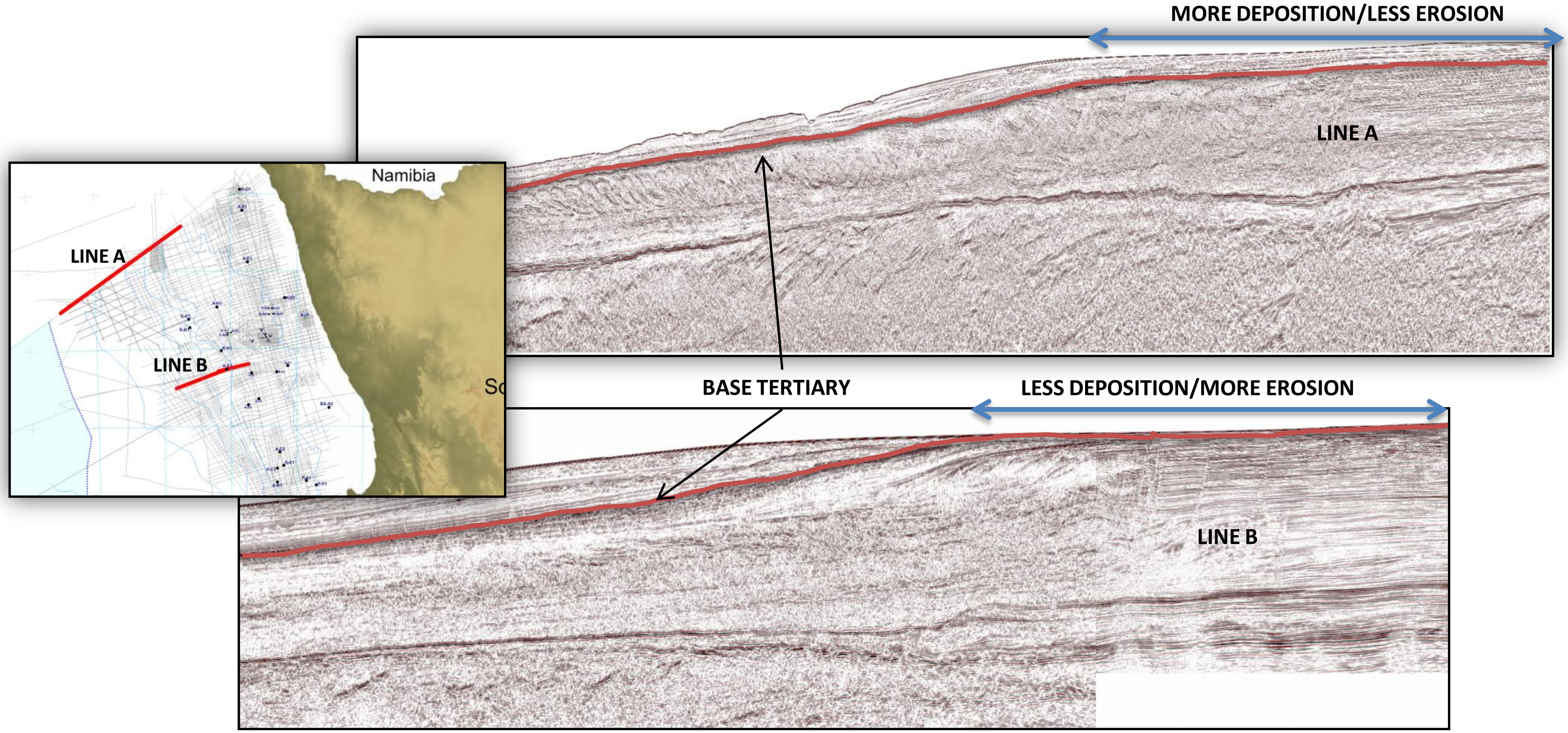
- This sequence represents the Cenozoic succession and the main style of deposition continues to be progradational beyond the shelf edge.
- This could be an indication that thermal subsidence during this period probably largely approaching the end.
- Deposition west of the shelf break, prograding progressively into deep water.
- Gravity tectonics considerably older in the Northern Orange Basin than in the southern and central parts



5 POST-RIFT 5

BASE PALEOCENE TO RECENT (64 – 0 Ma)

- The Cenozoic succession in the central and southern parts of the basin subjected to more erosion on the shelf
- More sediments are deposited on the slope in the central and southern parts
- The thicker Cenozoic section in the north attributed to its location with respect to depocentre and reduced effects of uplift



Conclusions

SYNRIFT

- SDR's confirm the volcanic nature of the Orange Basin rifting and the interplay of volcanism and passive margin evolution.
- Lacustrine, fluvial and aeolian facies sequences may be interbedded with these intermittent subareal volcanics

POST RIFT 1 (TRANSITIONAL)

- Seismic character and reflection geometries away from the shelf suggest a strong marine influence
- Barremian source sediments may have been deposited west of the marginal ridge

POST RIFT 2

- Deposited under strong gravity driven tectonics
- Most prospective interval, as on the shelf

POST RIFT 3, 4 & 5

- Valuable as an aid in understanding depositional processes that exist throughout the sedimentary succession of the Orange Basin.

Thank You

Seismic data courtesy of Petroleum Geo-Services