Structural Evolution of Ubadari Field, Bird's Head, Papua, Indonesia*

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Abstract

The Ubadari Field is located in the Berau PSC, about 50 km southwest of the Tangguh LNG area in Bird's Head region, West Papua, Indonesia. The Ubadari-1 well was drilled in 1997, discovering gas in the Middle Jurassic "Roabiba" sandstone and in Paleocene sandstone reservoirs. The Roabiba sandstone was deposited in a fluvial to marginal marine environment. Following the discovery in 1998, Ubadari-2 was drilled to test a structure down dip of the Ubadari-1 well, but no hydrocarbon accumulation was encountered.

Why was Ubadari-2 dry? That is a question that has been an issue for further exploration in the Western Berau region. In order to unravel this puzzle a paleo-reconstruction study was undertaken to understand the structural evolution of the area. The Bird's Head region has experienced three main erosion events: Permo-Triassic erosion, Oligocene erosion, and Pliocene erosion. The Oligocene and Pliocene erosion events have had the greatest effect on the Ubadari structural development, both occurring post deposition of the reservoir. Therefore, understanding the amount of section removed by these two events is fundamental to understanding the results of Ubadari-1 vs. Ubadari-2.

Results of the study suggest that the Ubadari Field was a low relief structure before Pliocene time, while the structure at Ubadari-2 was down flank on the structure. Ubadari-2 was located on the flank of the structure between the culmination to the north and a low to the south prior to Pliocene age and the present structural configuration was formed post hydrocarbon charge. Both structures continued to grow to produce the present day structural configuration. That is why there are now two separate structures.

Introduction

The Ubadari Field is located in Berau PSC, about 50 km southwest of Tangguh LNG area in Bird's Head, Papua, Indonesia (Figure 1). The Bird's Head region is located in a complex tectonic setting, between three major crustal plates: the Indo-Australian Plate, the Eurasian Plate and the Pacific Plate (Dow and Sukamto, 1984). Deformation in Bird's Head has uplifted and re-activated older fault systems, providing evidence of continued tectonic activity.

The initial collision between Australian and Pacific plates occurred during Oligo-Miocene ages. The NW-SE structural trend of the Ubadari, Kalitami, Wiriagar, and Vorwata ridges are believed to be a result of this collision and possibly re-activated from Paleozoic structure. During Plio-Pleistocene, the change in direction of relative plate motion between the Pacific and Australian plates to E-W brought changes in the deformation style, from contractional to strike-slip (Sapiie et al., 2000). The Lengguru Fold Belt, Sorong Fault, Tarera-Aiduna Fault and Seram Thrust are structural features associated with this compression (Figure 2).

In Bintuni Bay, several exploration wells targeting Pre-Tertiary reservoirs were drilled with gas accumulations discovered at Roabiba, Ofaweri, WOS, Wiriagar Deep, Vorwata, and Ubadari (collectively referred to as the Tangguh Fields). Ubadari-1 and Ubadari-2 are the last exploration wells of the Bintuni exploration campaign.

The Middle Jurassic Roabiba Sandstone is the main reservoir target in the Tangguh area. The Roabiba Sandstone was deposited in a transgressive succession (back stepping) relatively from southwest to northeast (Figure 3). Ubadari-1 well was drilled in 1997, discovering gas in the Middle Jurassic Roabiba Sandstone and in Paleocene sandstone reservoirs. The Roabiba Sandstone was deposited in a fluvial to marginal marine environment. Following the discovery in 1998, Ubadari-2 was drilled 8 km southwest of Ubadari-1, on a local culmination and failed to encounter hydrocarbons.

Methods

Several approaches were thoroughly worked to define an integrated structural evolution of Ubadari Field, including:

a. Well post mortem review.
b. Seismic interpretation to generate various depth structure maps.
c. Chrono-stratigraphy cross-section.
d. Calculate missing section by 1D modeling.
e. Determine missing section by 2D map approach.
f. Reconstructed Lower Roabiba depth map.

Results and Discussion

Seismic Cross Section

The Bird's Head area has experienced three main erosion events: Permo-Triassic erosion, Oligocene erosion, and Pliocene erosion (Figure 4). The Permo-Triassic erosion event was deformed by major compression in the Late Triassic. This event was related to the Late Triassic compression that caused folding and faulting from the Northwest Shelf of Australia to the Bird's Head area.

The Oligocene folding gave rise to a significant erosional surface due to the collision between Australian and Pacific plates. This compression resulted in formation of the Ubadari structure and other Oligocene structures in the Tangguh area.

These erosion events are observed in many seismic sections over Bird's Head area, including the Ubadari Field area (Figure 4). The change in direction of relative plate movement between the Australian and Pacific plates during Plio-Pleistocene to east-west changed the deformation style from contractional to strike-slip (Sapiie, et al., 2000). It caused Pliocene folding and erosion in some areas. Pliocene erosion can be observed in the Western Berau area.

The Oligocene and Pliocene erosional events have had the greatest effect on the Ubadari Field, both occurring post-deposition of the Middle Jurassic and Paleocene reservoirs. Based on seismic stratigraphy in the Ubadari Field, it is observed that Oligocene sediments were eroded by Oligocene and Pliocene erosional events and the Miocene-Pliocene section was eroded by a Pliocene erosional event.

Amount of Missing Section (1D Model)

To determine the amount of missing section over the Ubadari area, a 1D model was generated for several wells in the Ubadari Field and surrounding area. The total amount of erosion at Ubadari-1 is around 8750 ft based on Vitrinite Reflectance (VR) data (Figure 5). The total missing section is eroded in the Pliocene.

Determining Missing Section by 2D Map Approach

After using 1D modeling to estimate the total amount of erosion in Ubadari Field, this study also used 2D/3D seismic sections to estimate the amount of erosion. By reconstructing missing section from older to younger intervals, the 1D model was used to calibrate the amount of erosion determined from the 2D map approach.

Oligocene Missing Section

In the Ubadari area, the Oligocene section was eroded by Oligocene and Pliocene erosional events. To estimate the Oligocene missing section, the original thickness of Oligocene section first needed to be determined. The thickness of the Oligocene sediments was determined from a regional isopach map, and then applied as the constant original Oligocene thickness. A projection of the Oligocene erosional surface was made. This was used to divide erosion of the Oligocene deposits into separate Oligocene and Pliocene erosional events (Figure 6).

The Oligocene missing section due to Oligocene erosion was obtained from reconstructed original Oligocene isopach thickness minus reconstructed Oligocene erosion surface. And the Oligocene missing section resulting from Pliocene erosion was obtained from reconstructed Oligocene erosion event minus present day Oligocene thickness.

Miocene Missing Section

The Miocene section in the Ubadari area was eroded by a Pliocene erosion event. The reconstructed Miocene interval was determined by a similar approach as above. The original Miocene thickness was determined and applied as the reconstructed Miocene interval. The amount of missing section from Pliocene erosion was obtained from reconstructed original Miocene interval minus present day Miocene thickness (Figure 7).

Pliocene Missing Section

The Pliocene erosional event also eroded Pliocene sediments. The Pliocene missing section was determined with a similar procedure used to estimate Miocene missing section, i.e. reconstruct the present day Pliocene interval with the estimated original Pliocene thickness. The difference between reconstructed original and present day Pliocene interval generated gives an estimate of Pliocene missing section (Figure 8).

Reconstructed Lower Roabiba Depth Map

A good estimate of total missing section resulting from Oligocene and Pliocene erosional events was necessary to reconstruct the Roabiba depth map. By adding the total of Oligocene and Pliocene missing section, the paleo-structure map of Lower Roabiba was derived (Figure 9).

The paleo-reconstructed Lower Roabiba maps show Ubadari-2 was on the flank of broad structure downdip from the culmination to the north and updip from a low to the south before Pliocene time. The Ubadari structure was deformed during Oligocene time and was a low relief structure before Pliocene time (Figure 10). After Pliocene, the Ubadari structure continued to grow and modify to produce two separate present day structural culminations (Figure 11). The Western Berau area was likely charged from a gas kitchen prior to

Pliocene time. Ubadari-2 is most likely wet because it was downdip, outside the large broad closure prior to the Pliocene and the post-Pliocene structure formation at Ubadari-2 occurred post-charging.

Conclusions

Three main erosion events were identified in the Ubadari area: Permo-Triassic erosion, Oligocene erosion, and Pliocene erosion. The Oligocene and Pliocene erosional events are the main events that affected the area of the Ubadari Field, both occurring post Middle Jurassic Roabiba deposition. Quantifying the amount of missing section from these two events was necessary for reconstruction of the paleo-structure and understanding the structural timing between Ubadari-1 and Ubadari-2.

Calibration between 1D model and 2D/3D seismic interpretation is very important to the estimation of eroded section. Using the total Oligocene and Pliocene missing section, a paleo-structure map of Roabiba was generated - a requirement for understanding the results of the Ubadari-2 failure.

Results from this study suggest that Ubadari Field was a low relief structure before Pliocene time while the Ubadari-2 was down dip and outside the closure. The present day structure likely developed post-charging. Both structures then continued to grow, producing the present day structural closure including both Ubadari-1 and Ubadari-2. That is why at present day there are two separate structures.

Acknowledgements

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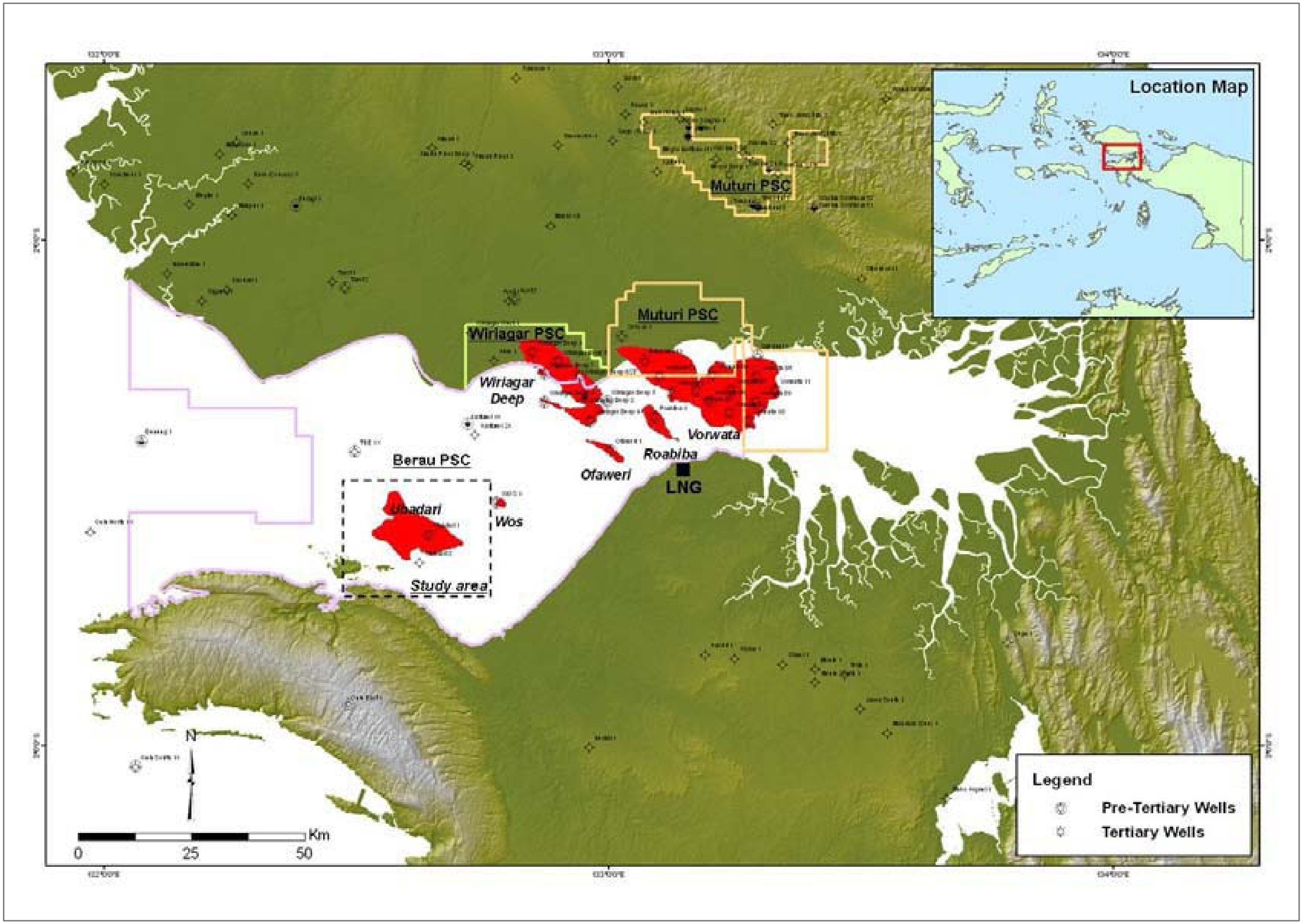

Figure 1. Geographic map of Bird's Head area, showing the Tangguh gas fields (Vorwata, Wiriagar Deep, Roabiba, Ofaweri, Wos, and Ubadari) and study area at the Ubadari Field.

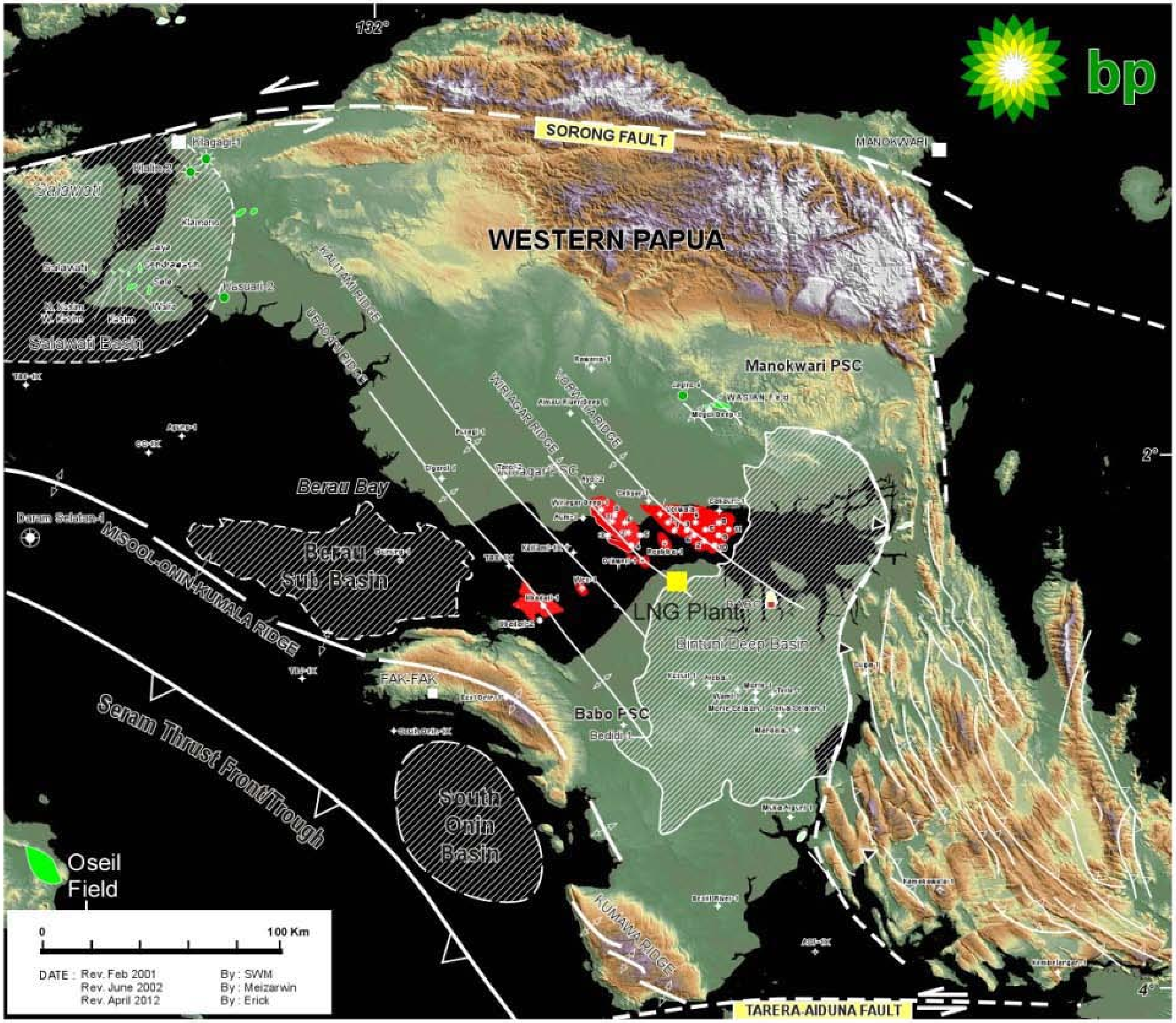

Figure 2. Structural elements map of the Bird's Head area. The area is bounded by the Sorong Fault Zone in the north, Tarera-Aiduna Fault Zone in the south, Lengguru Fold-Belt in the east and Seram Trough in the southwest. The map also identifies the basins and the NW-SE trending ridges (modified from Syafron et al., 2008).

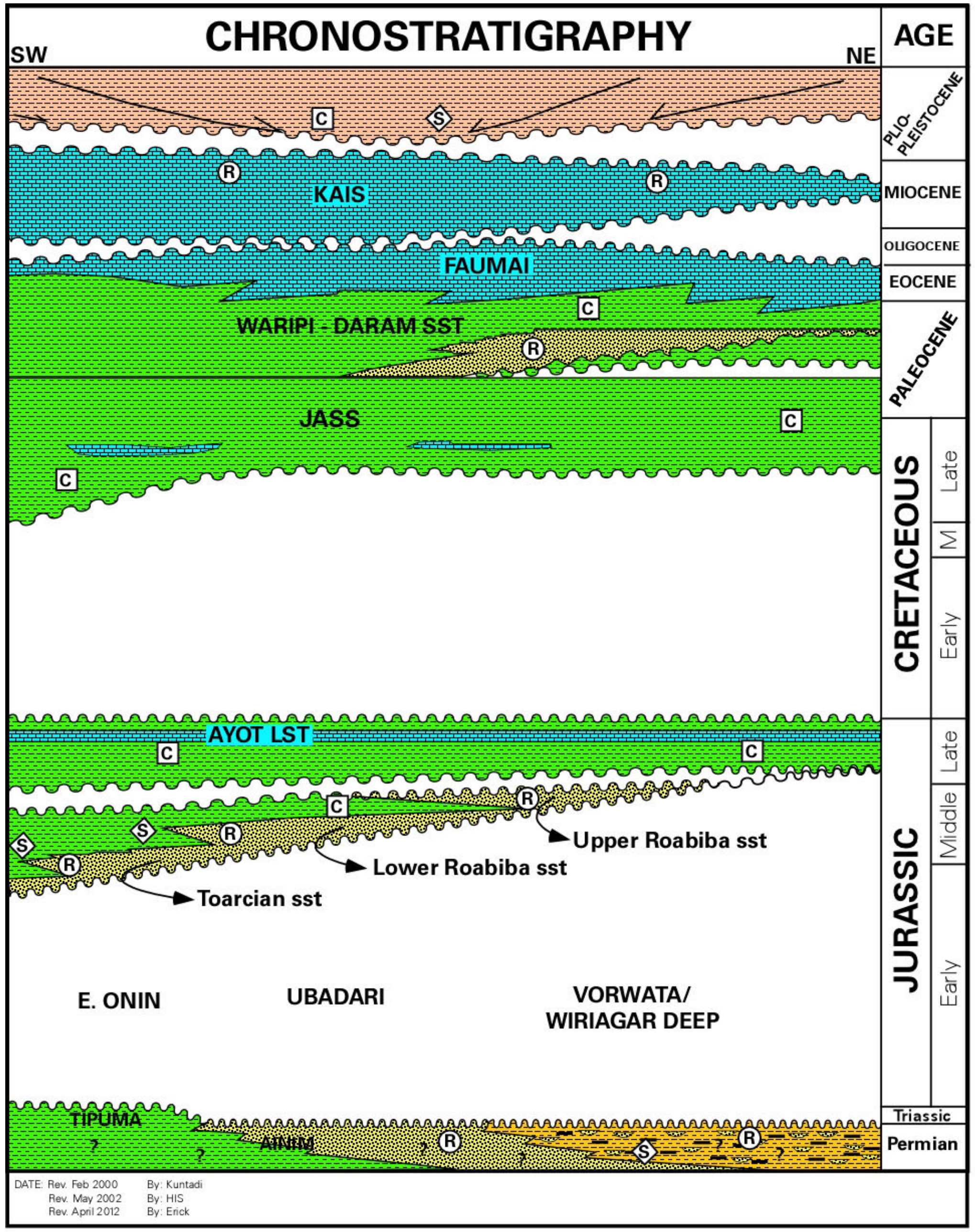

Figure 3. Chronostratigraphy of Bintuni Bay, West Papua. Middle Jurassic Roabiba sandstone is the main reservoir target in Tangguh gas fields. The Roabiba sandstone is deposited as a transgressive succession (back stepping) from southwest to northeast.

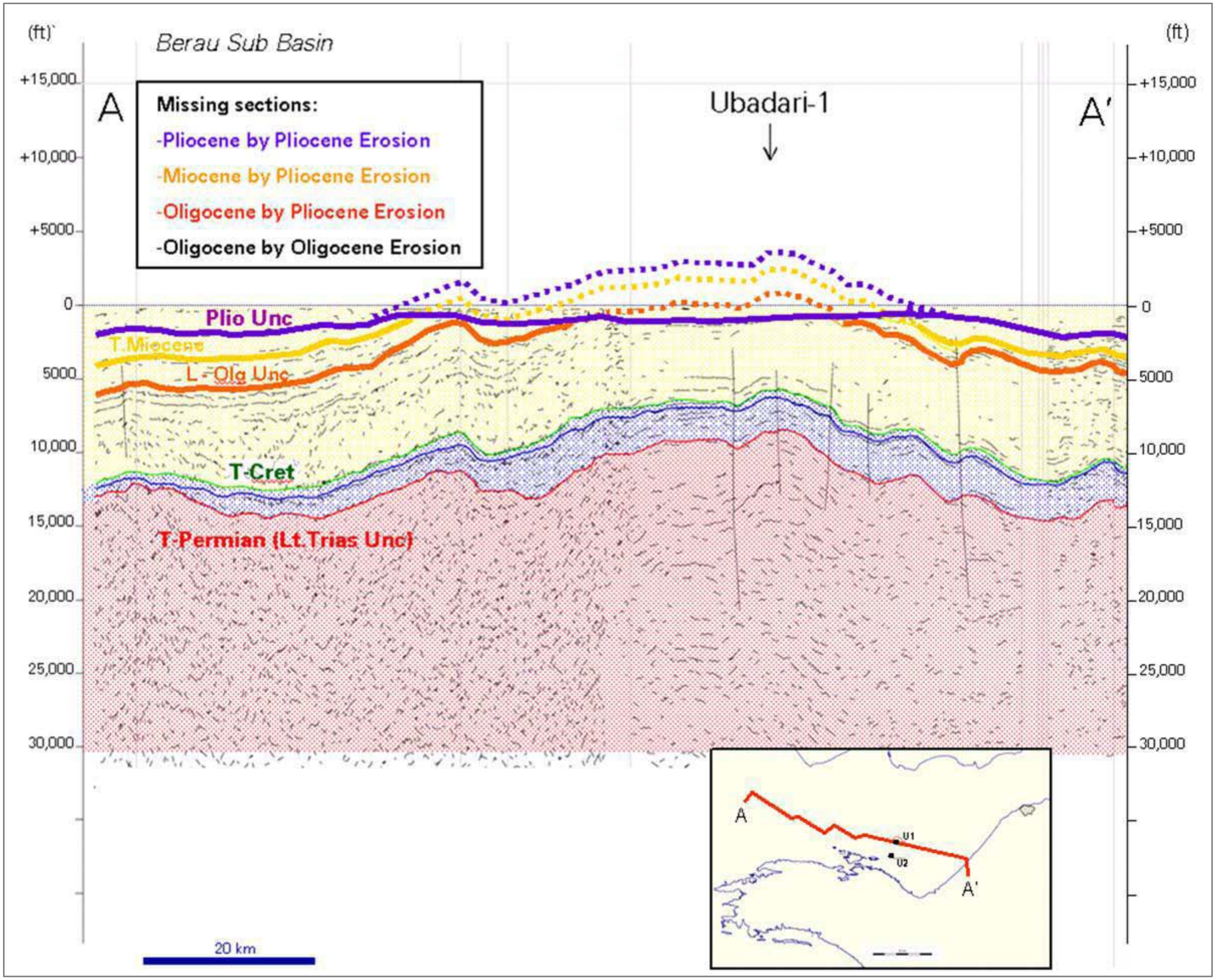

Figure 4. A-A' Seismic Transect, showing the area has three main erosional events: Permo-Triassic erosion, Oligocene erosion, and Pliocene erosion. The Oligocene and Pliocene erosional events had the greatest effect on the Ubadari structure.

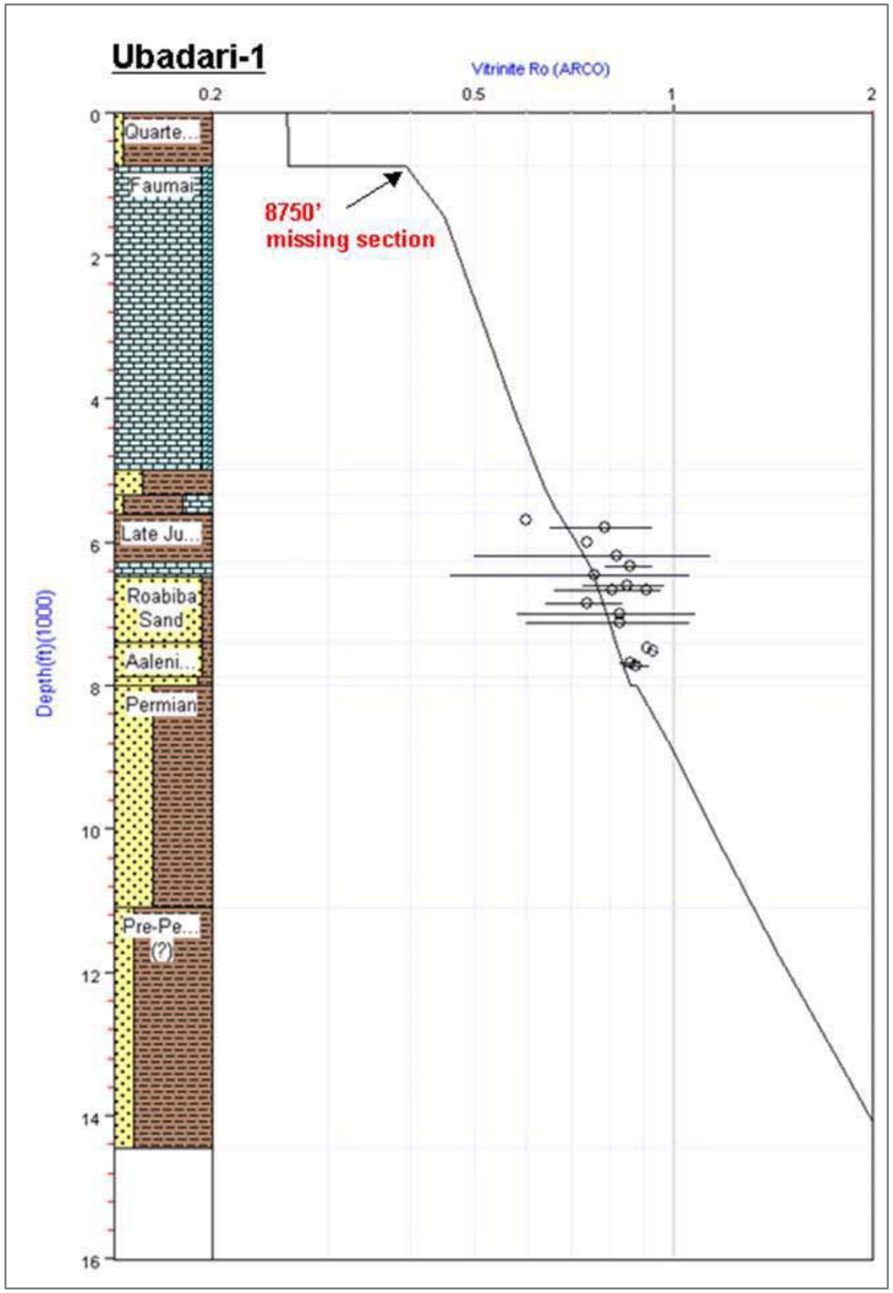

Figure 5. Ubadari-1 1D modeling. Correlation between depth and vitrinite reflectance data showing total missing section due to Pliocene erosional event is ~ 8750 ft.

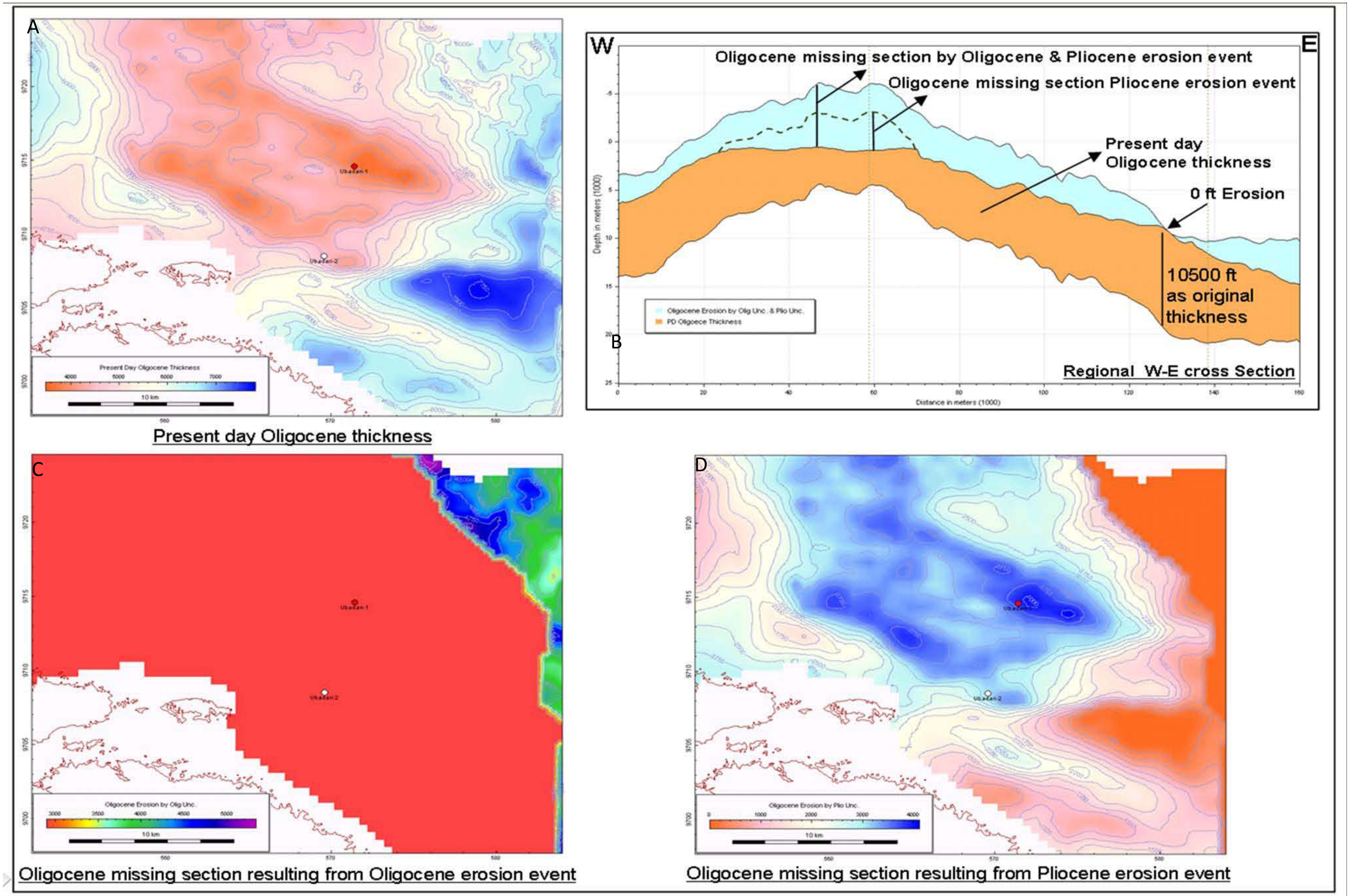

Figure 6. Oligocene missing section by using 2D map approach. In Ubadari area, the Oligocene section was eroded by Oligocene and Pliocene erosion events. Reconstruction of the Oligocene section to estimate the amount of erosion. (A: Present day Oligocene thickness; B: Regional W-E cross section; C: Oligocene missing section resulting from Oligocene erosion; D: Oligocene missing section resulting from Pliocene erosion).

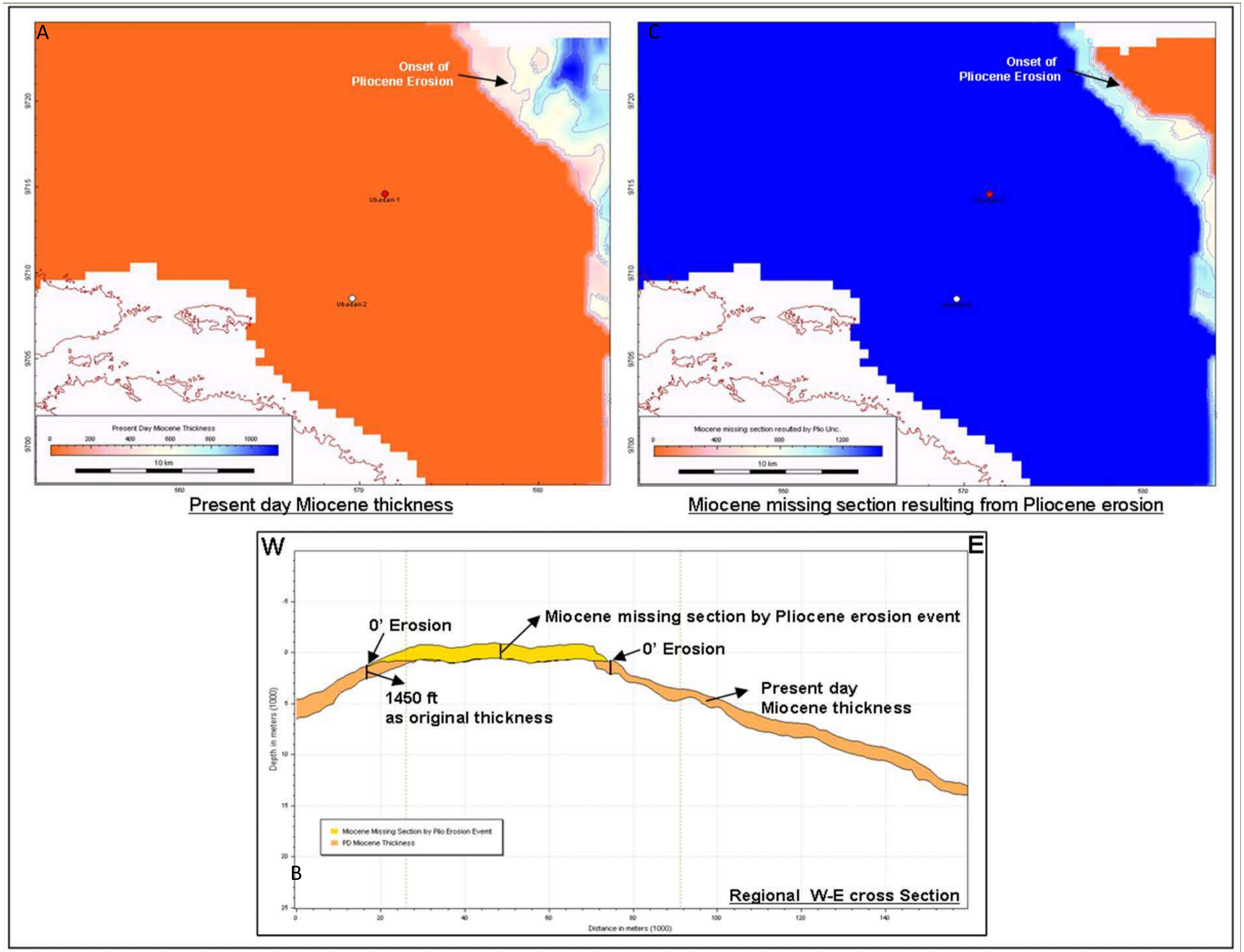

Figure 7. Miocene missing section by using 2D map approach (A: Present day Miocene thickness; B: Regional W-E cross section; C: Miocene missing section resulting from Pliocene erosion).

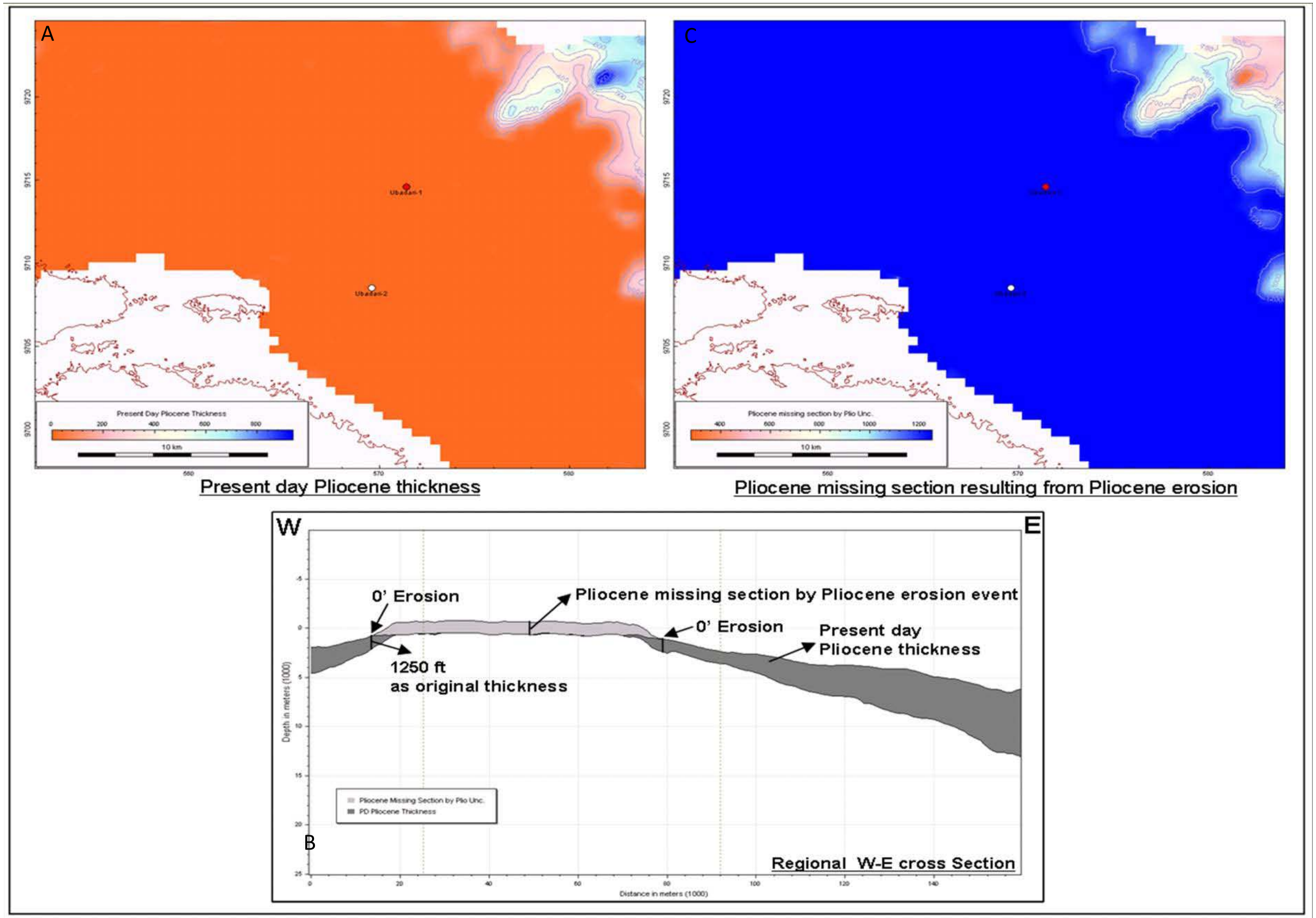

Figure 8. Pliocene missing section by using 2D map approach (A: Present day Pliocene thickness; B: Regional W-E cross section; C: Pliocene missing section resulting from Pliocene erosion).

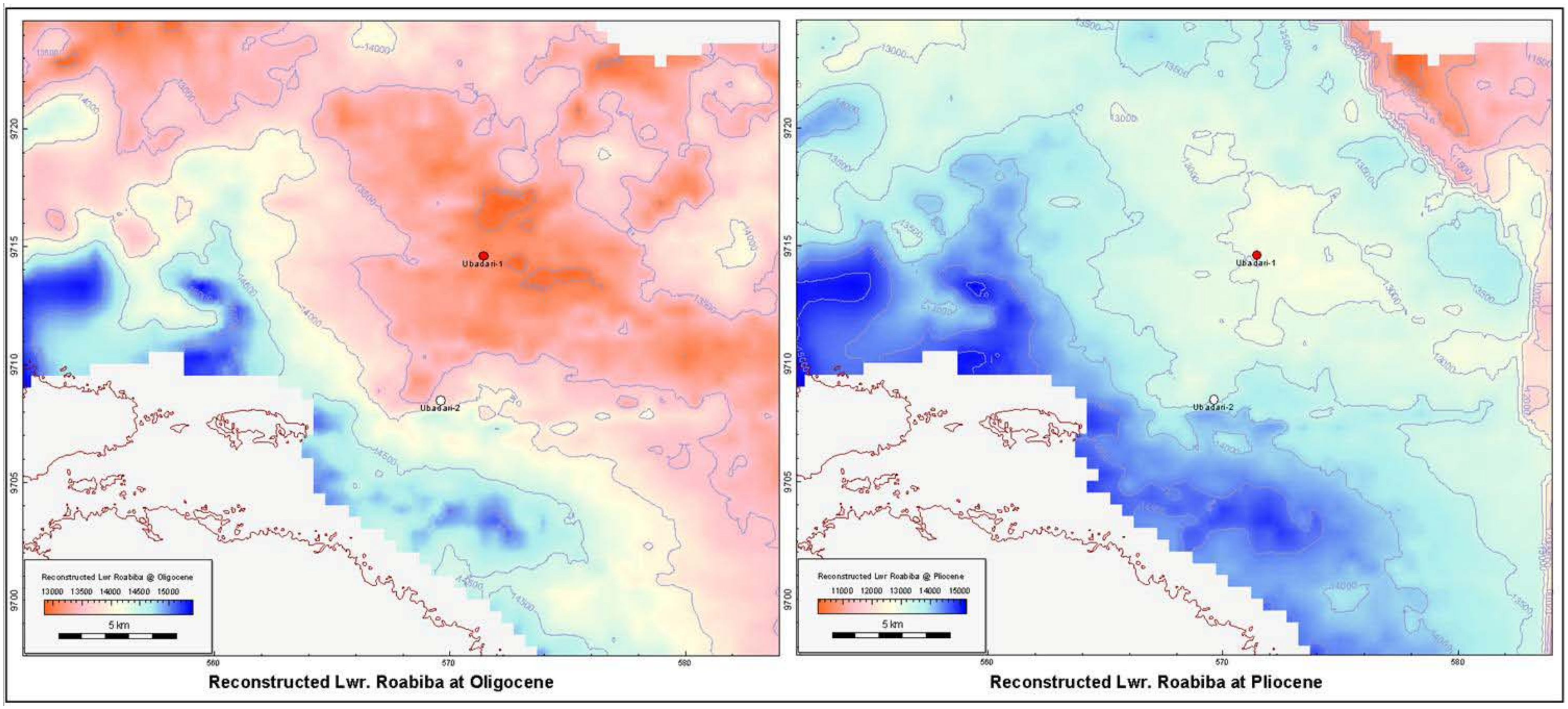

Figure 9. Reconstructed Lower Roabiba depth map at Oligocene and Pliocene time. Paleo-reconstructed Lower Roabiba maps show Ubadari-2 was on the flank of a broad structure between the culmination at present day Ubadari-1 and a low to the south. Ubadari structure was deformed in Oligocene time and was a low relief structure until Pliocene time.

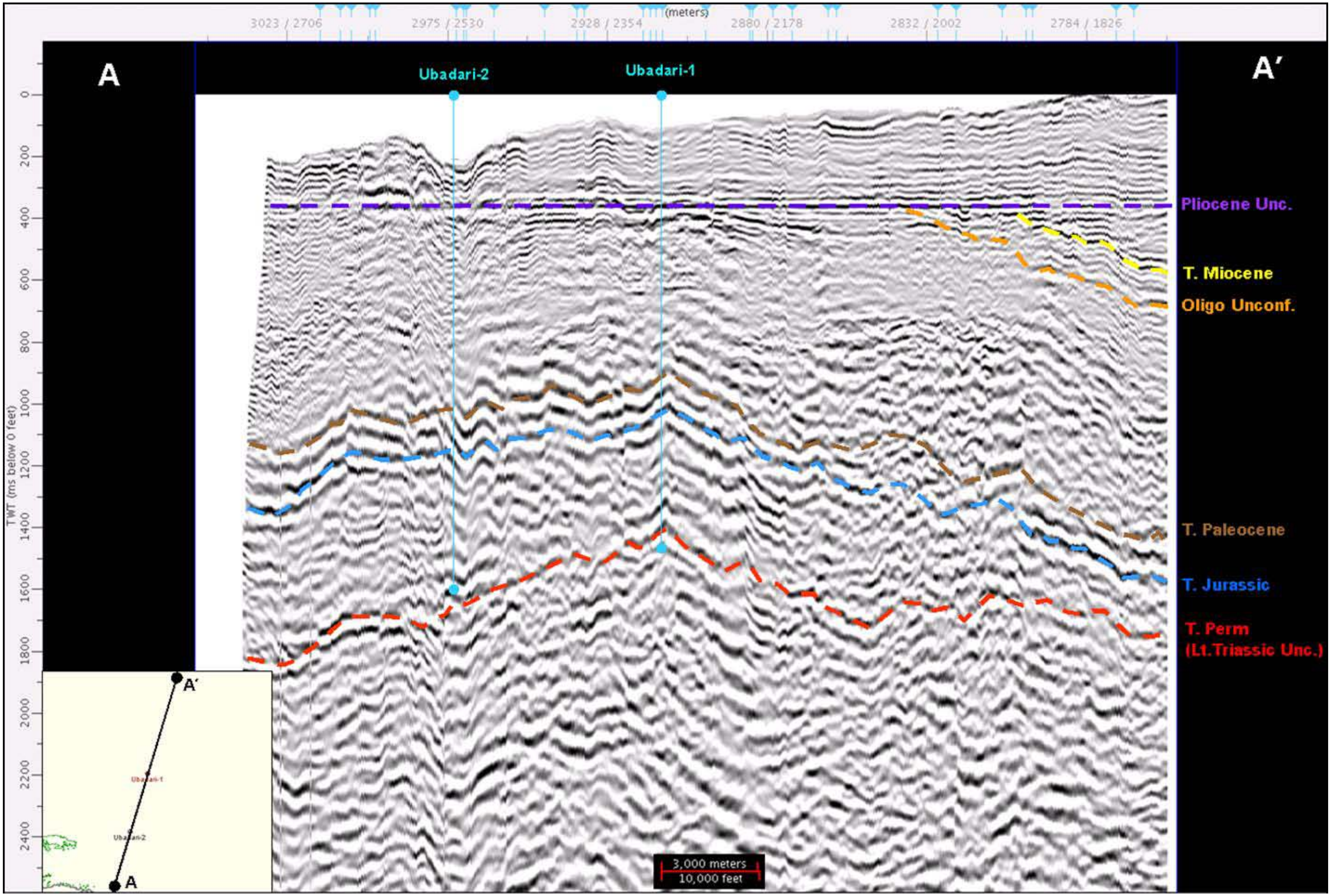

Figure 10. A-A' seismic transect, showing Ubadari structure was a low relief structure before Pliocene time.

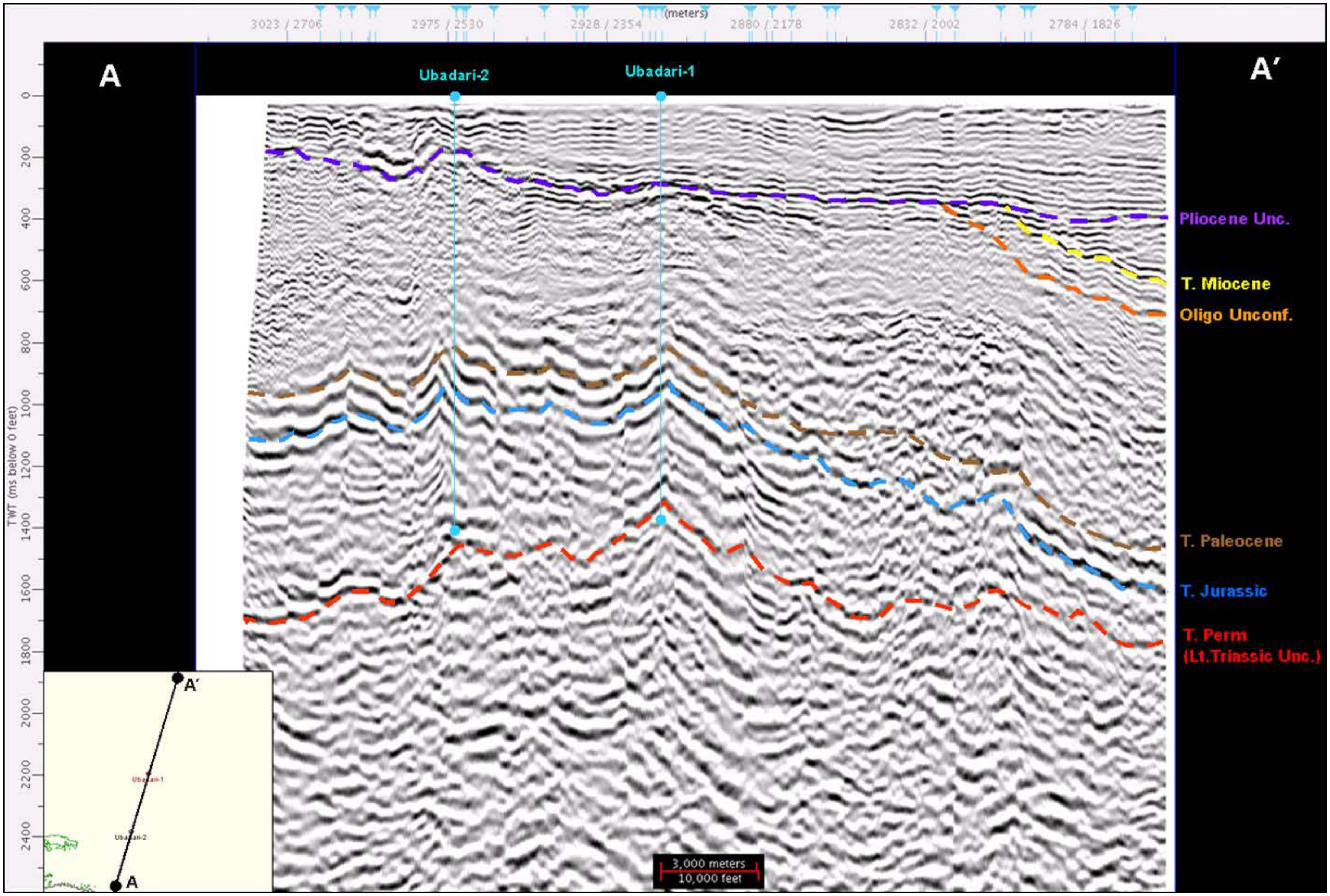

Figure 11. A-A' seismic transect, showing both Ubadari-1 and Ubadari-2 structures continued to grow after Pliocene time to produce the present day structural configuration.