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THE BIAK BASIN AND ITS SETTING IN THE BIRD'S HEAD REGION OF WEST PAPUA

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ABSTRACT

The Bird's Head region of West Papua is dissected by several major strike-slip faults, namely the Sorong, Ransiki and Yapen faults. Although the age and current activity of these faults is disputed, it is generally accepted that they were initiated within the last 23 million years. Several sedimentary basins, including the Biak Basin, filled largely by Cenozoic (mainly Neogene) carbonates, are found in close proximity to these faults, indicating a potential genetic link between faulting and basin formation.

The Biak Basin is situated between the islands of Biak and Yapen, north of Cenderawasih Bay. The basin fill consists of three sequences with bounding unconformities traceable across the wider Bird's Head region. These sequences form a complete megasequence that records changes in relative sea-level driven by uplift and subsidence within the region.

The lowermost sequence comprises island arc volcanics accreted to the northern New Guinea margin at the end of the Paleogene. The top is marked by a Lower Miocene angular unconformity that can be traced to basins in the Bintuni region to the west. The middle megasequence within the basin is composed of Lower Miocene platform carbonates possibly correlative with the Kais Limestone found in the Salawati Basin to the west. The final sequence is marked by an unconformity caused by diachronous regional subsidence across the northern Bird's Head that led to the drowning of localised carbonate platforms, including the collapse of the Kais Platform, and the initiation of strike-slip faulting. The movement along these faults has led to the formation of many of the modern sedimentary basins in the region.

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INTRODUCTION

The Biak Basin is a frontier region, located between the islands of Biak to the north and Yapen to the south, off the coast of West Papua in eastern Indonesia (Figure 1). The basin is bounded by faults of the Biak Array, a series of parallel NW-SE trending faults, to the northeast and the Yapen Fault to the south, but the relationship of these faults and the basin to the Ransiki and Sorong Faults to the west is unclear. The basin is filled with up to 7km of mainly Neogene strata.

The island of New Guinea is the remnant of part of the Australian Mesozoic passive margin (Hall, 2002; Hill and Hall, 2003). During the Paleogene this passive margin became the site of island arc-continent collision as it approached a northward-dipping subduction zone beneath the Caroline Sea Plate (Dewey and Bird, 1970; Milsom et al., 1992; Hall, 2002; Cloos et al., 2005) creating the Caroline Arc (Hill and Hall, 2003) which forms the basement to Biak and its basin.

During the Neogene, convergence of the Pacific with the Australian Plate was accommodated through contractional tectonics in the Central Range and by sinistral movement of newly developed faults in the region.

METHODOLOGY

This work is based on the results of several months of fieldwork carried out during two field seasons in 2011 and 2013 together with the results of seismic interpretation studies and biostratigraphic analyses.

Fieldwork was undertaken over a large area of Bird's Head's east coast and also the islands of Biak and Supiori to the north of Cenderawasih Bay. Samples collected during fieldwork were mainly carbonates which were sectioned and dated using biostratigraphic analysis of concurrent range zones in conjunction with Marcelle BouDagher-Fadel at University College London.

Multibeam bathymetry and a 2D seismic dataset of the Biak Basin was provided by TGS and analysed using IHS Kingdom seismic and geological interpretation software. In all, 48 seismic lines, covering an area of ~11,500 km^2 were examined on the nature of lapout of the upper and lower boundaries, truncation and internal configuration of reflections and amplitude strength based on the Ramasayer (1979) classification.

REGIONAL CORRELATION

The stratigraphy broadly north and east of the Ransiki and Sorong Faults on the Bird's Head can be correlated with that of Biak to the east (Figure 2). The Arfak Volcanics and Auwewa Formation are similar in their composition and age and constitute the Paleogene island arc basement to this area. These are unconformably overlain by Lower to Middle Miocene platform carbonates of the Imskin, Maruni, Kais and Wai Limestones and the Wainukendi, Wafordori and Napisendi Formations on the Bird's Head and Biak respectively.

The Lower to Middle Miocene platform carbonates then form part of a drowning succession that can be observed in outcrop (Figures 3 and 4). The platform carbonates are overlain by a repetitive succession of deep-water impure carbonate muds and shallow-water limestones that represent the drowning succession of which the base and top of this package marks the inception and completion of the drowning process (Marino and Santantonio, 2010). Alternating planktonic and benthic deposits formed on the platform shelf as carbonate production rates failed to keep pace with the rate of relative sea-level rise and subsequent influx of siliciclastic sediments onto the platform. The top of the sequence is marked by a drowning unconformity which marks the siliciclastic inundation of the platform by the deposits of the Pliocene Befoor Formation. Elsewhere across the region, the drowning succession is absent and the equivalent unconformity marks an abrupt change from carbonate facies below to siliciclastic facies above and this boundary is conspicuous in outcrops across the region (Figure 5). Sediments above this boundary form a condensed section which represents deposition outboard of the shelf margin where the basin was starved of sediment. Biostratigraphic dating of samples across this boundary reveals that much of the Late Miocene (Tortonian – Messinian) is missing. Deposition resumed in the Early Pliocene, or from the very latest Messinian (N18) at the earliest, corresponding to a hiatus of nearly 6 Myr (Figure 6).

This progression of basement island arc material, followed by platform carbonate then siliciclastic strata is laterally extensive and observed in well data from across the Bird's Head Region (Figure 2). The Auwewa Formation is interpreted to comprise the basement in the Iroran and Apauwar wells in the Mamberamo area (Wachsmuth & Kunst, 1986) and basement described as 'volcanic' is reported at the base of the succession from the O1 well east of Biak. It must be noted, however, that the basal unit of the succession within the Niengo 1 well is reported as greenschist, possibly correlating to the Korido Metamorphic unit found on the island of Supiori (Pieters et al., 1983).

The Lower to Middle Miocene carbonates can be correlated with those of the Kais Platform found in the Salawati and Bintuni basins (Decker et al., 2009; Phoa & Samuel, 1986; Gibson-Robinson, 1986) to the west. In wells in the Mamberamo area to the east they are correlated with the Darante and Sarmi Formation platform carbonates (Wachsmuth & Kunst, 1986; Pieters et al, 1983). The final sequence comprising the Befoor Formation is congruous with the change in deposition from carbonate to Klasafet/Klasaman siliciclastics coinciding with the collapse of the Kais Platform in the Salawati basin (Decker et al., 2009). In the east, Plio-Pleistocene siliciclastic strata of the Makats Formation and Members B-E of the Mamberamo Formation bury earlier platform carbonates (Wachsmuth & Kunst, 1986).

SEISMIC STRATIGRAPHY

These three unconformity bounded sequences seen in outcrop can be correlated with sequences observed in seismic data from within the Biak Basin. Sequences A-C were formed as a part of a megasequence recording the history of relative sea-level fall and rise in the basin (Figure 7a-e).

Sequence A

The oldest sequence, Megasequence A, comprises Paleogene island arc material of the Auwewa Formation and Arfak Volcanics derived from edge of the Pacific Plate. Collision of the Pacific arcs and the Australian margin in the Early Miocene caused folding of this material resulting in uplift and relative sea-level fall (Figure 7a). Subaerial exposure and erosion of this material produced a pronounced angular unconformity that can be identified in seismic data where there are erosionally truncated anticlines (Figure 8) with up to 820m of section missing in places. During this relative sea-level fall island arc material was eroded, transported and deposited as the Batu Ujang Conglomerate found in Wafordori Bay on Biak.

The folded strata in the Biak Basin are correlatable with structures identified in the Tangguh Gas Fields within the Bintuni Basin. Here, folding is truncated by an angular unconformity prior to the deposition of the Lower Miocene Kais Limestone (Keho and Samsu, 2002). It is interpreted that this regional deformation ended in the Late Oligocene by 25 Ma (Keho and Samsu, 2002).

Sequence B

Following the relative sea-level fall, Sequence B was deposited during an ensuing marine transgression (Figure 7b). The sequence began with the deposition of platform carbonates during a period of slow transgression in the Early Miocene (Figure 7b) when platform margin stacking was aggradational. Outboard of the platform, deposits shed from the shelf margin were deposited basinward and are identified by chaotic reflections onlapping the slope profile. By the Middle Miocene the rate of transgression increased, and backstepping of carbonate platforms and growth of pinnacle reefs in the region may have been a response to this (Figure 7c, Decker et al., 2009). The platforms were subsequently drowned beneath the drowning unconformity which is marked by a sharp change from carbonate to siliciclastic deposition.

In seismic data the drowning unconformity is marked by high amplitude reflections due to the change in acoustic impedance of the different facies above and below this boundary and downlap onto this surface by the sequence above (Figure 9).

Within seismic sections the drowning succession observed in outcrop cannot be identified as it is only approximately 10m thick. The drowning unconformity is identified by the ‘U’ Marker, a conspicuous horizon which is easily recognised in seismic and logs within the Salawati Basin (Gibson-Robinson and Soedirdja, 1986).

Sequence C

The final Sequence C comprises entirely siliciclastic deposits above the drowning unconformity. Deposits from this sequence include clinoforms that downlap onto this boundary and prograde along the former platform top. Slope apron deposits and mass transport complexes fill the basin.

CONCLUSIONS

The basement rocks of the Biak Basin formed in an arc setting in the Caroline Arc during the Paleogene. It was brought close to northern New Guinea by subduction of oceanic crust north of the Australian passive margin by the Late Oligocene. The accretion of parts of the Caroline Arc to the northern New Guinea margin resulted in the folding, uplift and exposure of arc material forming the sequence boundary at the base of Sequence B.

The Sequences described above may represent individual systems tracts, where Sequences A, B and C equate to Lowstand, Transgressive and Highstand Systems Tracts respectively (Figure 7a-e). The Transgressive Systems Tract of Megasequence B was formed during widespread carbonate deposition in the Early to Middle Miocene. Deposition occurred in the Salawati and Bintuni Basins up to the Biak Basin which may have been situated further east than its current position. The backstepping and subsequent drowning of carbonate platforms in Sequence B can be correlated with the drowning of the Kais Platform carbonates (~5-7 Ma) in the Salawati and Bintuni Basins. These basins have proven oil and gas reserves from the Kasim and Walio oil fields, and Tangguh gas field.

In the Salawati Basin the event overlying the Kais Limestone marking a sharp change in deposition from carbonates and marls to the siliciclastics of the Klasafet and Klasaman Formations is termed the ‘U’ Marker (Gibson-Robinson and Soedirdja, 1986) The stage between the ‘U’ Marker and Kais Limestone, termed the ‘U’ Interval or Lower Klasafet Formation (Gibson-Robinson and Soedirdja, 1986), may mark a contemporaneous drowning succession and condensed section in the Salawati Basin.

The time of the drowning of the Kais Platform is thought to coincide with the initiation of the Sorong Fault Zone, an active, broad zone of inferred sinistral shear that runs approximately 800km from New Guinea in the east to Sulawesi in the west. The organic-rich clays of Sequence C may have originated as deposits of the Mamberamo Delta at least 260 km to the east of the present location of the Biak Basin. The basin may have been translated westward to its present position by action of the Sorong Fault Zone. This implies a rate of slip of between 37-52mm/yr for the Sorong Fault Zone since the Pliocene.

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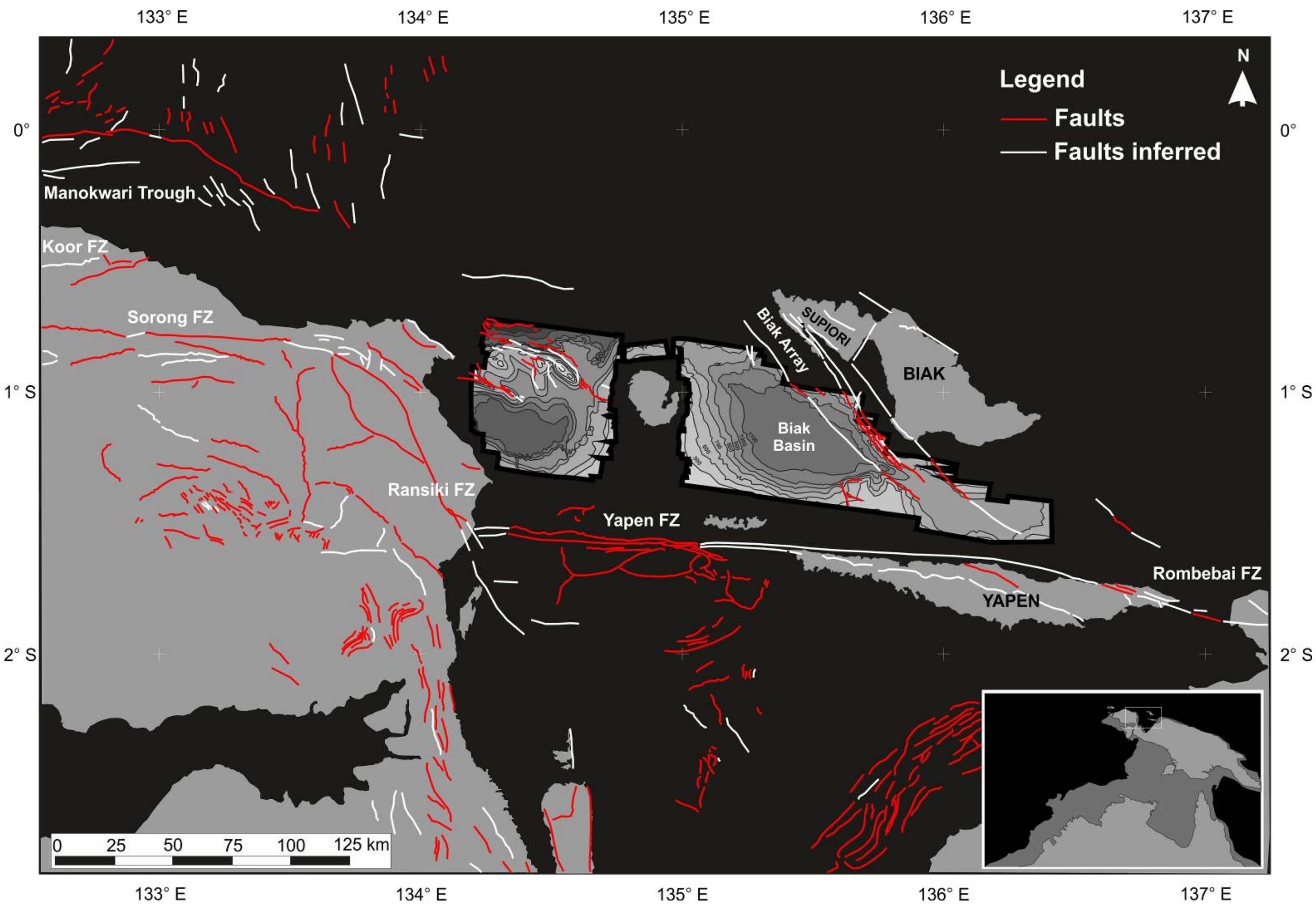

Figure 1 - Major fault zones and position of Biak Basin in the north-eastern Bird's Head interpreted by ASTER topographic, GLORIA sonar and multibeam bathymetric data (modified from Milsom et al., 1992).

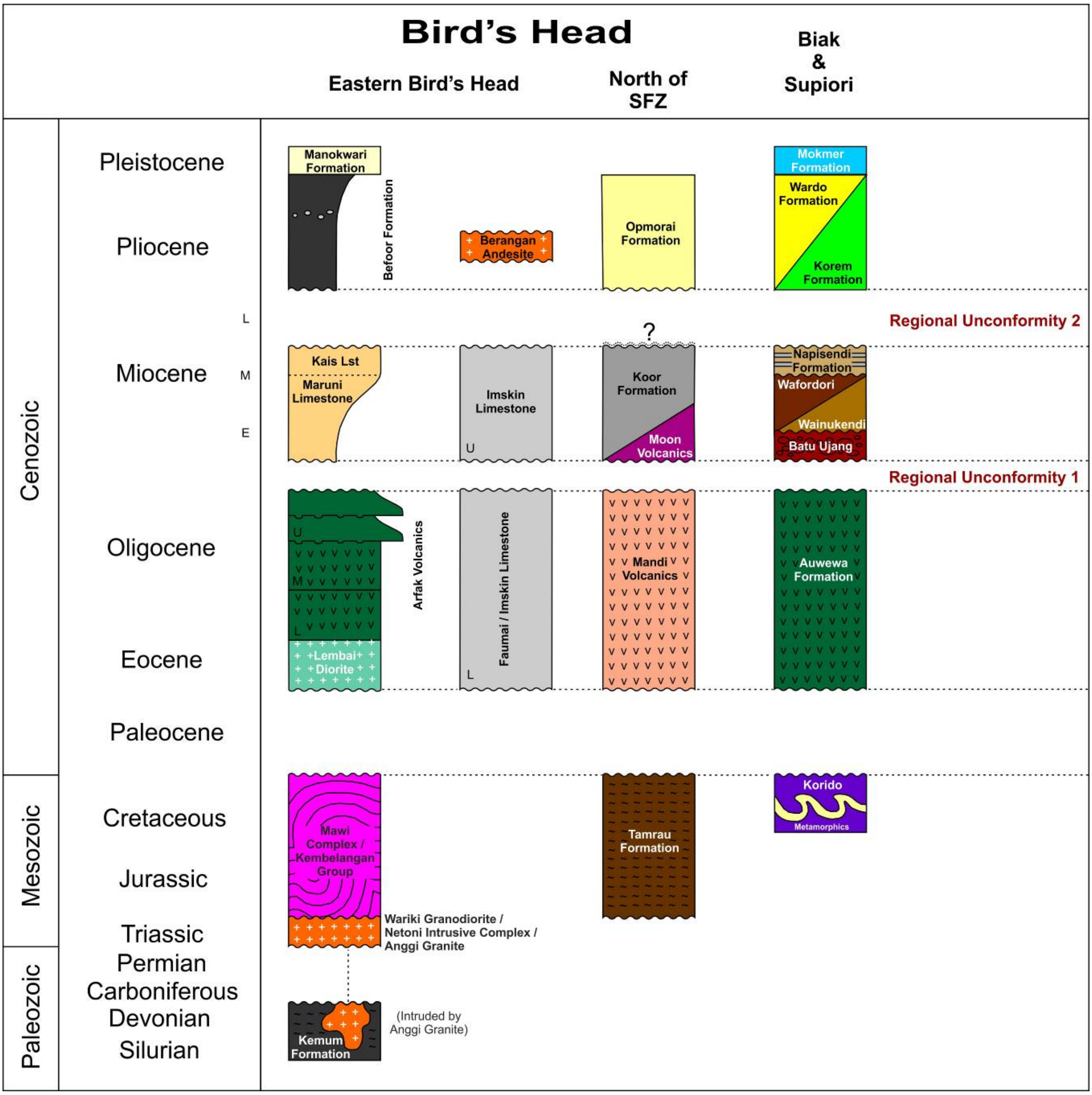

Figure 2 - Stratigraphy of Biak and the northeastern Bird's Head.

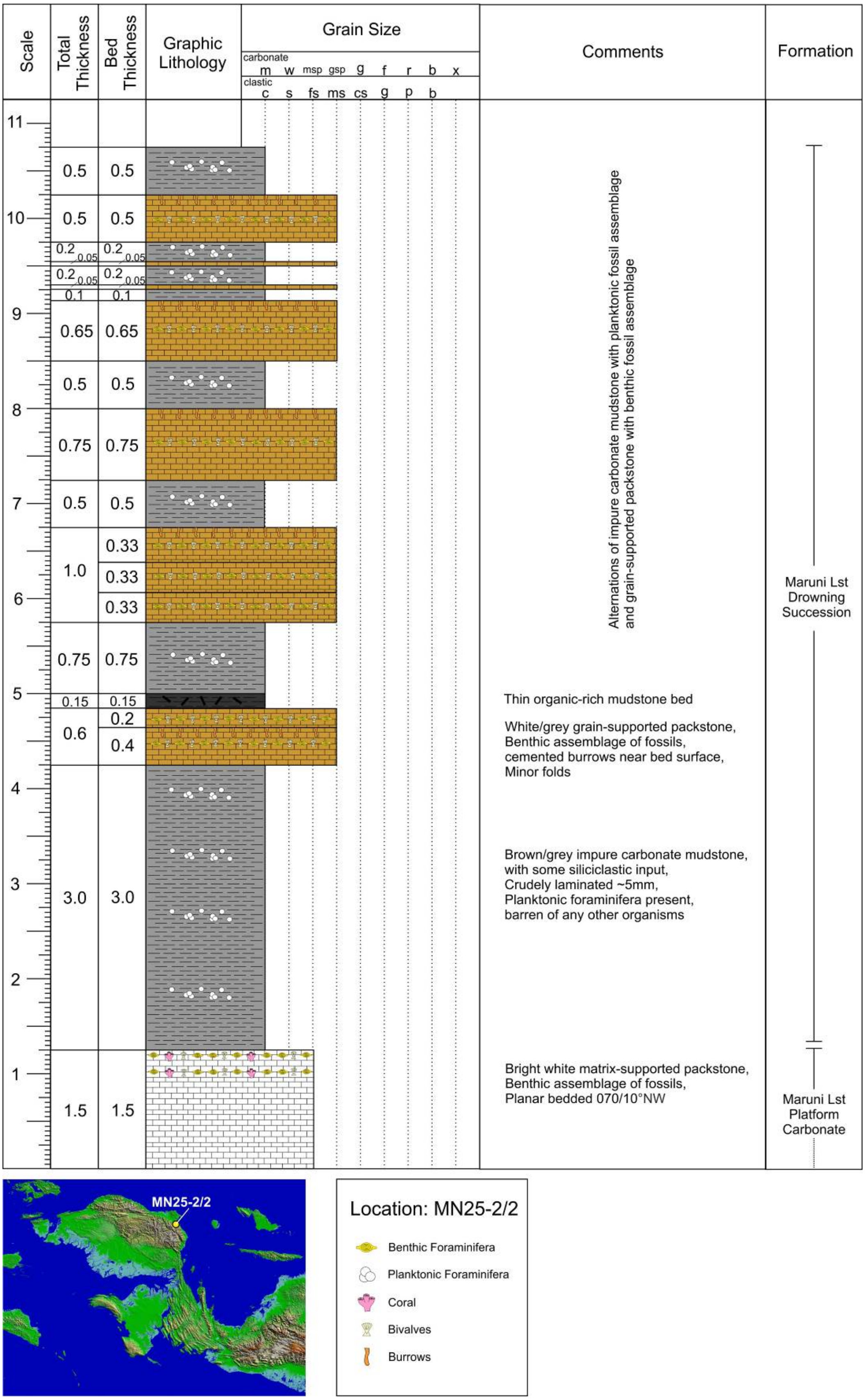

Figure 3 - Graphic log of drowning succession at Locality MN25-2/2.

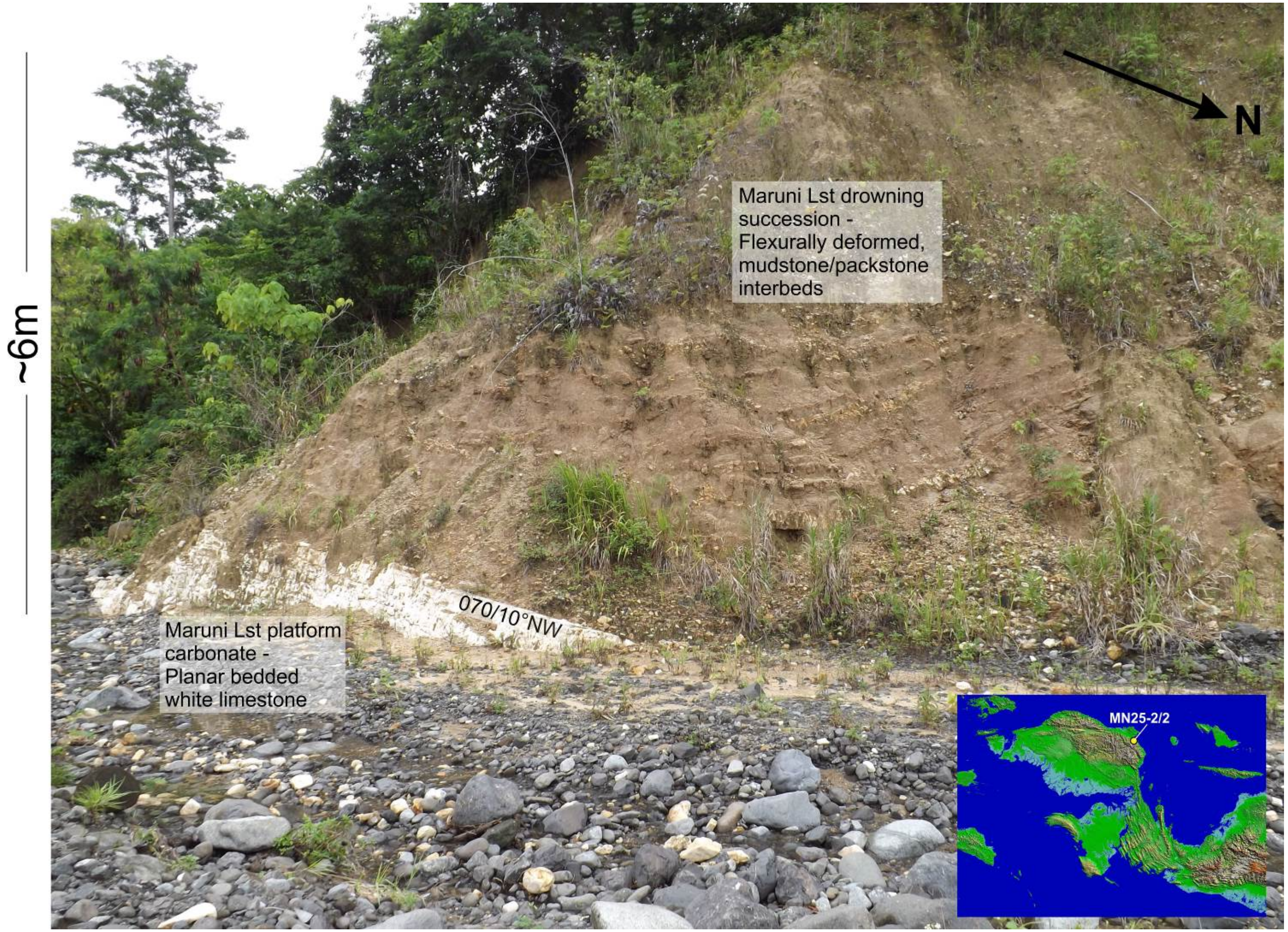

Figure 4 - Drowning succession observed in outcrop at MN25-2/2.

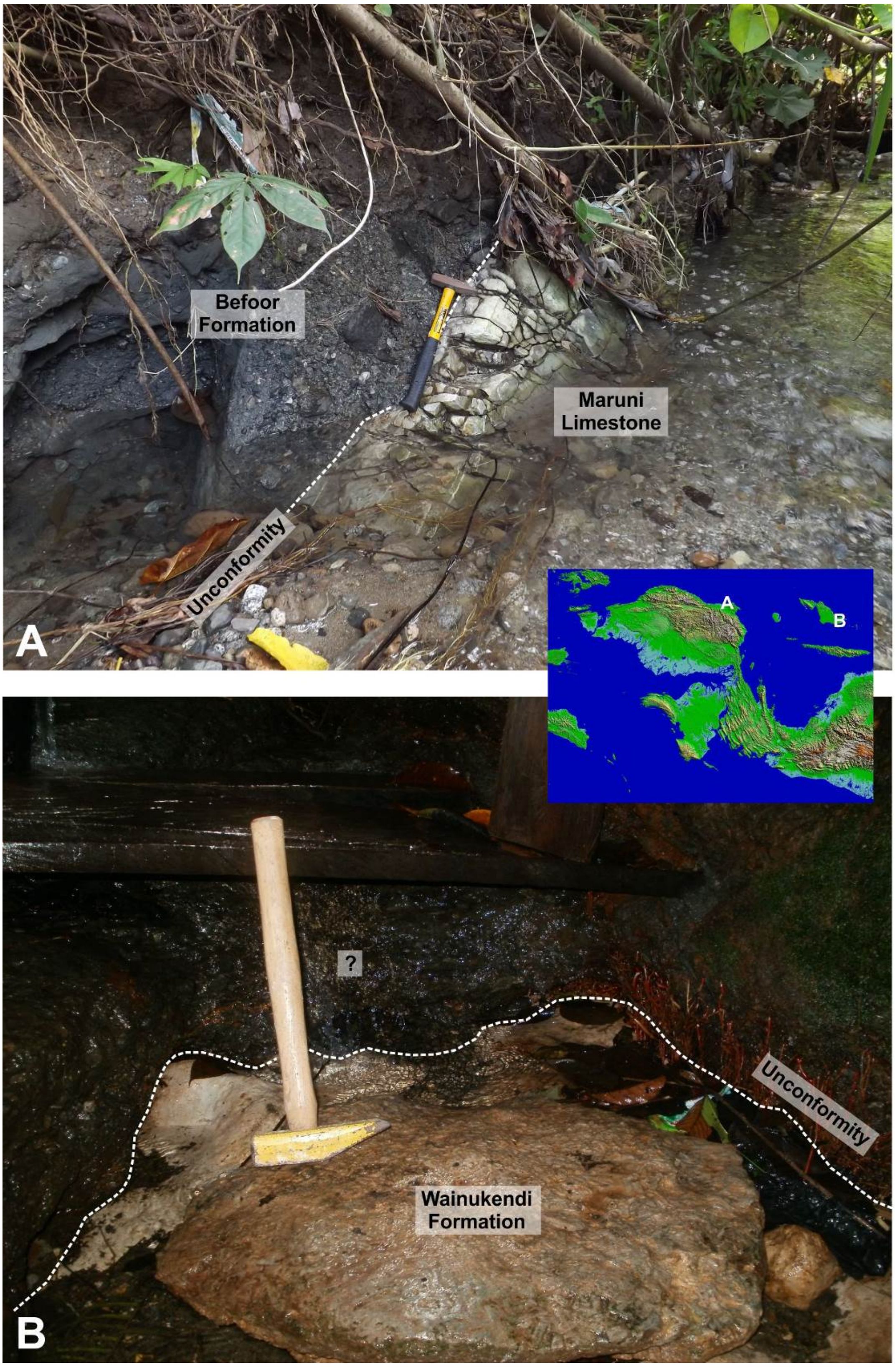

Figure 5 - Unconformities on the Bird's Head (A) and Biak (B).

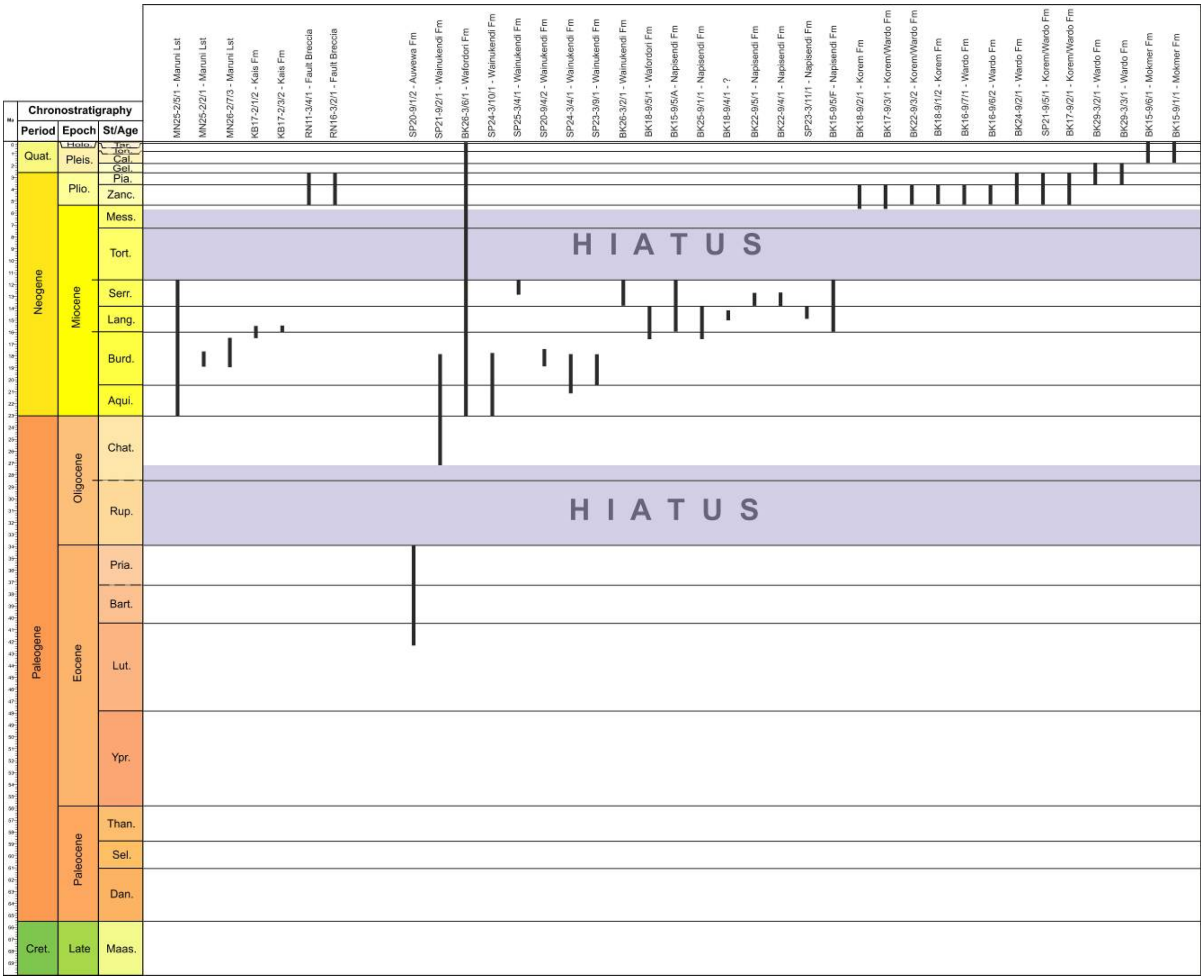

Figure 6 - Biostratigraphy of samples from Biak and north-eastern Bird's Head suggests a Lower Oligocene hiatus of approximately 7 Myr and an Upper Miocene hiatus of approximately 6 Myr. Sample BK26-3/6/1 contains long ranging genera that could have been deposited at any point within given time range.

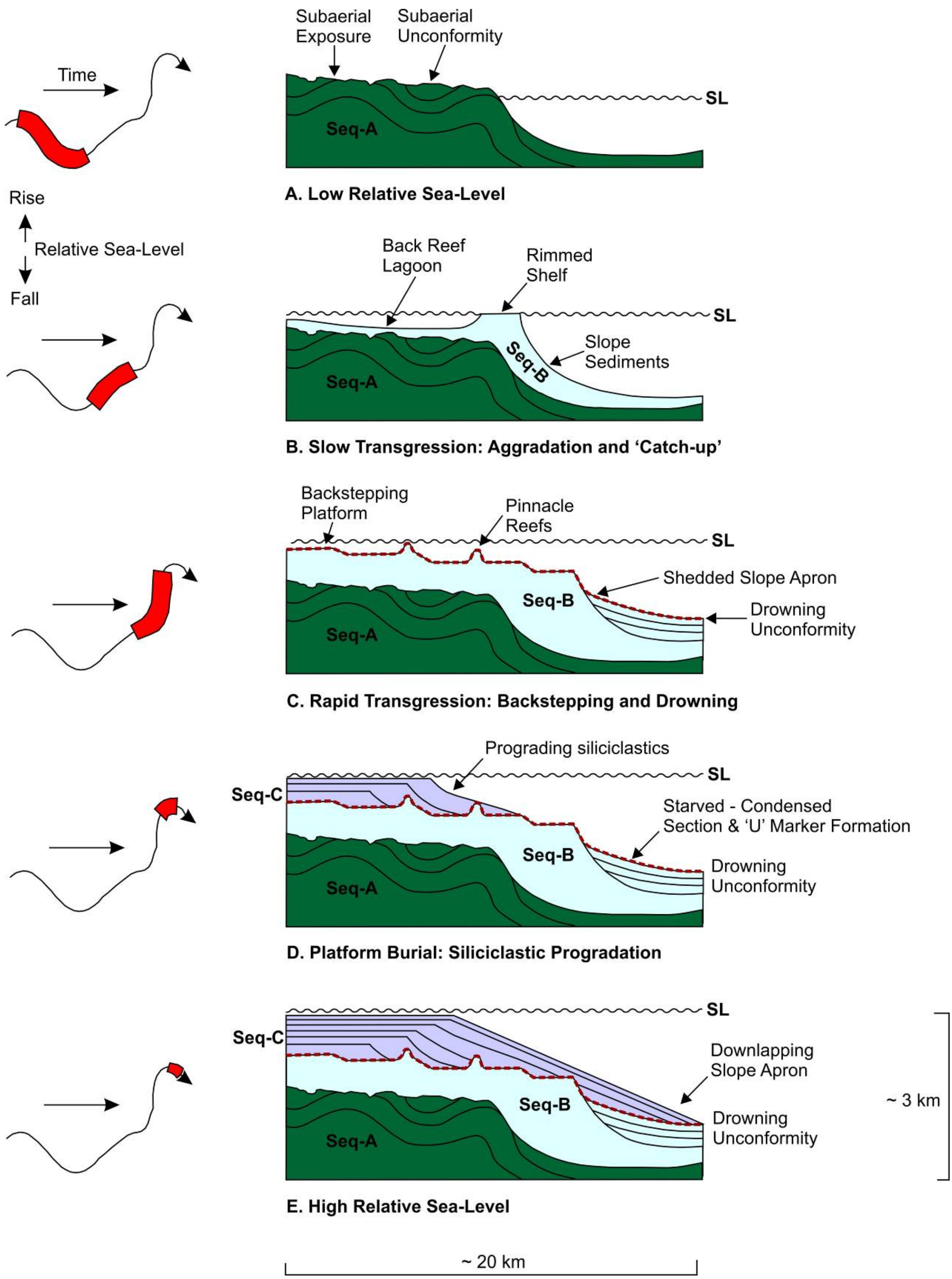

Figure 7 - Schematic sequence stratigraphy of the Biak Basin (modified from Catuneanu, 2013).

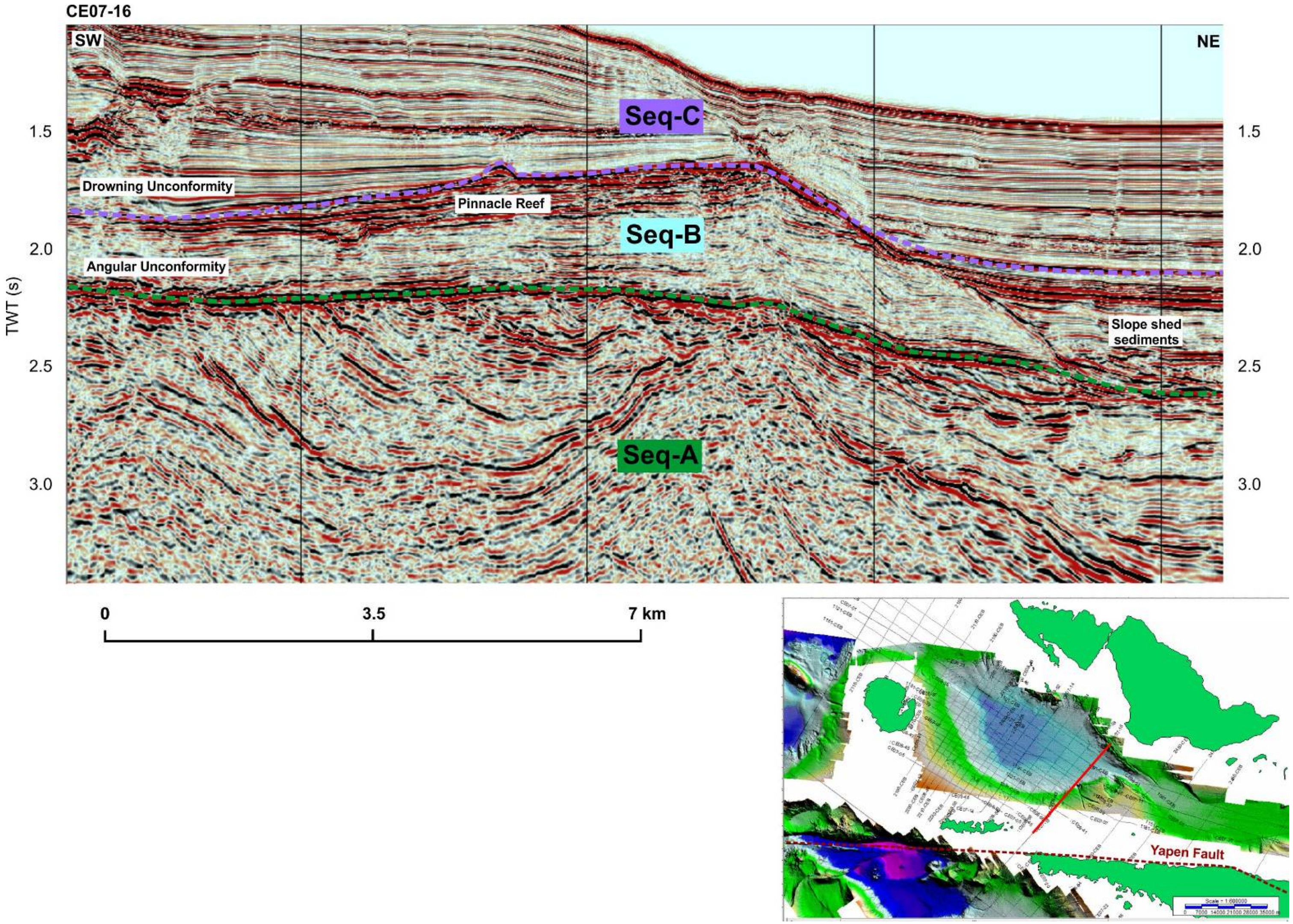

Figure 8 - Striking angular unconformity showing erosionally truncated folded unit of Sequence A beneath succeeding sequences.

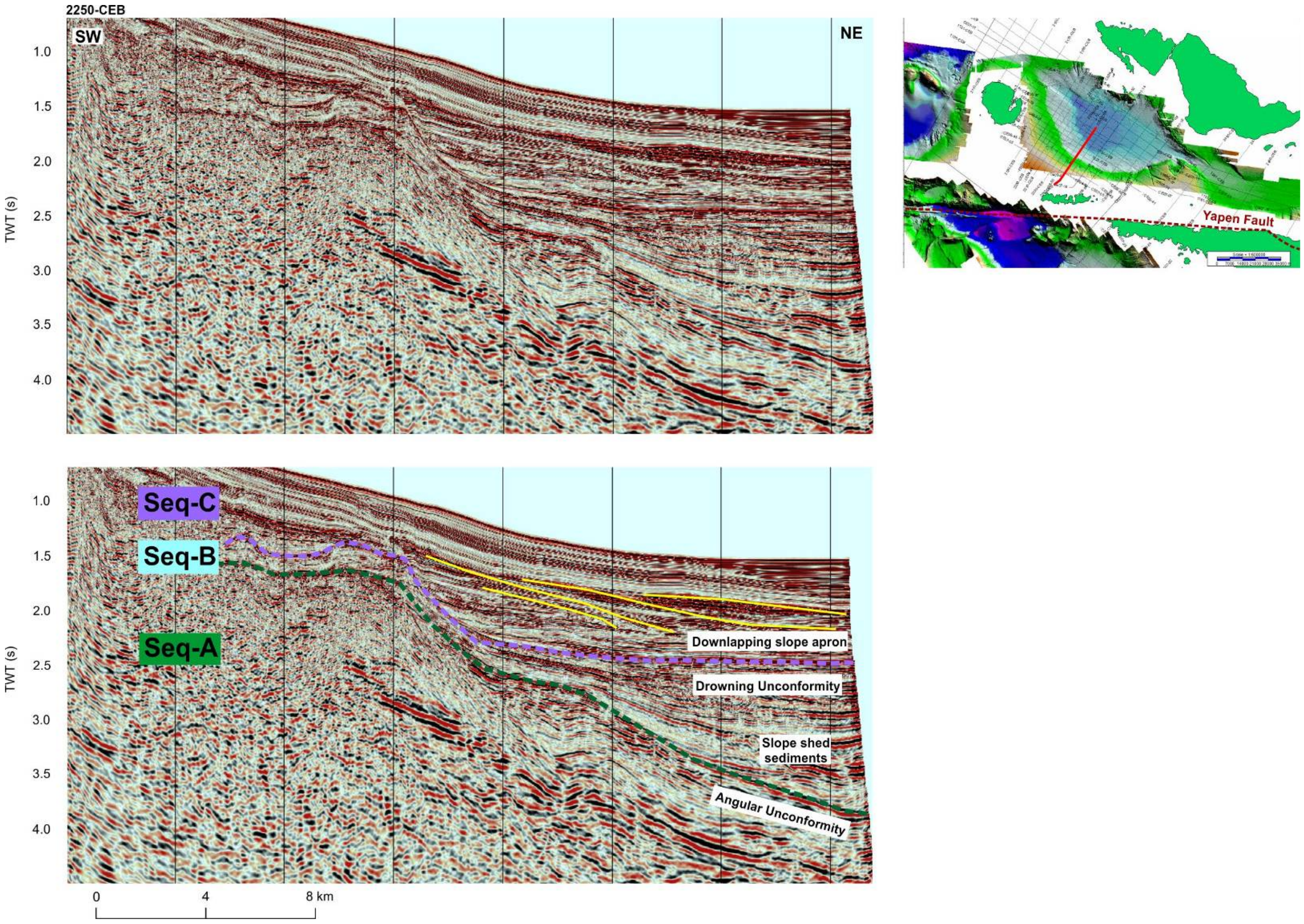

Figure 9 - Seismic line showing complete succession from the folded strata and angular unconformity above Sequence A, transgressive carbonate shelf capped by drowning unconformity of Sequence B and downlapping units of Sequence C.