Seismic Expression of the Timor-Tanimbar, Eastern Indonesia

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Introduction

The Timor-Tanimbar Trough is an oceanic trough, which is an eastern continuation of the Sunda Trench. It marks the boundary between Indo-Australian Plate's continental shelf and the Timor Plate in the north. The trough is located in the south of Timor Island and is called the Timor Trough with WSW to ENE orientation. Further east, the trough orientation changes to SW-NE and is called Tanimbar Trough.

A number of seismic lines across Timor-Tanimbar Trough have recently been published by different authors in several publications. Five of those seismic lines which provided regional geological understanding of the southern part of Banda arc, are discussed in this paper (Figure 1). These seismic lines provide a better geological understanding of the area after Hamilton published regional seismic lines in 1979. In this paper, consistent stratigraphic nomenclature has been applied to these key seismic lines. This will help to understand the regional geological process in chronological order.

From west to east, the coverage of the sections published in this article are as follow:

- **Section 1:** West part of Timor trough, published by Jones et al (2011; Figure 2);
- **Section 2:** East part of Timor trough to Australian Platform, published by Lee and Bawden (2011; Figure 3);
- **Section 3:** A regional older section, which provides a regional understanding of the tectonic in the area, is published by Hamilton (1979; Figure 4);
- **Section 4:** South of the Tanimbar trough, published by Carter at al. (2003; Figure 5);
- **Section 5:** A regional section across the northern part of Tanimbar trough published by Dinkelman et al, (2010; Figure 6), with details which is published by Roberts et al (2011).

This article discusses the observations of these seismic lines, but the alternative interpretations are quite limited, for the lack of access to the original data. Seismic-to-well tie is not explained in the source of these seismic sections, and it will not be discussed in this paper

Stratigraphy

The stratigraphic nomenclature used in this article, refers to the chart published by Jones et al (2011) after Charlton, 2006 and Edwards et al, 2004 (Figure 7). The key stratigraphic information in this area is taken from Timor Island outcrops and a number of wells in the Australian side of Timor Sea. The stratigraphy chart only goes as old as Permian and doesn't cover the Carboniferous to Precambrian interval indicated in the south of Tanimbar trough.

Five seismic markers, which are commonly used in the sections, are added into the stratigraphic chart. These markers are Top Permian, Top Triassic, Darwin, Turonian and Base Cenozoic. All horizons, apart from Darwin horizon, are related to major unconformities caused by tectonic events.

The outcrops in West Timor are not easily tied to the offshore seismic in the trough, because seismic correlation across the accretionary complex is very difficult. Complex fault system has disturbed the seismic reflectors as shown in Figure 2 (for an example).

In the stratigraphic chart (Figure 7), Triassic and lower Jurassic with sand dominating formations, are existing in Bonaparte Basin and part of West Timor. The Lower Cretaceous interval is dominated by a shaly formation of Wai Bua Nakfunu Formation in West Timor and Echusa Shoals Formation in Bonaparte Basin. Carbonate sequence developed well in most of the area during the Lower Tertiary. Neogene formation does not exist in West Timor due to tectonic uplift in the area.

Timor Trough

The Timor Trough is located in the south of Banda Arc with water depth up to 2000 meters. In this area, the Australian plate is subducting northward below the Asian Plate and generating an accretionary complex. Part of this complex is exposed in Timor Island. Several model of the tectonic system in this area has been discussed by Richardson and Blundell (1996).

Two sections represent the Timor Trough in this article. Section 1 is located the south of West Timor (Figure 2), published by Jones et al, 2011. This section mainly shows the structure and stratigraphy in the middle of the trough with a little part of Ashmore Platform in the south and part of the accretionary complex in the north. The water depth in this area reaches 3 seconds two-way-time.

Permian unit is the deepest interpreted interval in this section (Figure 2). In the south, the Permian interval comes as shallow as 4 seconds. The intra Permian seismic reflector

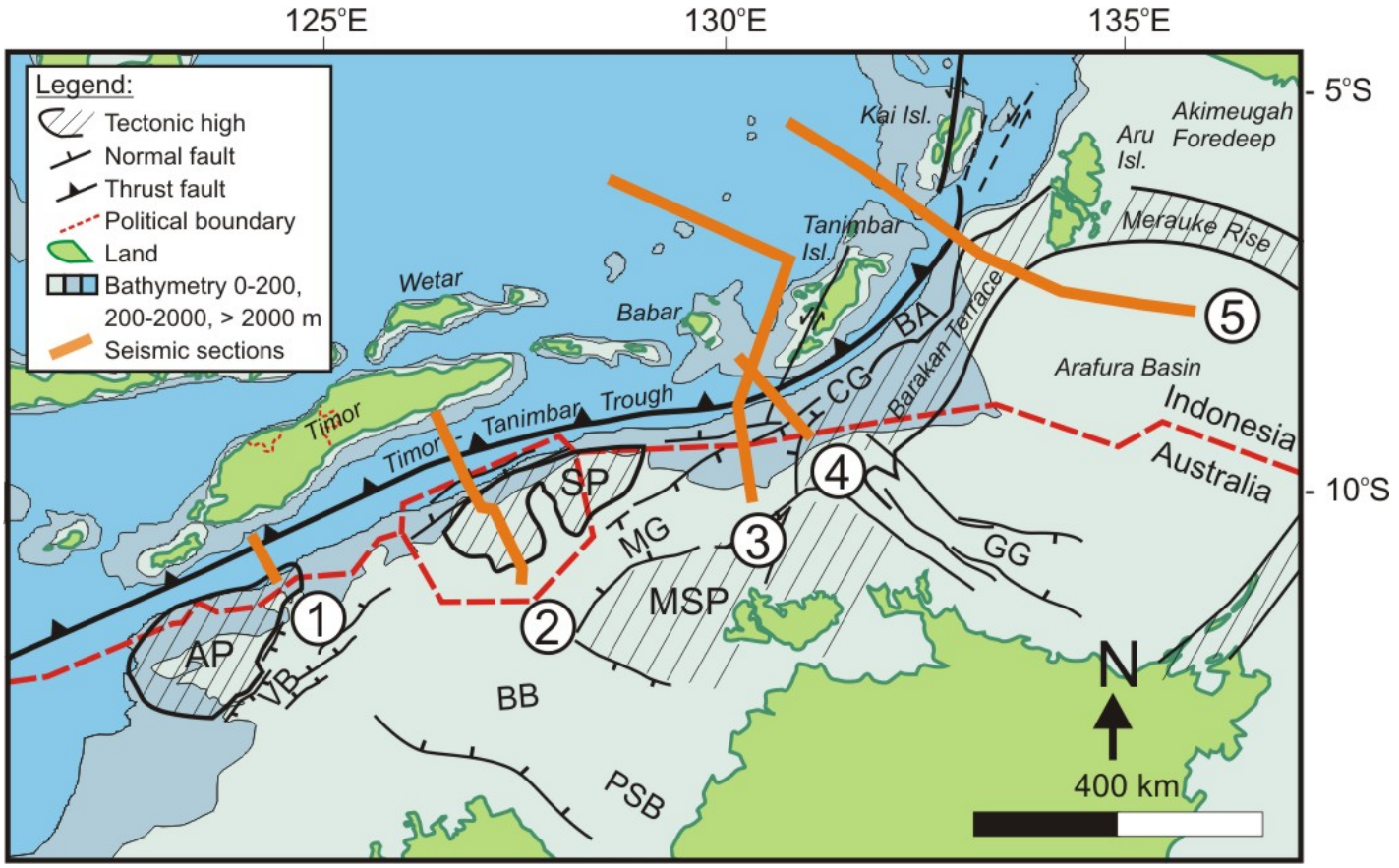


Figure 1. *Map of the Timor-Tanimbar Trough showing the location of seismic sections discussed. AP = Ashmore Platform; SP = Sahul Platform; VG = Vulcan Graben; MG = Malita Graben; CG = Calder Graben; GG = Gouburn Graben; MH = Mereuke High; MSP = Money Shoal Platform; BA=Barakan Basin; BB = Bonaparte Basin. Modified after Charlton, 2004 and Carter et al., 2003.*

is generally clear in the south but they are poorly imaged in the middle of the section.
The Triassic unit is very thick compare to other sections discussed in this paper. Towards the centre of the trough, the Triassic section is up to 2.6 seconds. This unit is sub-divided into three units by the base Chalis and Pollard Formation horizons. These nomenclatures come from Bonaparte Basin stratigraphy chart shown in Figure 7.

A series of normal faults cut through the Permian and Triassic section in the south of the section. These faults generated a series of horst and graben in the Permian section. The south and north heading faults cut each other in the Triassic section in the Triassic interval with minor offset. In other sections these faults formed hourglass structure pattern as discussed in detail by Çiftçi, N. B. & Langhi, L. (2012).

In the south of Section 1, the seismic reflectors of the Triassic unit has been truncated, indicating an erosional process which formed an angular unconformity. This phenomenon is probably caused by a tectonic uplift related to the Ashmore Platform, which is started in Late Triassic (Carlton et al, 2012, this volume).

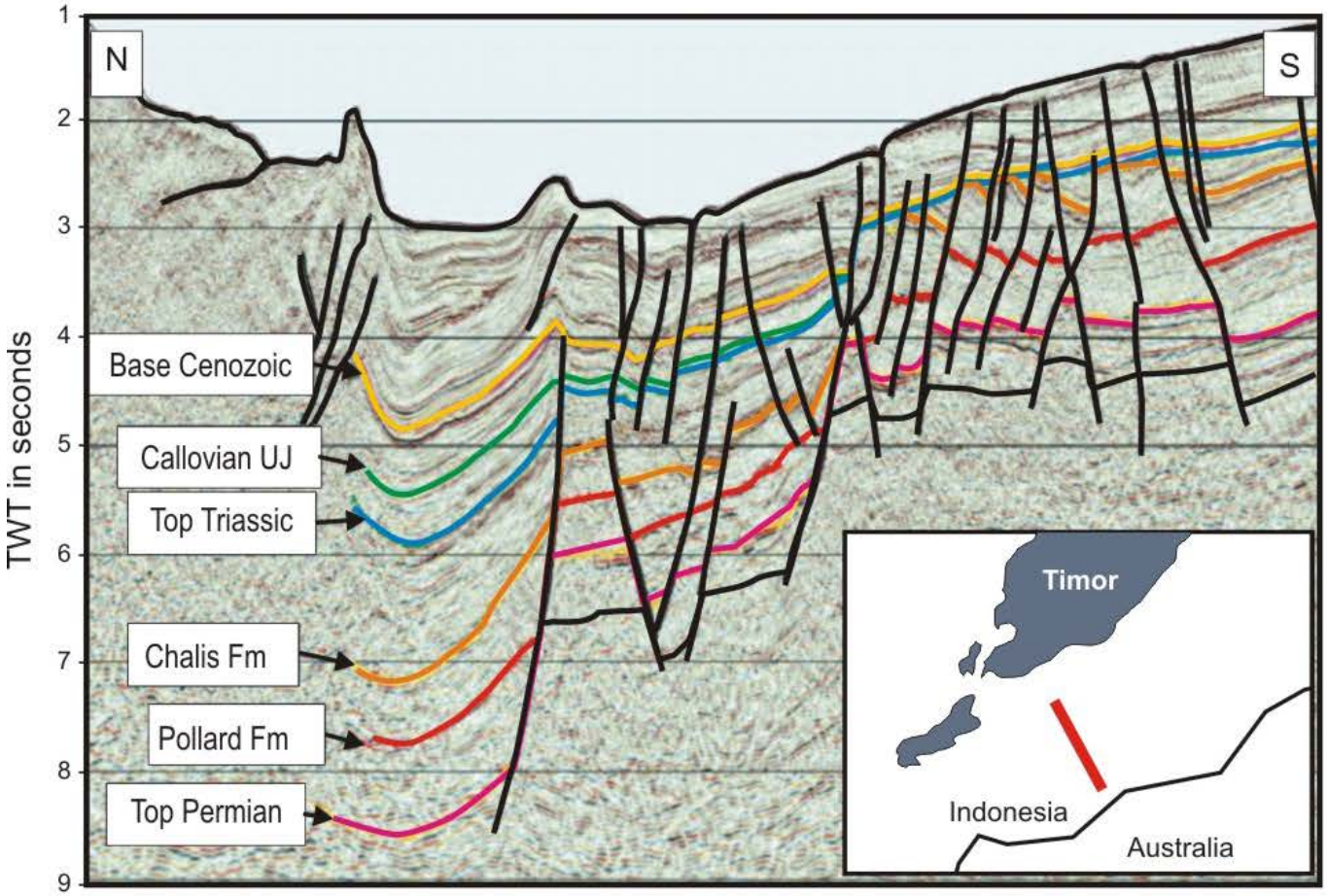
The majority of Jurassic and Cretaceous unit is not existed in the south of Section 1. To the north the Jurassic unit in Section 1 is gradually thickening towards the centre of the trough. The Cretaceous unit also only appears in the trough area, but there is no significant thickening is seen on the seismic section. Possibly the sediment transport direction is perpendicular to Section 1.

The Cenozoic section in Section 1 is also thickening towards the trough. A number of faults has gone through this unit and go up to top of section, creating some sea bottom expressions. The thrust fault in the north of this section has created a significant sea bottom relief (Figure 2).

In the east of the Timor Trough, longer Section 2 shows more of the accretionary wedge and the tectonically stable Sahul Platform (Figure 3). Similar to Section 1, Lee and Bawden (2011) started their interpretation with Permian interval. Below the base Permian interval, however, a number of continuous reflectors are still well observed. These reflectors are probably belong to Carboniferous or older stratigraphy.

The overlain Triassic unit in Section 2 is relatively constant in its thickness (Figure 3). Carlton (2012, this volume) indicates an early development of Sahul Platform in late Triassic. Unfortunately this section is not detail enough to support this model, but the thickness changes of the overlain Jurassic unit to the south and north may support it.

A major northward dipping fault in edge of the Australian Shelf generates an offset of nearly 1.5 sec. TWT at the lowest part of the section. Poorly imaged seismic downthrown of the fault makes the correlation across the fault difficult. This major offset is also seen in Section 1 (Figure 2) at the similar position of the trough.



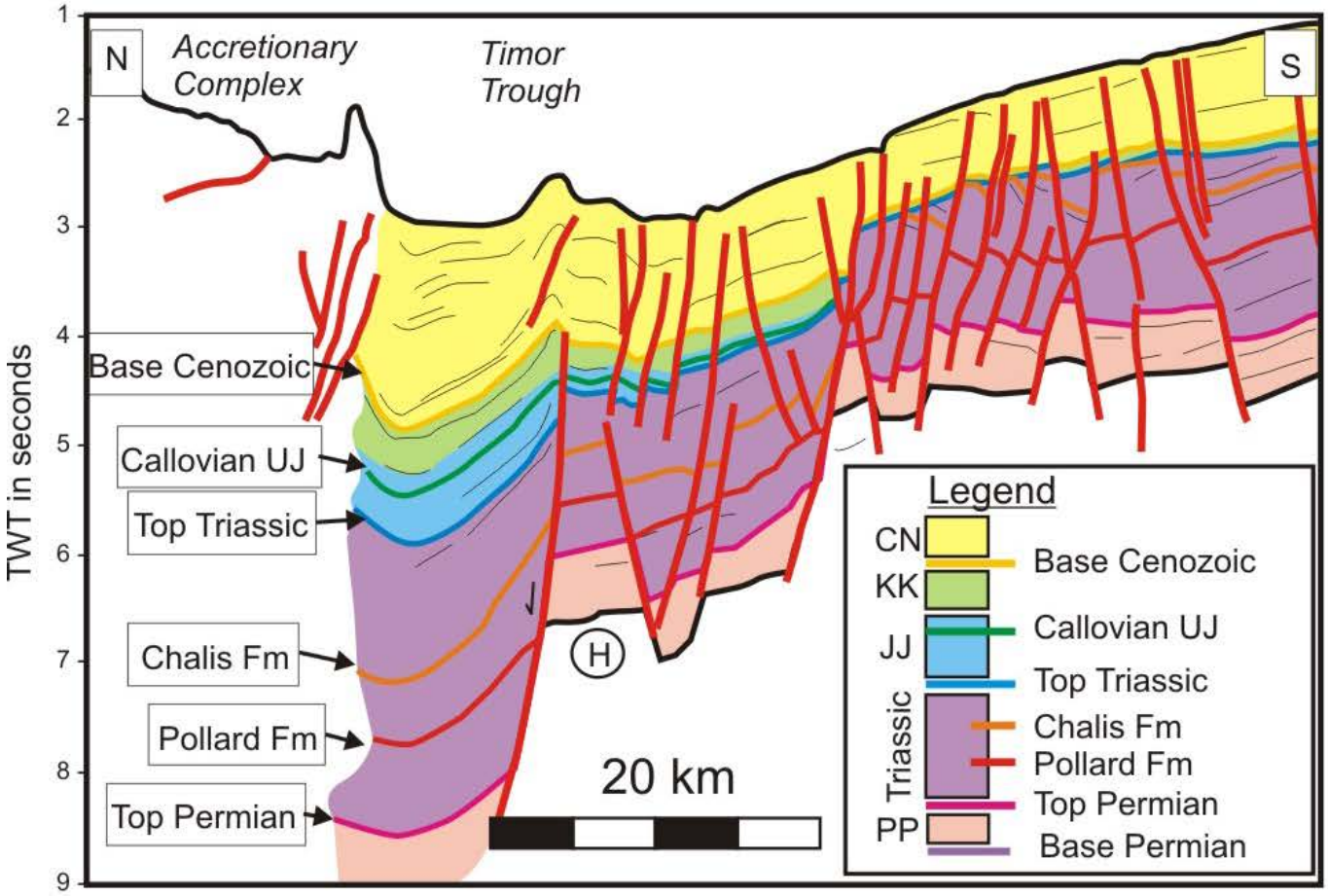


Figure 2. *Seismic Section 1 of the western part of Timor Trough after Jones et al, 2011. "H" marks the western most horst observed on this section.*

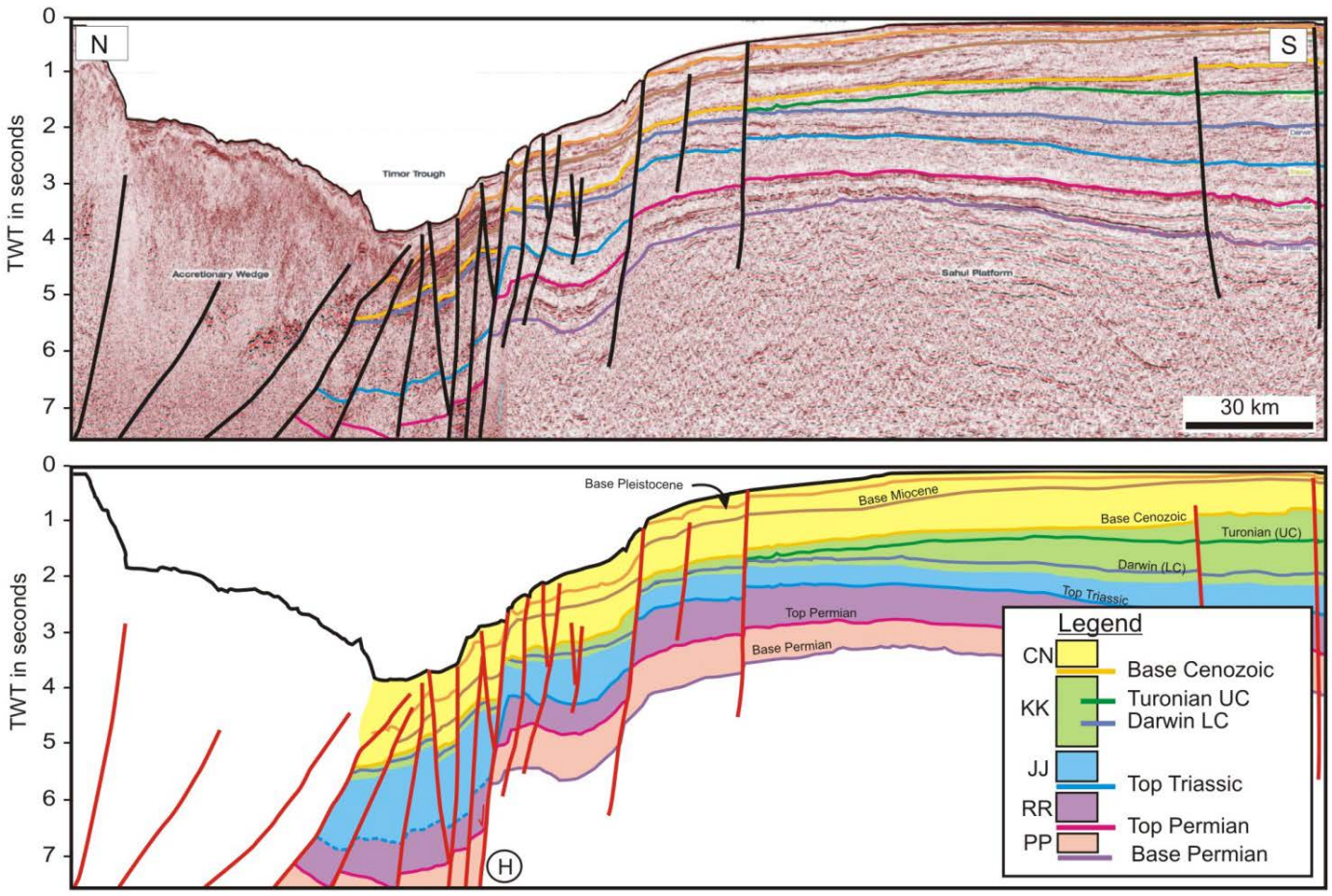


Figure 3. Seismic Section 2 of the eastern part of Timor Trough after Lee and Bawden (2011). This section also shows the accretionary wedge in the north and the Sahul Platform in the south.

The Cretaceous unit in Section 2 (Figure 3) shows a gradual thinning towards the trough. In the proximal part, Lee and Bawden (2011) sub-divided the Cretaceous interval into 3 subunits by the Darwin and Turonian horizons. The Darwin Formation is ranging from Valanginian to Aptian in age. The horizons in Section 2 indicate the top of the formation. This formation is dominated by shale. Edwards et al (2004) called this interval Echusa Shoals Formation in the Bonaparte Basin. In West Timor this formation is equivalent to Wai Bua Nakfunu Formation. The top Darwin horizon is also a marker of the hiatus above Echusa Shoals Formation and close to the top of Wai Bua Nakfunu Formation.

Tanimbar Trough

The eastern extension of the Timor Trough goes to the south of Tanimbar Islands and so it is called the Tanimbar Trough. The orientation of the trough has changed to SW-NE orientation and it is narrower than the Timor Trough. The maximum water depth in this area is also up to > 2000 meters. The water depth in Section 4 and 5 (Figure 5 & 6), are about 2.5 sec. TWT.

Section 3 (Figure 4) shows a regional setting from Australian Continental Shelf to the Weber Basin, published by Hamilton (1979). The water depth is gradually deepening from south to north. In the north part of the section, the water depth is getting shallower in shorter distance towards the Tanimbar Islands. This steeper slope is generated by the subduction process. Further to the north, the section goes through the outer arc basin, and it is called the Weber Basin. The deepest part of the basin reaches 7 km of water depth. The seismic reflections in the Australian Continental Shelf are clearer than the rest of the section because the shelf is tectonically less disturbed. The Tanimbar Island complex is caused by complex faulting mechanism. And in the south of Weber Basin, a recent accommodation space has developed in a water depth of 4-5 km, as shown by the flat seabed.

Carter et al. (2003) has interpreted Precambrian to Carboniferous interval at the base of Section 4 (Figure 5). This unit is the deepest observed stratigraphy in this article. The shallowest Carboniferous unit is observed in the northern part of Abadi High, about 4 sec. TWT deep. The seismic section shows a missing section and it probably happened due to tectonic uplift and erosion in the SE of this fault block. The seismic reflector of the base of Ordovician unit is not well defined in this section. However, Carter et al (2003) has interpreted SE ward thickening in the Calder Graben and the east most part of this section. In Calder Graben, the Ordovician section varies from 0.6 to 1.7 sec. TWT. In the NW of Calder Graben this section has small variety of thickness change and in Tanimbar trough this unit is only 0.5 sec. TWT thick or less.

Minor Permian and Triassic interval have been interpreted by Carter et al (2003) in the northwest of Section 4. The missing Permian to Triassic interval in the southeast of Section 4 is not well explained. Charlton (2012, this volume)

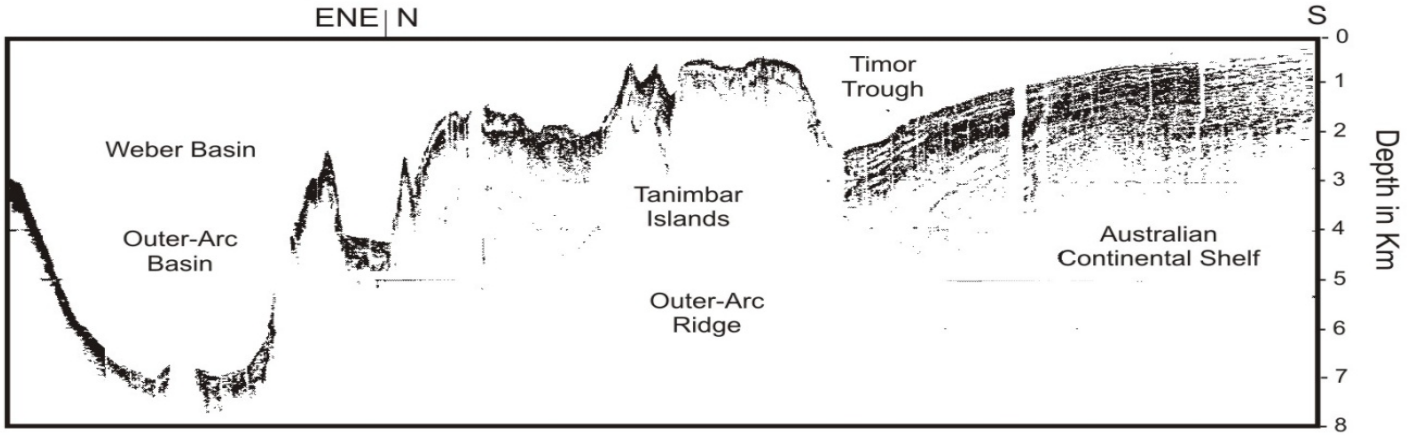


Figure 4. *Seismic Section 3, a long regional seismic section covering Australian Continental Shelf in the south to Weber Basin in the outer Banda Arc, published by Hamilton (1979). The quality of the seismic is poor for detail stratigraphic interpretation but it clearly shows the major tectonic unit in the region such as the Tanimbar outer-arc ridge and Weber outer-arc basin which is almost 8 km deep.*

indicates a major NNE-SSW sinistral lateral fault in this area during Permian. This may explain the missing Permian to Triassic interval in the majority of Section 4 (Figure 5).

The Jurassic interval covers Section 4 entirely (Figure 5). Carter et al (2003) interpretes thicker Jurassic interval in the Calder Graben, in southeast and thinner unit in the northwest. The fault pattern in Section 4 has indicated that the faults have created a local depression in Calder Graben and generating an accommodation space for the Jurassic unit. The faults work in a similar way for the overlain Cretaceous unit. In the south of the Northern Abadi High, the Cretaceous unit is about 1.5 msec TWT and in the north of the high it changes to < 0.5 sec. TWT.

Above the Cretaceous unit, the Cenozoic interval covers the entire Section 4. The Cretaceous interval is gradually getting thicker towards the trough. In the SE of the section, the thickness of this unit is about 1.2 sec. TWT and is changing to 2 sec. TWT in the centre of the trough.

A regional seismic section goes across the north of the Tanimbar Trough (Figure 6A), showing the relationship of the Arafura Basin, the Tanimbar Trough and the accretionary wedge complex in the west. In Section 5A, Dinkelman et al. (2010) shows the pre-Cambrian Wessel Group and Mc Arthur Basin in the north of Tanimbar Trough. These two units can reach up to 25 km in the south of the Arafura Basin. Base on Arafura-1 well and outcrops in Wessel Islands, Struckmeyer (2006) describes these units as consist of mainly shallow marine sandstone, siltstone and mudstone with minor conglomerate and carbonates.

A detail section of the regional section in Figure 6A is published by Roberts et al (2011), shown in Figure 6B. The interpretation of this section is based on the horizons used in Figure 3, where both have similar section of the Australian shelf. The interpretation of this section is started with Permian unit which underlain the SE part of the section. The overlain Triassic unit has poor seismic reflectors in the ESE part of the section.

An insignificant thickness change is observed from Jurassic to Cretaceous interval as seen on Section 5. It is very clear in the section (Fig 6B) that the Australian Shelf goes below the Tanimbar accretionary complex. The Jurassic interval is about 0.3 to 0.5 sec. TWT and the Cretaceous interval is divided by Darwin and Turonian as displayed in Section 2.

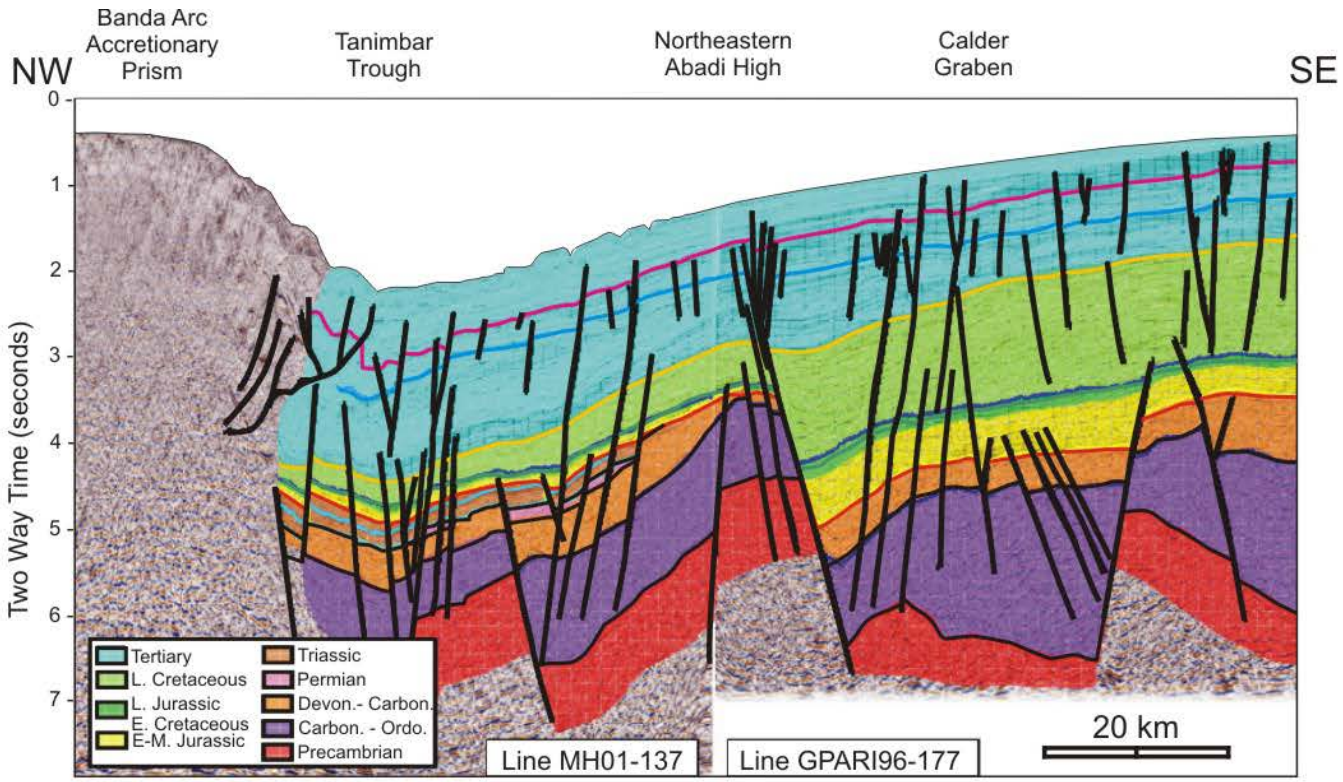
Conclusion

The Timor-Tanimbar trough is bounded by the Banda Accretionary Wedge in the north with complex structures and poor reflectors. Seismic interpretation is hardly possible in this tectonic unit. The faults generate an irregular sea bottom surface.

In the south of the Timor Trough, thick sedimentary sequence above the stable Australian Plate is dipping to the north. Close to the trough, the sequence is cut by intensive fault system. Several faults go up to the surface and generate some sea bottom expressions. There are sea bottom terraces caused by major faults.

Towards the east, the orientation of the trough gradually swings to the north and commonly called as the Tanimbar Trough. Strike slip fault system developed at the northern end, close to Kai Islands.The trough becomes narrower and shallower compared to the Timor Trough.

The northward direction of Australian plate movement may cause the geometry of the trough system. In the south of this study area, the Australian plate moves almost perpendicular to the Asian plate margin. The collision formed the accretionary complex, Timor Island and Timor trough subsequently. To the north, the Australian plate movement direction is subparallel to the eastern edge of the Asian plate and this lateral movement formed the narrower Tanimbar trough with strike slip faults.



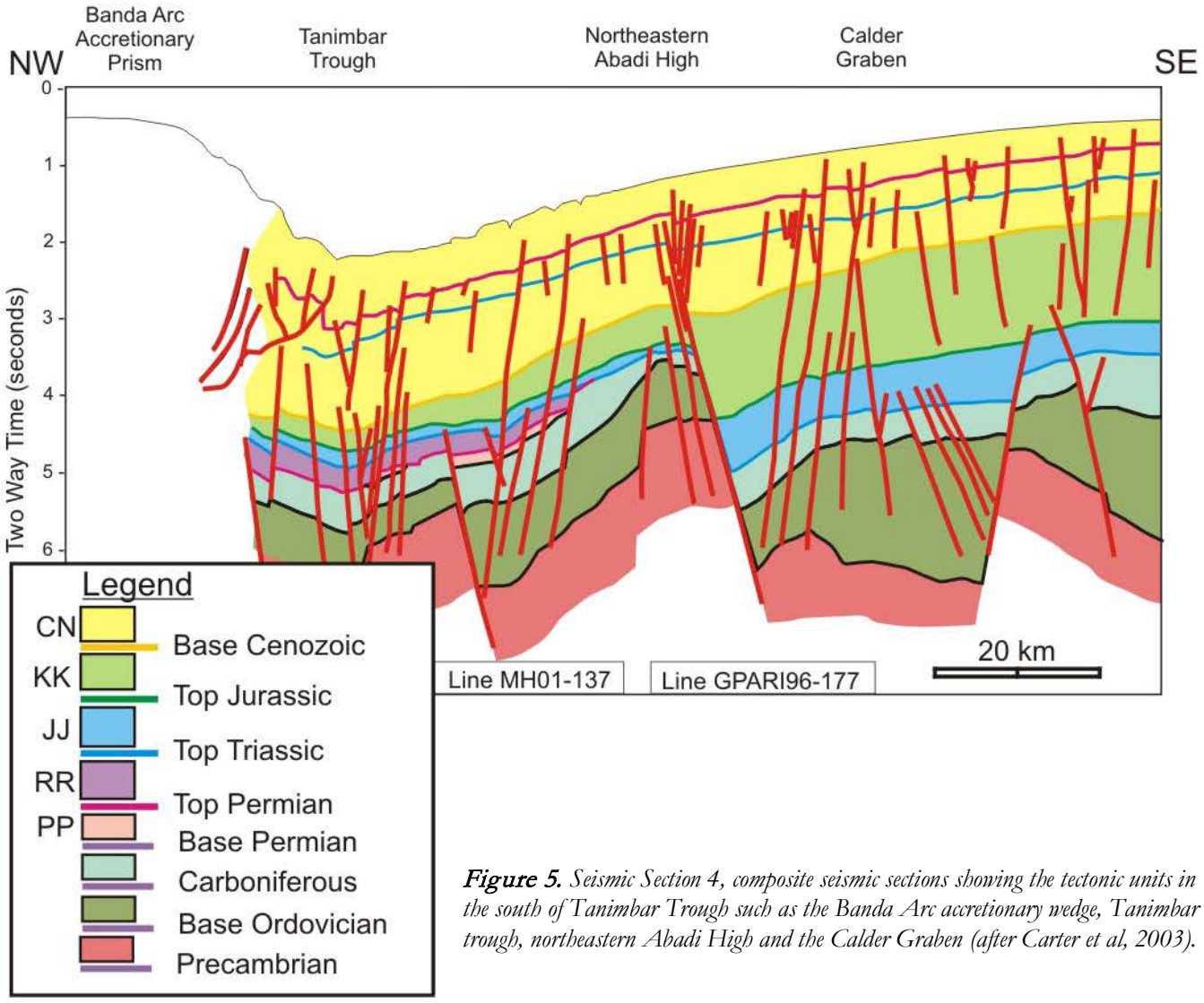


Figure 5. *Seismic Section 4, composite seismic sections showing the tectonic units in the south of Tanimbar Trough such as the Banda Arc accretionary wedge, Tanimbar trough, northeastern Abadi High and the Calder Graben (after Carter et al, 2003).*

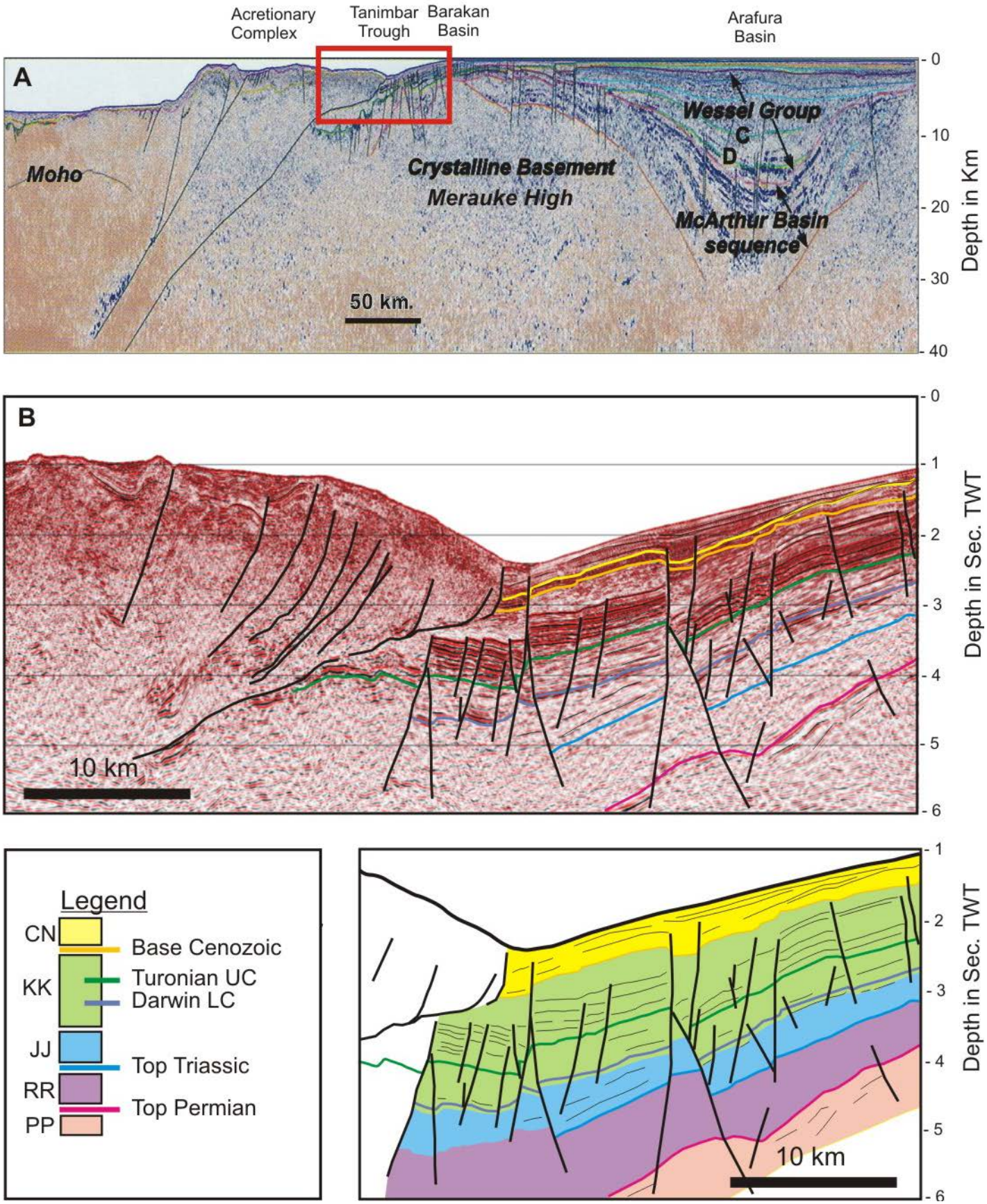
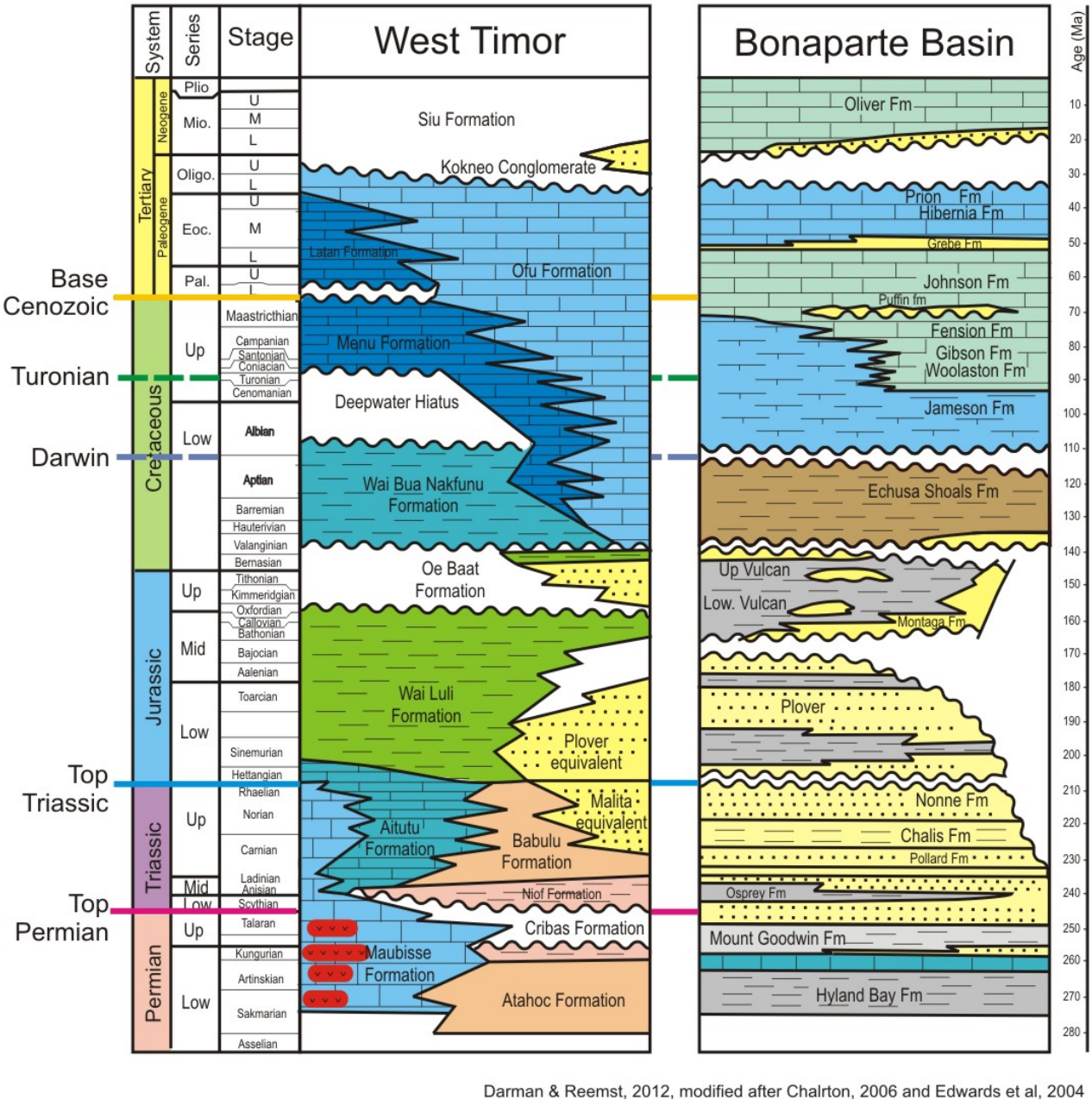


Figure 6. A) Section 5 regional seismic line from the Arafura Basin in the east to outer Banda Arc in the west after Dinkelman et al, 2010; B) Detail section of Section 5 published by Lee & Bawden, 2011, showing part of the Australian Platform subducted below the accretionary complex; C) Stratigraphic interpretation of B).



Darman & Reemst, 2012, modified after Chalrton, 2006 and Edwards et al, 2004

Figure 7. *Stratigraphy of West Timor (Charlton, 2006) and Bonaparte Basin (Edwards et al, 2004)as reference for the stratigraphy of the Timor-TanimbarTrough.*

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