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Geological Structures Appearances and Its Relation to Mechanism of Arc-Continent Collision Northen Alor-Wetar Islands

Kenampakan Struktur Geologi dan Kaitannya dengan Mekanisme Tumbukan Busur-Kontinen Di Utara Pulau Alor-Wetar

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ABSTRACT: Study area is located in South Banda Basin near the triple junction between Eurasian, Pacific and Indo-Australian Plates. This area is part of back-arc thrusting zone that evolved to compensate convergence between Australia Continent and Banda Arc. Based on seismic section in this area, geological structure analysis is characterized into three distinctive zones. There are Thrust Zone (TZ), Proto Thrust Zone (PTZ) and Normal Fault Zone (NFZ). TZ is defined by distribution of numerous of thrust fault, PTZ contains a blind zone or folds instead of thrust fault, and NFZ defined by distribution of numerous normal fault in the upper portion of seismic section. PTZ identified at several seismic section along the bending zone of oceanic crust. The appearances of bending zone will be easily understood by comprehend the driving mechanism of Australia Continent to the Northeast. The bending zone also related to geometry and tectonic stress of collision. Based on this mechanism it was clearly understood why the western end of study area was not identified the bending zone but it probably the initial process of bending. Contradictive to the western end, the eastern part was clearly shown the bending zone that assumed to have the biggest tectonic stress at this moment. Map of structural analysis also explain that PTZ getting narrow towards the west as the indicator of less of tectonic stress.

Keywords: Arc-Continent Collision, Proto Thrust Zone, Wetar, Back arc Thrusting, Banda Sea.

ABSTRAK: *Lokasi penelitian berada pada Cekungan Banda Selatan sekitar area triple junction antara Lempeng Eurasia, Pasifik dan Indo-Australia.Daerah ini merupakan bagian dari zona back-arc thrusting yang berkembang sebagai kompensasi dari konvergensi antara kontinen Austalia dan Busur Banda.Berdasarkan penampang seismik di daerah ini analisis struktur geologi dikelompokan kedalam tiga zona. Tiga zona tersebut meliputi Thrust Zone (TZ), Proto Thrust Zone (PTZ) and Normal Fault Zone (NFZ). TZ didefinisikan oleh distribusi dari sejumlah sesar naik, PTZ mengandung sejumlah blind thrust atau lipatan pengganti sesar naik dan NFZ didefinisikan oleh distribusi dari sejumlah sesar normal pada bagian atas dari penampang seismik. PTZ teridentifikasi pada beberapa penampang seismic sepanjang zona bending dari lempeng oseanik. Kenampakan dari zona bending akan mudah dipahami dengan mengetahui mekanisme pergerakan dari kontinen Australia ke arah timurlaut. Zona ini umumnya berhubungan dengan bentuk geometri dan besaran dari tectonic stress dari tumbukan. Berdasarkan mekanisme ini dapat dipahami dengan jelas mengapa bagian ujung barat dari daerah penelitian tidak teridentifikasi zona bending. Kontradiktif terhadap ujung barat, ujung timur memperlihatkan zona bending yang sangat jelas yang diperkirakan mempunyai tectonic stress yang paling besar pada saat ini. Peta dari analisis struktur juga menjelaskan bahwa zona PTZ semakin ke arah barat semakin menyempit sebagai indicator dari berkurangnya tectonic stress.*

Kata Kunci: *Tumbukan Busur-Kontinen, Proto Thrust Zone, Wetar, Back arc Thrusting, Banda Sea.*

INTRODUCTION

Alor-Wetar Islands are located in eastern Indonesia where arc-continent collision is one of the most dominant tectonic process occur in this area (Figure 1). Study area is part of South Banda Basin in the central position within eastern Indonesia that opened as back-arc or intra-arc basins relatively to the Banda subduction zone.The Banda subduction zone began to develop about 15 to 12 Ma and the trench formed as the eastern partof the Sunda–Java Trench (Hall, 2002). This trench had been destroyed by the tectonic collision, (Audley-Charles, 2004, 2011).

The rifting of the SouthBanda Basin at about 6 Ma separated the Wetar and the Lucipara volcanic arc, and intra-arc opening processes occurred from about 6.5 to 3.5 Ma(Late Miocene-Early Pliocene) forming the present Banda Sea. The opening of South Banda Sea are interpretated based on dredge sample and paleomagnetic analysis (Silver, et.al, 1985, Honthaas et al., 1998; Hinschberger et al., 2000, 2001). The analysis support the interpretation by Hamilton(1979).

Paleomagnetic analysis by Hinschberger in 2001 was only carried out at Damar Basin due to magnetic interferences by volcanic bodies northern Wetar, but it was suggested that based on tectonic continuity and geochronological results, the opening extend to the whole South Banda Sea including northern Wetar Island. The active spreading stopped during in the middle Pliocene due to collision between Banda Arc and Australia Continent when the leading edge of the Australian continental crust entered the Timor Trough(Carter et al., 1976; Hamilton, 1979; Bowin et al, 1980; Abbott and Chamalaun, 1981; Audley-Charles et al., 1988; Richardson and Blundell, 1996).The young deformation in the Banda Orogen and initial stage of collision is used as a modern analog for the transformation includes the poorly understood transitions from subduction to collision, from an accretionary wedge to a fold and thrust belt, from arc volcanism to arc accretionand fore-arc destruction, R. Harris in D. Brown and P.D. Ryan (eds.), 2011.

The collision is keep continuing and geological evidences have been found to understand the tectonic process of collision. This collision also influence the marginal basin northern part of Banda Arc system, the observation and analysis along the marginal basin also should be done in order to understand comprehensively.

The aim of this paper is to discuss the geological structures in the marginal basin in South Banda Basin, northern Alor-Wetar Islands, affected by mechanism of Arc-Continent collision between Banda Arc and Australian Continent. The study area shown in the Figure 1. This paper also to completed map of geological structure analysis that was published in previous paper (Subarsyah, et.al, 2014), especially the delineation of structural zone and volcanic bodies.

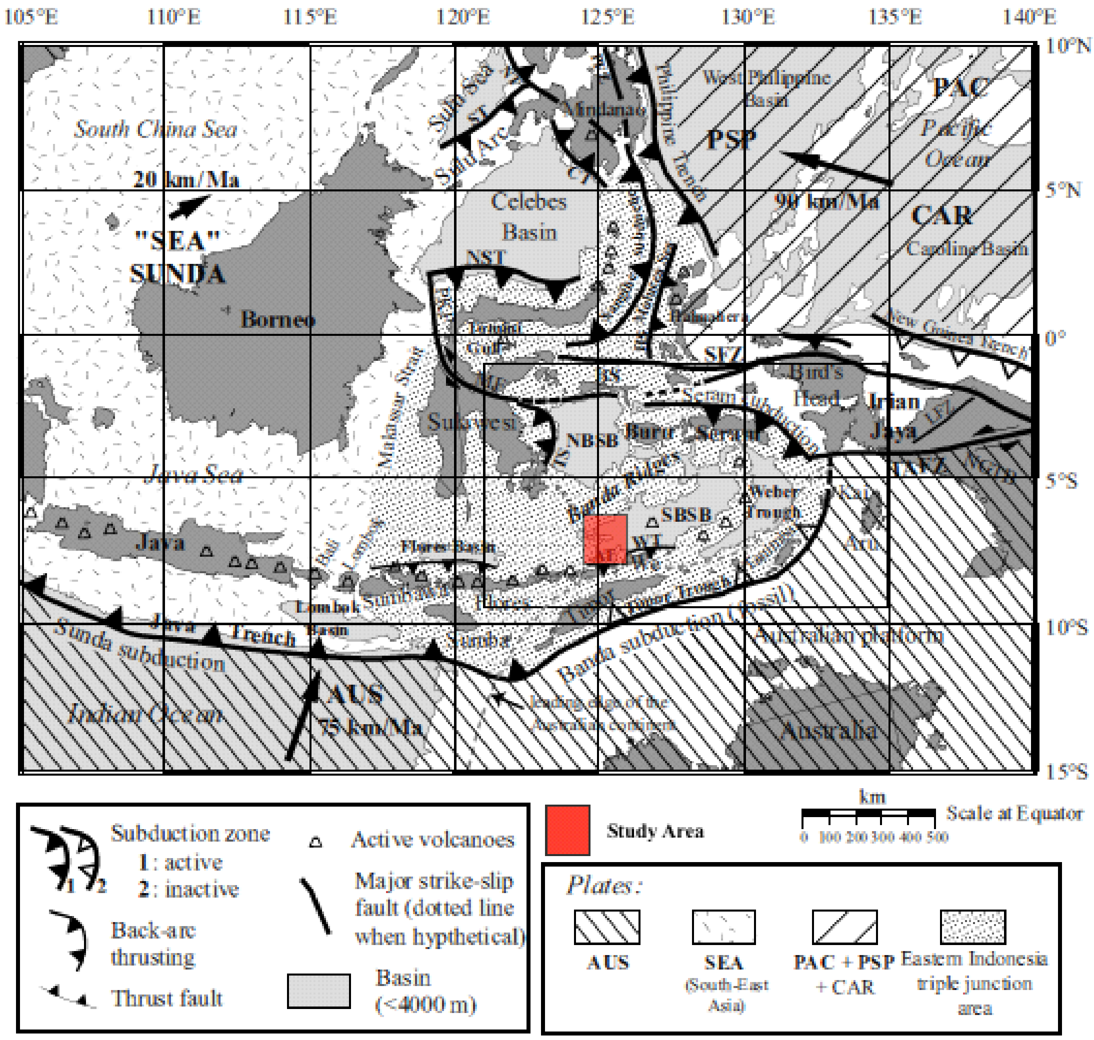

Figure 1. Map of the eastern Indonesian region showing the major tectonic structures and basins (Hinschberger, 2005).

METHODS

Geological structure analysis will be done in the marginal basin of South Banda refers to Chia-Yen Ku and Shun-Ku Hsu classification (2007). Geological structure approach was analysed on several seismic section at northern Alor-Wetar Islands. Geological Structures were characterized by three distinctive zones: a normal fault zone (NFZ), a proto-thrust zone (PTZ) and a thrust zone (TZ). The seismic section interpreted by following characteristic of each zone and the results were plotted into a maps.

RESULTS

Geological structures analysis have been approached by using seven seismic section in northeast–southwest direction (Figure 2). Each seismic section has been characterized into three distinctive zone which is comprise of Thrust Zone (TZ), Proto Thrust Zone (PTZ) and Normal Fault Zone (NFZ), (Subarsyah et. al., 2014). The boundary between the zones are Frontal Thrust FT and Deformation Front (DF). Thrust fault clearly identified along Alor-Wetar islands it simplified to determine Thrust Zone.

PTZ identified in the westernmost part, seismic line 17, relatively narrower than in the eastern part, seismic line 07. Bending zone was not identified on seismic line 17 but it seem probable that the initial bending has been occurred behind NFZ as an indicator of higher tectonic stress , Figure. 3. In contrast with Figure. 3, Seismic section line 15 (Figure. 4) have shown bending zone near the through. Bending zone was a key indicator in order to determine a Proto Thrust Zone, and its length about 25 km then it followed by Normal Fault Zone that relatively narrow compared to Proto Thrust Zone because of other tectonic activities in the northern part which led to the development of flower structures, Figure. 4.

Delineation of structure zone in seismic section line 01, Figure. 5, similar to seismic section line 15. Bending zone appear near the through but it has less steep slope. The width of each zones relatively the same. Normal fault actually identified further to the northern part in the upper layer of seismic section, but this normal fault assumed to occur due to other tectonic activities instead of arc-continent collision.

Structure zone interpreted on seismic line 03, Figure. 6, differ from previous line, particularly on the structural appearances on PTZ. Two previous line has shown bending zone clearly on PTZ meanwhile bending zone was not identified in this seismic line because of volcanic body near the through. Commonly blind thrust or fold was easy to identify along the bending zone, because it was difficult to find out the structure that characterizes the PTZ so that it was decided that there is no PTZ in this seismic section. Gravity sliding or slump deposits also identified in the upper part of volcanic body as a result of collision process.

PTZ Zoning was difficult to identify on seismic line 05, Figure. 7, Geological structures such as blind thrust and fold that characterizes the zone was hard to find out. Strike slip of Wetar-Atauro estimated to disrupt development of blind thrust or fold. Its presence associated with flower structure that can be identified clearly on seismic section.

PTZ has identified back on seismic section line 07, Figure. 8, bending zone appear with small slope that almost parallel to the through. Intrusive body visible in the middle of seismic section where the presence difficult to determine NFZ, because the normal faults that appear in this section develop not only as a response of collision process but interfering with tectonic or volcanic activities in the north western part.

Structural interpretation on seismic line 09, Figure. 9, similar with interpretation on seismic line 03. PTZ and NFZ difficult to determine because the volcanic near the through disrupt development of blind thrust or fold, and it also has contribution to development of normal fault.

Boundary between two zone easily can be recognized, especially the frontal thrust which is defined as the most seaward thrust faults; this thrust fault can be traced at the seabed, meanwhile deformation front, which is defined as the location of the first seaward blind thrust fault or of the flank where sediments start to fold, difficult to recognized at some seismic line due to interference among geological activities.

Result of structural analysis depicted in a map, distribution of geological structure as a response to Banda-Arc-Continent collision can be seen easily.

DISCUSSION

Structure analysis is characterized into three particular zones: Thrust Zone, Proto Thrust Zone and Normal Fault Zone where each zone is separated by a boundary Frontal Thrust and Deformation Front. Distribution of structure differ between northern Alor and Wetar Islands, Northern of Alor clearly identified the structural zoning meanwhile northern of Wetar it was difficult to identified due to geological activities such as volcanic, intrusion and strike slip.

TZ easily observed on seismic section along back-arc thrusting of Alor-Wetar Islands, but it was complicated to delineate continuation of frontal thrust from line 03 to line 07 because details information about strike slip of Wetar-Atauro is required, especially width of deformation which is caused by this fault also denser interval of seismic line, Figure 3.

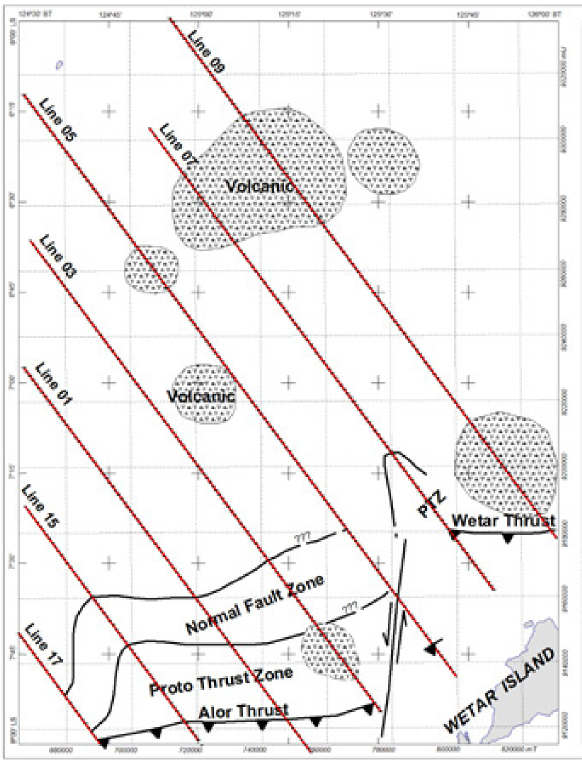

Figure 2. Seismic line and structural analysis, modified from Subarsyah, et. al, 2014.

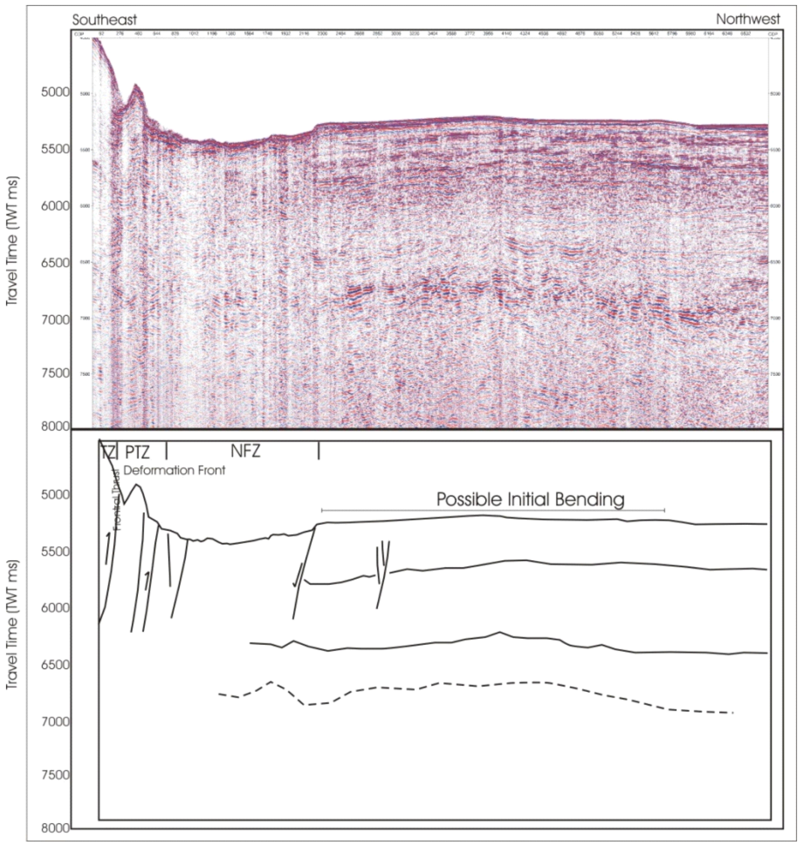

Fig. 3 Seismic section line 17 and its interpretation

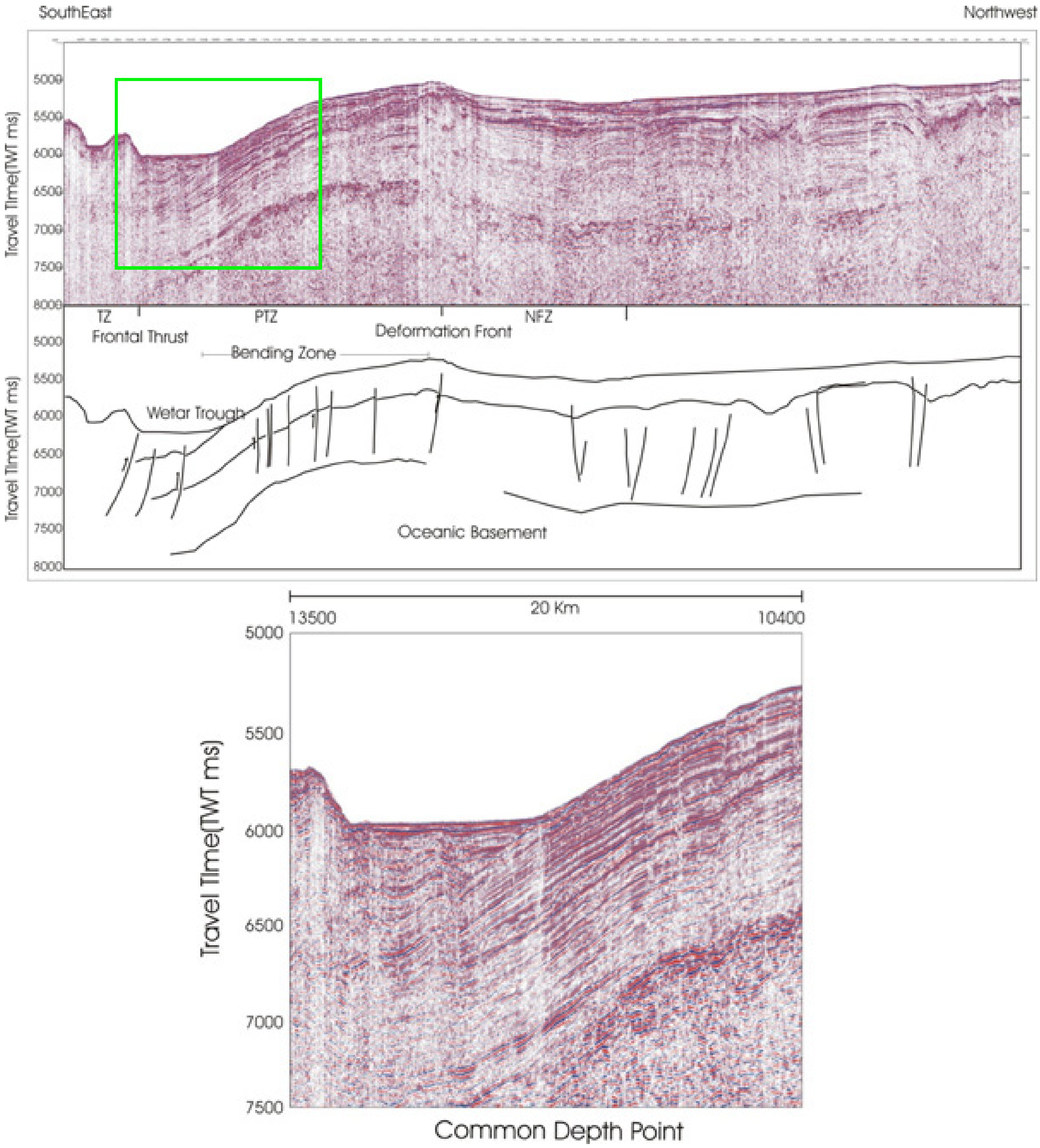

Fig. 4. Seismic section line 15 and its interpretation (Upper), zoom in of green box (lower).

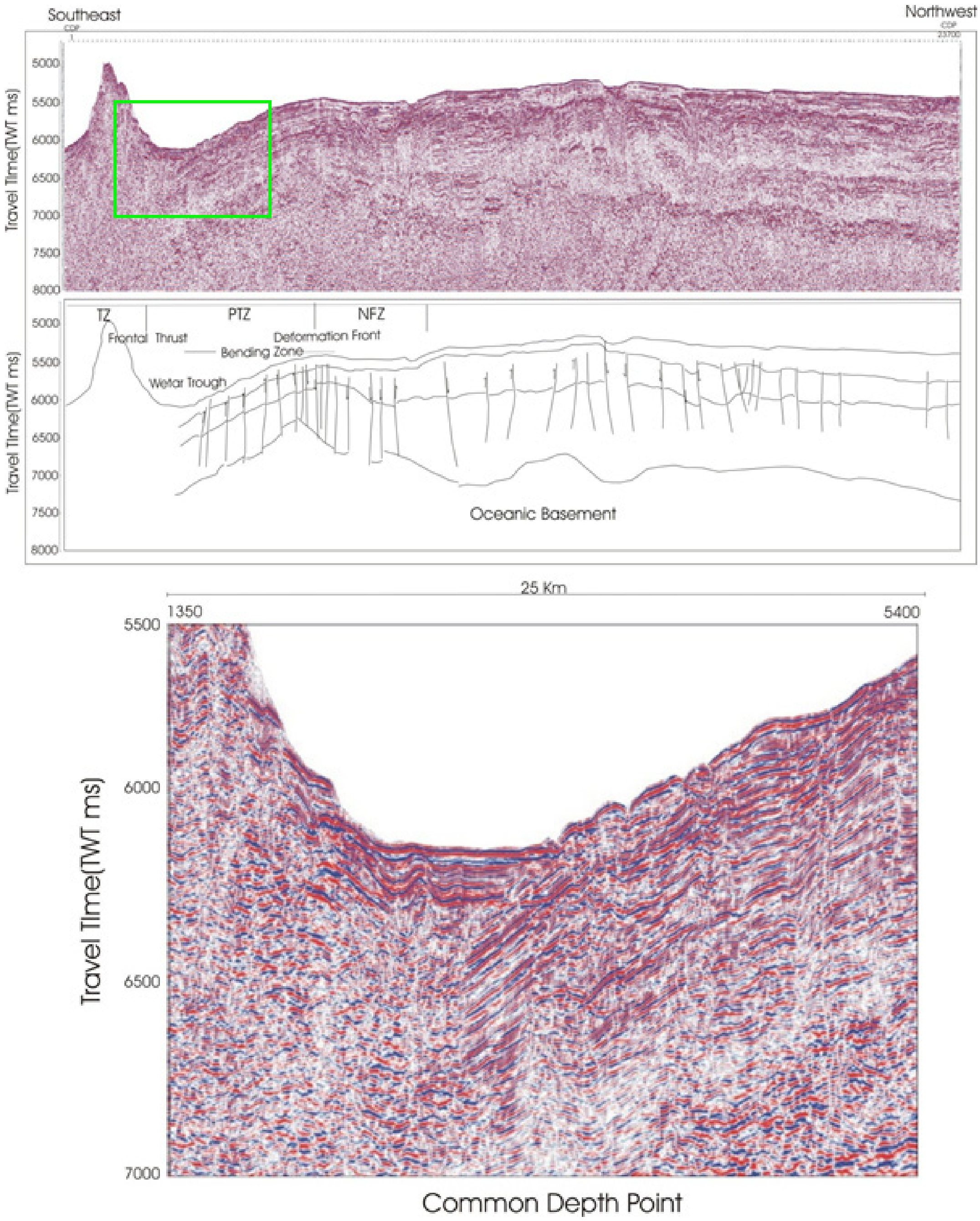

Figure 5. Seismic section line 01 and its interpretation (upper .), zoom in of green box (lower), Subarsyah, et.al., 2014.

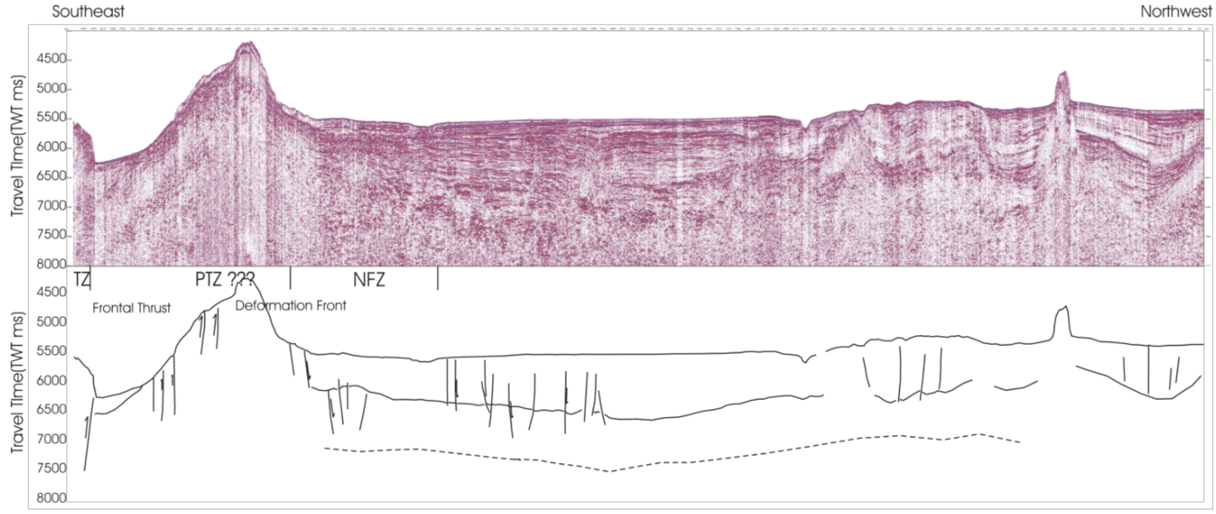

Figure 6. Seismic section line 03 and its interpretation

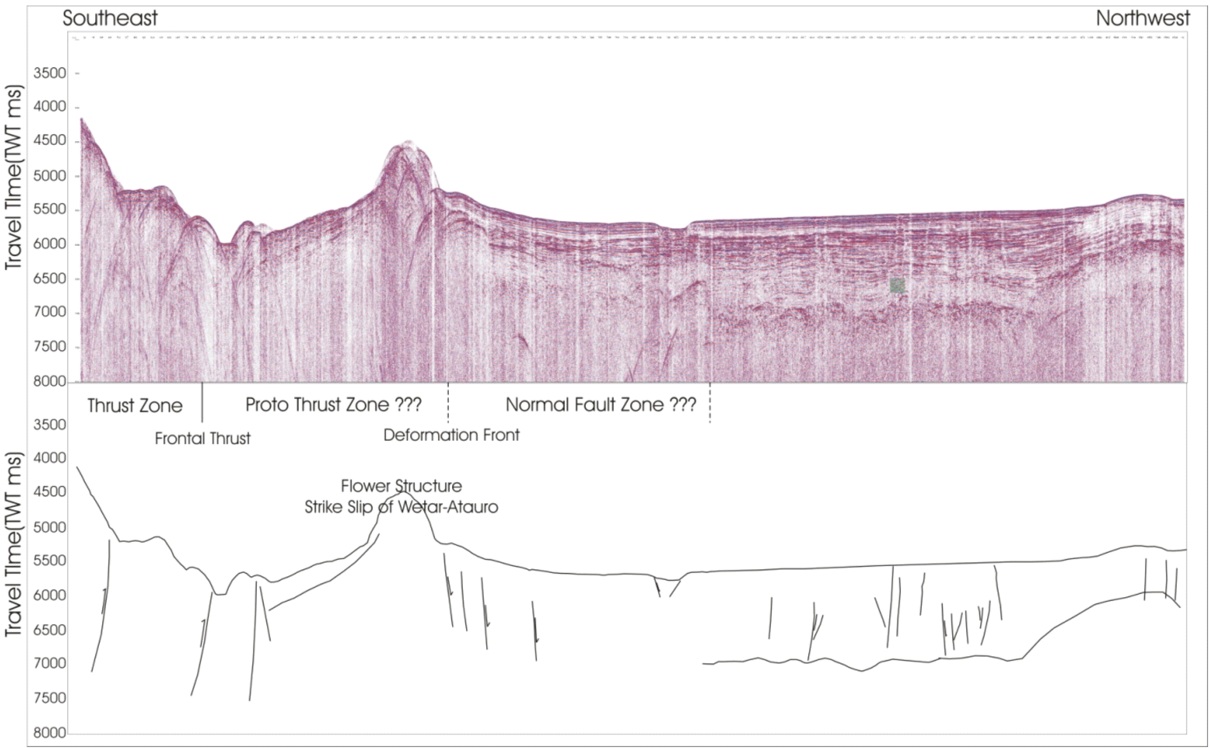

Figure 7. Seismic section line 05 and its interpretation

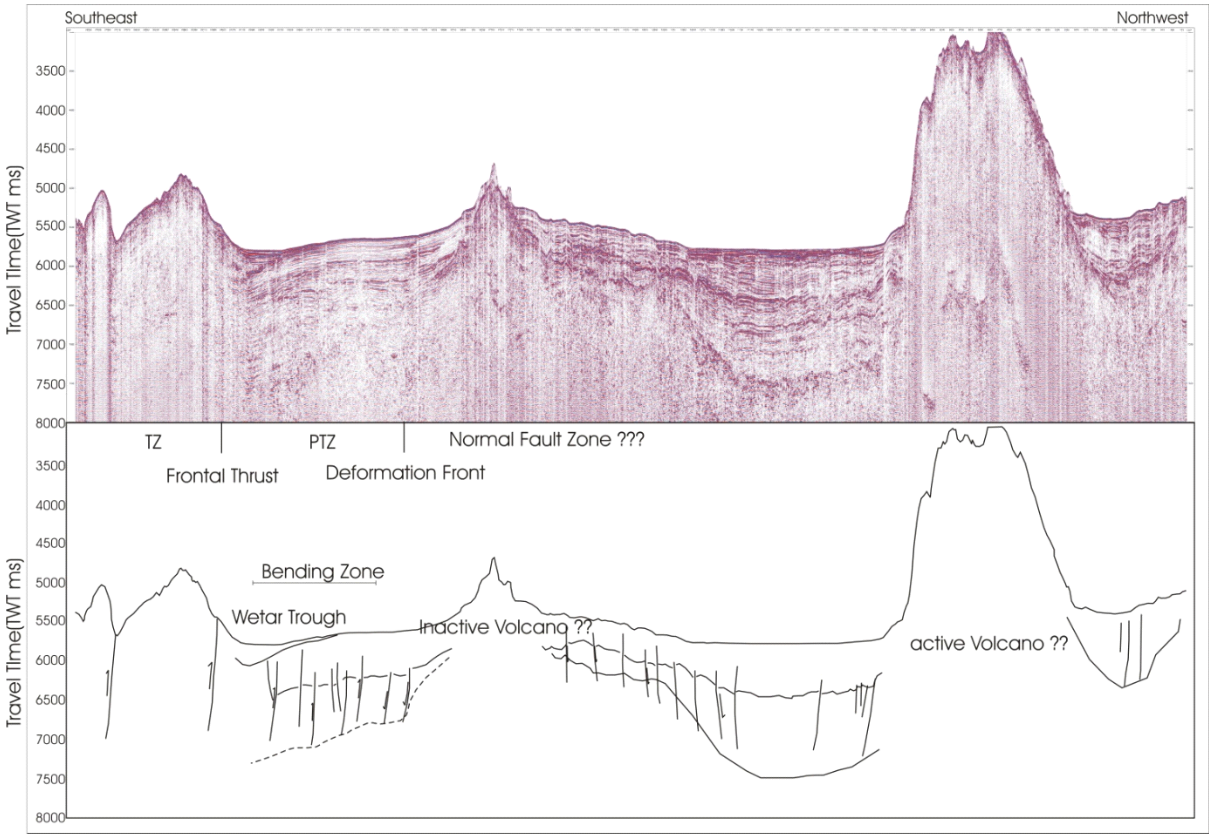

Figure 8. Seismic section line 07 and its interpretation

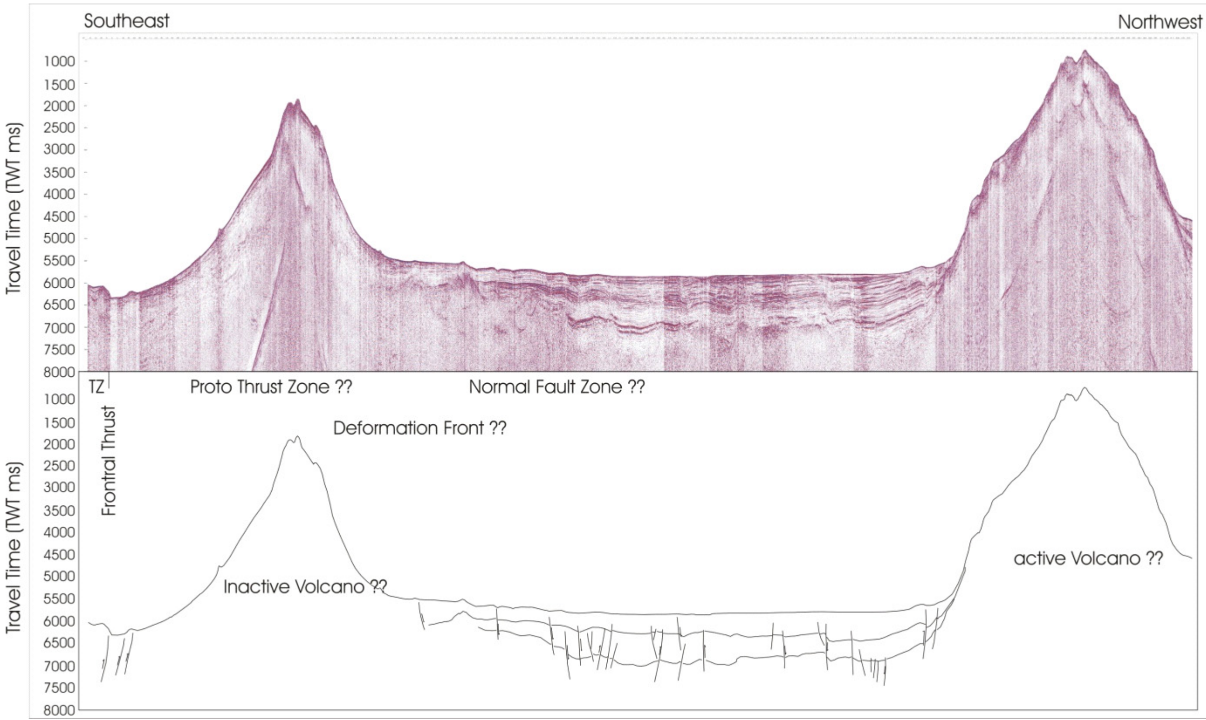

Figure 9. Seismic section line 09 and its interpretation

PTZ commonly characterized by bending zone except at the westernmost part of study area which is estimated the early stage of bending has been started. Bending zone as the characteristic of PTZ disrupted to develop due to volcanic appearances on seismic line 03 and 09 also disrupted by strike slip activities on seismic line 05. The presence of strike slip of Wetar-Atauro indicated by flower structure emergence on the seabed.

NFZ on marginal basin of South Banda not only affected by arc-continent collision but also affected by volcanic and other geological activities in the north near the Tukang - Besi Spur. NFZ in this publication defined as the distribution of numerous normal faults in the upper layer of seismic section due to Banda Arc-Continent Collision. Analysis is necessary to distinguish NFZ as consequences of arc-continent collision from other geological activities. It was easy to distinguish NFZ in the western part then eastern part because volcanic activities, intrusion and others geological activities dominantly influence the development of normal faults.

Appearances of bending zone on seismic section is interesting to discuss especially why in the western part of study area there is no bending zone or why the initial stage of bending zone has been started. Geometry and driving mechanism of arc-continent collision are factors that will determine what kinds of geological structure will occur. Harris in Brown and Ryan (eds.), 2011.

Considering model of driving mechanism has been published Harris. R in Brown and Ryan (eds.), 2011, about how and when the arc- continent collision was happen, Figure 10.

Six million years ago, Australian Continent continue moving relatively to the north at 66 mm/a, Timor in that time was a deep accretionary ridge under-thrust by most distal parts of Australian Basement, meanwhile in the northern part Banda Volcanic Arc was still part of subduction system of Sunda Arc trench system. Two million later Timor started to form and emergence to sea level from shortening of accreted Australian continental margin cover units uplift and erosion of Banda Terrane and shallow exhumation of Aileu Complex while Sumba as deep fore-arc basin about 3-4 km, Savu and Rote are deep fore-arc ridge about 3 km and Banda Volcanic Arc began to contaminated by continental crust.

Two million years ago shortening, uplifted and lateral expansion of Timor Island continued, Sumba had experienced of rapid uplift of coral terrace from collision with Scott Plateau, Savu also experienced a rapid uplift, Rote entered the initial of uplift phase meanwhile Banda Volcanic Arc began to entered phase of back arc thrusting.

Geometry of collision and driving mechanism affected different tectonic stress along Banda Volcanic Arc, the biggest tectonic stress was occured along Alor – Wetar Islands. This occurrence led to development of bending zone on oceanic crust of Banda Sea. Seismic section has shown that the westernmost part of study area is the boundary between the biggest and lowest tectonic stress due to no bending zone appearances. However the bending zone disrupted to develop when any geological or tectonic activities occur or exist. Volcanic and strike slip of Wetar - Atauro are geological activities that disrupt development of bending zone in Banda Sea, Especially Northern Alor-Wetar Islands.

CONCLUSION

Structural analysis in the Banda Arc –Continent Collision Characterized into three distinctive zone, TZ, PTZ and NFZ, each zone separated by a boundary Frontal thrust and deformation front. PTZ has characteristic of bending zone except in the westernmost part of study area also at several seismic line that disrupted by volcanic and strike slip of Wetar – Atauro. The presence of strike-slip was indicated by flower structure appearances on seabed. Distribution of PTZ and bending zone depend on geometry of arc-continent collision, tectonic stress and driving mechanism of Australian Continent. Based on geometry of collision the biggest tectonic stress was in eastern part of study area from seismic line 15, 01, 03, 05, 07 and 09. Seismic line 17 as boundary between the biggest and lowest tectonic stress at present, there is possibility that in this area begin to have bigger tectonic stress.

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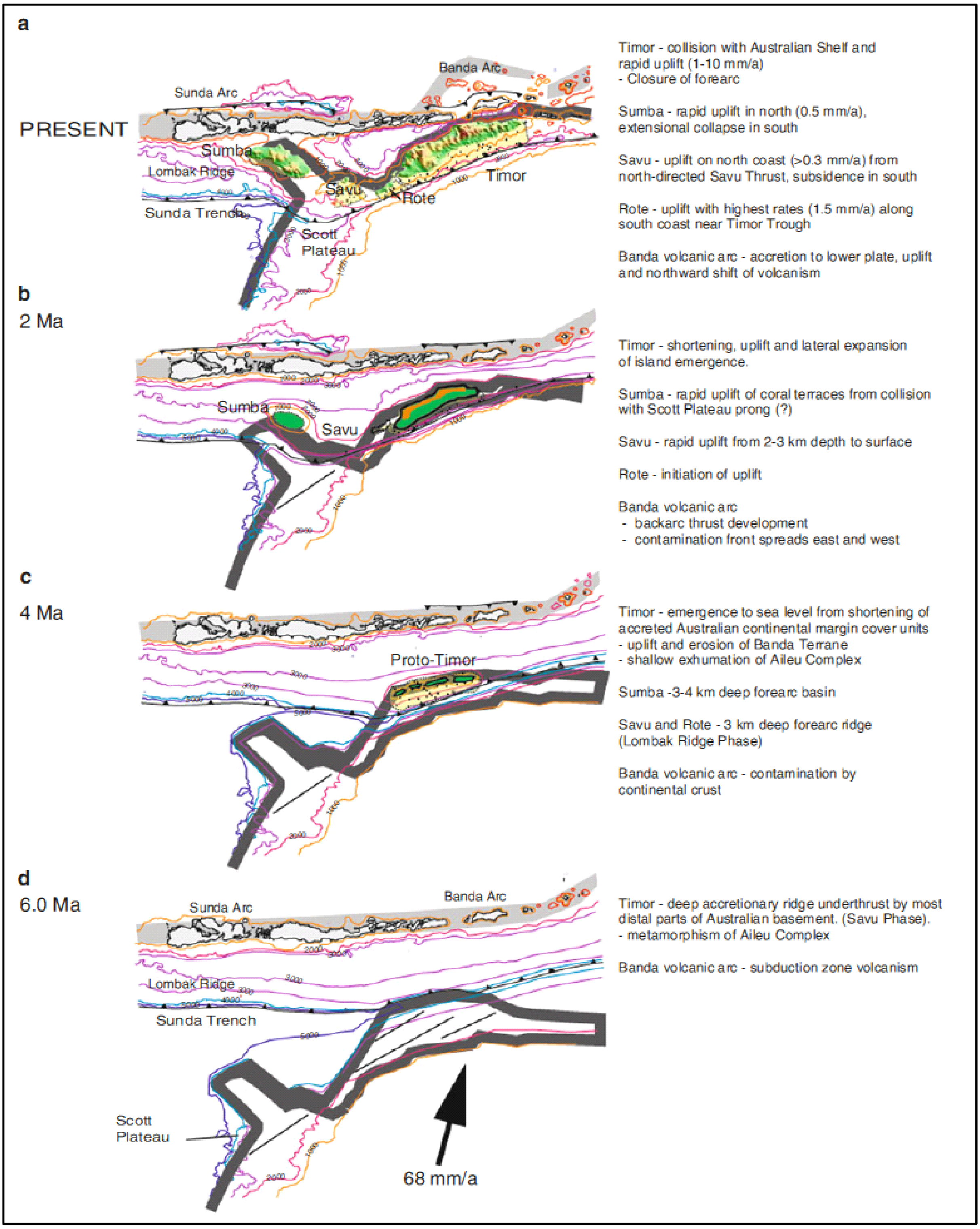

Figure10. Geometry and model of driving mechanism of Australian Continent, R. Harris in D. Brown and P.D. Ryan (eds.), 2011.

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