Initial Studies of the Marine Geophysical Survey in the Offshore Waigeo, West Papua

Kajian Awal Survei Geofisika Kelautan di Lepas Pantai Waigeo, Papua Barat

Dida Kusnida, Subarsyah, Eko Saputro and Arif Ali

Marine Geological Institute of Indonesia
Jl. Dr. Junjunan 236, Bandung-40174
Email : dida@mgi.esdm.go.id

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Abstract - The offshore northern Waigeo situated and evolved within the obliquely converging of the Australian and Pacific plates boundary zone and bound by an active left-lateral transform fault of the Sorong Fault Zone (SFZ) in the southern part. In general the Waigeo offshore characterized by +200 nT to-150 nT of total magnetic intensities which indicate that the study area possibly overlain by a homogenous rock of oceanic origin in the form of highs (terranes) and lows (basins). Seismic data indicate that the morphology of the study area relatively steep due to the tectonic contact boundary between island-terranes of Waigeo and between Ayu islands and Pacific Oceanic crust.This tectonic contact boundaries characterized by the present of Waigeo Trough that extends southeast-northwest direction. Seismic data reveals about 1000 meters thick of acoustically chaotic to laminated, indicate fine-grained sediments of slumps at Waigeo Trough slope and trough floor, and about 1500 meters thick of pelagic sediments at the Ayu Trough.

Keywords : Waigeo Trough, Ayu Trough, Ayu Islands, convergence, seismic sequence, slump.

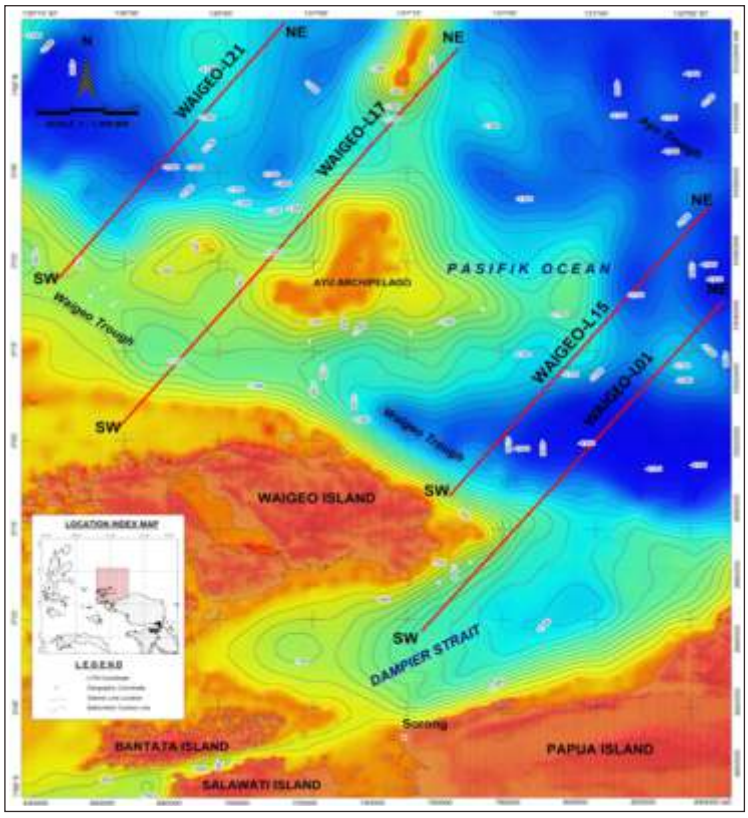
Abstrak *- Lepas pantai Waigeo bagian utara beradadan berkembang pada zona konvergensi oblig antara lempeng Australia dan lempeng Pasifik dan dibatasi oleh sesar geser aktif mengiri Sorong (Zona Sesar Sorong) di bagian selatan. Secara umum perairan Waigeo dicirikan oleh intensitas magnet total antara +200 nT hingga -150 nT yang mengindikasikan bahwa daerah studi dialasi oleh batuan homogen asal samudera membentuk tinggian (teran) dan lembah (cekungan). Data seismik menunjukkan bahwa morfologi daerah studi relatif curam karena batas kontak tektonik antara pulau-teran Waigeo dan antara kepulauan Ayu dan kerak samudera Pasifik. Batas kontak tektonik ini dicirikan dengan adanya Parit Waigeo yang memanjang berarah tenggara-baratlaut. Data seismik menunjukkan sedimen yang secara akustik kaotik hingga berlapis dengan ketebalan sekitar 1000 meter, mencirikan sedimen slump berbutir halus pada lereng dan lantai Parit Waigeo, dan sekitar 1500 meter ketebalan sedimen pelagik di Parit Ayu.*

Kata kunci : *Parit Waigeo, Parit Ayu, Kepulauan Ayu, konvergensi, runtunan seismik, slump.*

INTRODUCTION

For the last two decades various marine geological and geophysical studies have been carried out in Indonesia both by domestic and foreign agencies. It completed in 2015 with a marine geological and geophysical mapping in the northeastern offshore of Waigeo-West Papua carried out by Marine Geological Institute of Indonesia. Indonesian offshore is not only interesting for economic intensions due to its content of oil and mineral resources but is also interesting for scientific and academic purposes as it considered the most tectonically complex regions of the world. Tectonic convergence situated around the western and southeastern regions of Indonesia have been studied considerably well informed. Study of forarc and trench of Sumatra (Mc Caffrey, 2009) and study of Neogene tectonic evolution models of the Banda Arc area, particularly with regarding to early subduction around the arc as well as the relationship between the tectonic unit consisting of Seram and the surrounding islands clearly delineated by Darman and Reemst (2012) and by Pownall *et al* (2013). Study on seismic sequences at the active Banda Arc-continent collision in the Seram Trough (Kusnida *et al*, 2016) gave valuable information on the depositional dynamics of this region. Studies of the nature of the Banda arc-continent collision in the Timor region (Harris, 2011) provided a broad outline of the geometry and sedimentary sequences of this active margin system and portrays the Cenozoic evolution of the area. Among these studies, plate boundary and forearc regions are the most intensely been studied such as studies of Sunda-Banda Arc (Hall and Spakman, 2015).

From the above studies, it appears that the studies related to the tectonic convergences in Indonesia so far more focused on the studies of subduction-collision tectonic especially along the Sunda-Banda Arc. Thus, very little literatures that discusses the tectonic convergence in the northeastern part of Indonesia which characterized by the obliquely converging of the Australian and Pacific plates boundary zone where the north Waigeo offshore located (Figure 1).Charlton *et al* (1991) remarked that tectonically Waigeo island occupies a critical position between the Halmahera-Philippine arcs to the northwest and Australia-New Guinea to the southeast and is interpreted to have been situated in a forearc position in an intra-oceanic island arc during the early Paleogene, forming part of the East Halmahera-Waigeo forearc terrane. The island consists of a deformed ophiolitic basement of supra-sabduction zone type overlain by probably Paleogene forearc sedimentary rocks.



Source : Gebco 2014

Figure 1. Map of the study area indicatebathimetry and the locations of seismic lines 01, 15, 17 and 21, produced in Figure 2, 3, 4 and 5.

Baldwin *et al* (2012) stated that the plate boundary zone and geodynamic evolution in New Guinea (Papua) region involved micro plate formation and rotation, lithospheric rupture to form ocean basins and arc-continent collision. While, Fraser (2015) mentioned that Papua region belongs to the mainly continental Australian Plate which incorporate a northern fringe of recently accreted arc material derived from the Pacific Plate. The Cenozoic tectonic evolution in Papua region clearly explained by Sapiie (2016) which show that structurally indicated by two stages of deformation which have occurred since ~12 Ma. The second stage resulted in a significant left-lateral strike-slip faulting sub-parallel to the regional strike of upturned bedding. The next tectonic stage was a strike-slip offset at ~4 Ma, followed by reactivated portions of pre-existing reverse faults from ~4 - 2 Ma.

However, according to the regional marine geological and geophysical studies mentioned above, the study area relatively is still unexplored, and so far never have been studied and discussed considerably in detailed and it is remains frontier and poorly understood. For this reasons, it was decided to study the major offshore tectonic and geologic components, including plate boundaries, faults and stratigraphic characteristics.

METHODS AND TECHNIQUES

Marine multichannel seismic reflection data acquisition carried out by using Sercel Seal Streamer with the length of 750 meters, which is composed of four active sections (ALS) with 60 active channels. Sleeve I/O capacity of air-gun array 550 cu. inch with a power output of 1000 psi supplied by the Marine Controller Geometric Computer used as a sound source with a firing rate of 12.5 second. Quality control of seismic data recording during the survey carried out by using the IBM workstation software O/S Linux Red Hat and ProMAX2D 3.3.2003 version. Stratigraphic framework divided into several seismic interval based on the sequence boundary and facies analyses. Marine SeaSpy magnetometer sensor was hauled some 250 meters behind the stern completed by Sea Link software unit. Bathymetric measurement carried out using 3.5 kHzsub-bottom profiling (SBP) Chirp Sub-bottom Profiler Bathy 2010. The navigation system in the study area carried out by mean the Differential Global Positioning System (DGPS) C-NAV using EIVA A/S NaviPac software.

RESULTS

The data obtained and collected during the survey covering bathymetric, geomagnetic and seismic are discussed in this paper to understand the geological phenomena that occurred around the northern Waigeo offshore. The morphology in the study area is relatively steep and probably relates to the contact boundary between the island-terranes Waigeo Island and Ayu Islands with the Pacific Ocean and the existing geological structures. The contact boundary can easily be identified on a cross section of the changes of low and high magnetic anomalies (Figures 2, 3, 4 and 5). In general the Waigeo offshore is characterized by +200 nT to -150 nT of total magnetic intensities which indicate that the study area possibly overlain by a homogenous rock of oceanic origin in the form of highs (terranes) and lows (basins). In several seismic lines, the contact boundary marked by the presence of Waigeo Trough that extends from the southeast to the northwest (Figures 2, 3 and 5). The occurred faults identified in the northern to northeastern part of Waigeo offshore generally arereverse and normal faults. Thrusting identified in the convergence zone between the island-terranes and the Pacific Ocean.

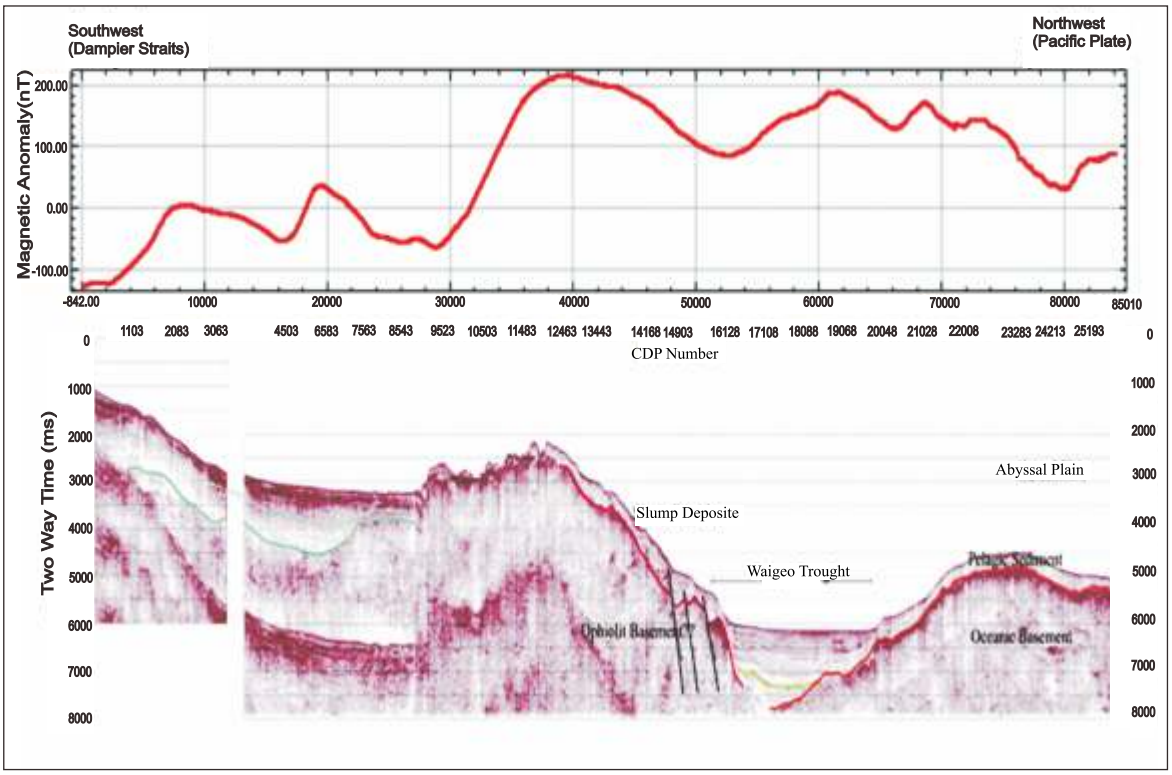
Seismic profile from the area shows four sequences which are estimated to represent four rock units, consisting of three clastical sedimentary rocks and the acoustic basement. The lowest sequence is the acoustic basement that estimated as the ophiolite rocks of the Tanjung Bomas Formation that extends in the northeastern part of the Waigeo island. The second sequence has a transparent reflector pattern with a very thin continuity. The third seismic sequence has a very clear continuous reflector pattern intercalated by transparent reflector pattern. The uppermost seismic sequence has a transparent reflector pattern as shown in Figures 4 and 5.

Interpretation of seismic lines around the Ayu Islands are shown in Figure 3, which, indicate the sequences in this seismic line shows a relatively same reflector pattern as the seismic sequences those in Waigeo Island. Not to many literatures related to the geology of Ayu Islands, therefore, it suggests that the Ayu Islands is probably a separate island-terranes. Seismic sequences in Abyssal Plain around the northwestern and southwestern part of Ayu Islands are different. The northwestern area of Ayu Islands expresses three seismic sequences.

The first sequence is a basement rock suggested to be oceanic, the second seismic sequence is clastic sedimentary rock characterized by transparent reflector pattern, and the third seismic sequence possibly a clastical sedimentary rocks characterized by sharp reflector continuity. In the southeastern area there are two seismic sequences those are sequence characterized by transparent reflectors suggesting as a pelagic sedimentary and oceanic basement rocks (Figures 4 and 5).

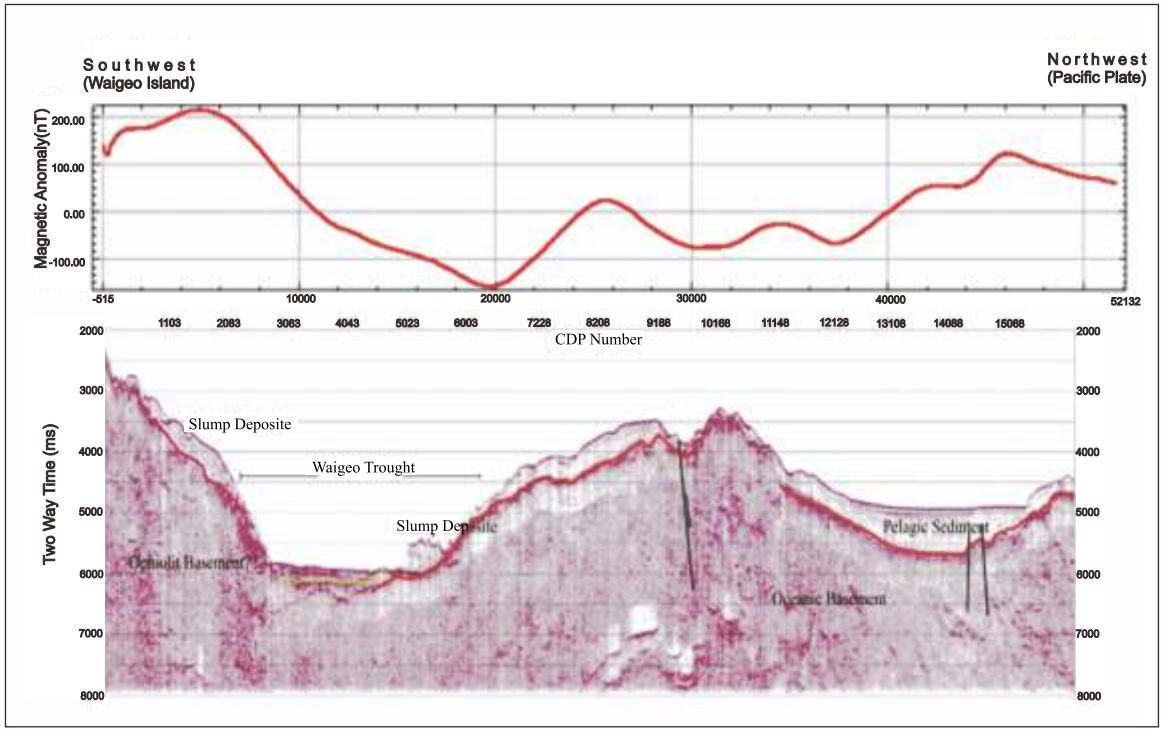
Slump deposits identified especially in the eastern and northern parts of Waigeo offshore, which is an island-terrane boundary with the Pacific Ocean. Seismic around Dampier Strait (Figure 2) shows that the morphology of the seabed along the rugged southern Waigeo Island and part of Waigeo Bird's Head of Papua is steep, while the flat morphology is located in the northeastern part of the Dampier Strait. Bathymetric pattern in Dampier Strait shows a relatively northeast-southwest lineation expressing the Sorong Fault Zone. There are three different contour patterns, where in the north the contour tends to extends south westwards, while in the middle part tend to extends north eastward and in southern part extend south westwards.

Magnetic anomaly contour pattern in the Dampier Strait exhibits an alignment lengthwise direction of the strait. This pattern is an indicator of deformation around Sorong Fault Zone in accordance with the publication of (Riandini *et al*, 2012). Seismic section in Figure 2 shows that the lineation of the bathymetric contour and geomagnetic at the Dampier Strait associated with the deformation of Sorong Fault Zones. In the seismic profile there is fault patterns in the form of flower sructure. Bottom Simulated Reflector (BSR) can be identified in the Dampier Strait, where it is usually associated with the presence of hydrates gas, or methane hydrate. Interpretation shows there are three clastic sedimentary rocks and two acoustic bedrocks. The lowermost seismic sequence is ophiolite possibly underlies the island of Waigeo and acoustic basement suggesting to underlies part of the Bird's Head of Papua.



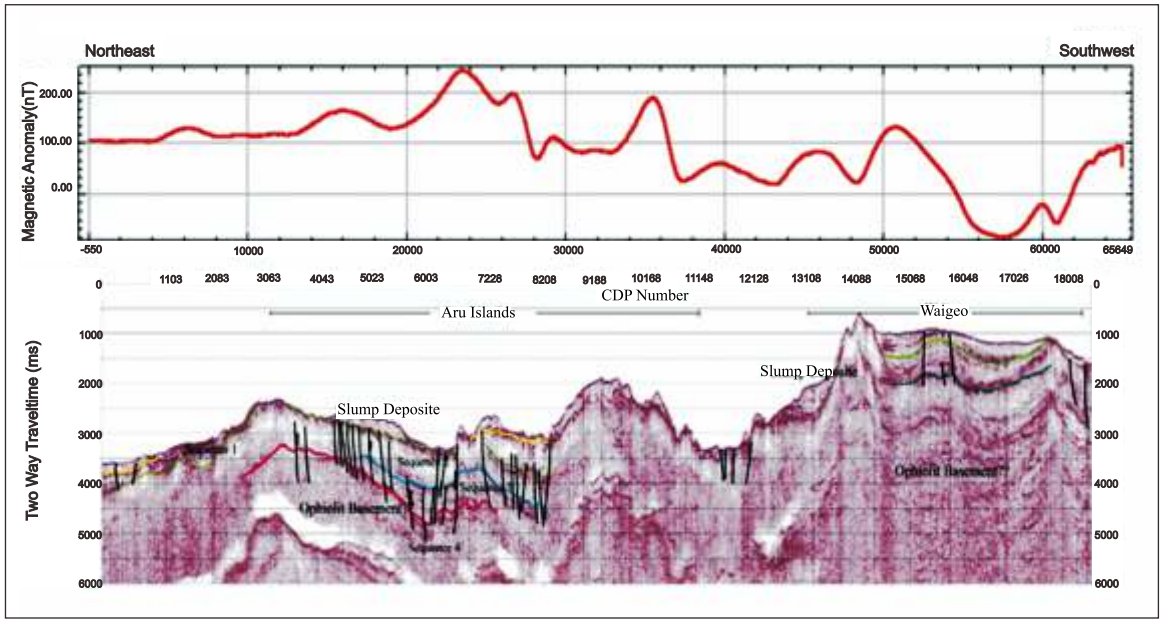
Source : Marine Geological Institute of Indonesia 2015

Figure 2. Seismic Line Waigeo - L01, For location see Figure 1.



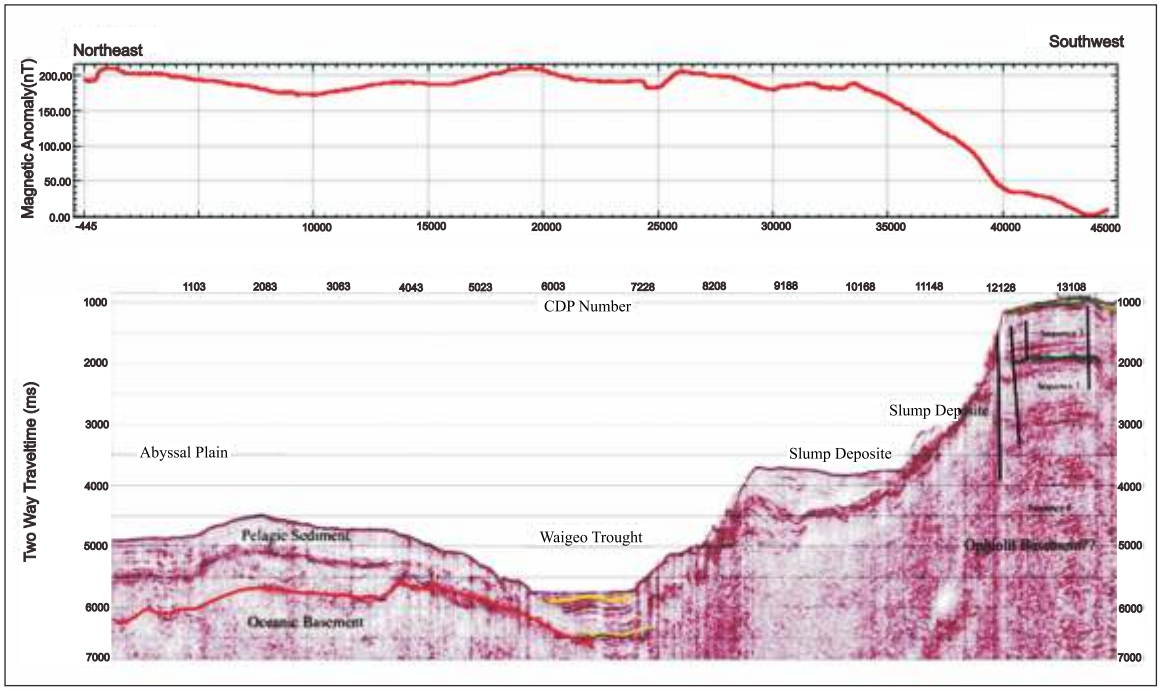
Source : Marine Geological Institute of Indonesia 2015

Figure 3. Seismic Line Waigeo - L15, For location see Figure 1.



Source : Marine Geological Institute of Indonesia 2015

Figure 4. Seismic Line Waigeo - L17, For location see Figure 1.



Source : Marine Geological Institute of Indonesia 2015

Figure 5. Seismic Line Waigeo - L21, For location see Figure 1.

DISCUSSION

Bathymetric and geomagnetic profiles indicate that the morphology of the northern offshore of Waigeo seem to be controled by compressional processes and differential uplift of basement rocks as response of the obliquely convergence between the Australian and Pacific Plates. The increased convergence between Papua and the Pacific plate associated with transform pressure, led to the uplift and the establishment of a regional unconformity across the Waigeo-Ayu Islands.

One of the most obvious characteristics of tectonic contact in the northern sector of the Waigeo is the occurrence of an east-west direction of escarpment topography with the steepness of >30° (Figures 2, 3 and 5). This steep escarpment associated with the normal fault with a northward dip in the form of pure dip-slip which resulted in compression perpendicular to the axis of Abyssal High (Ayu Islands ?). In some places, this steep escarpment acts as a local dike so that the sediment accumulated in the Waigeo Trough (Figure 3). This structural relationship indicates that the normal faults in the north Waigeo possibility subsided since the Late Miocene to Pliocene and perhaps until now as indicated in the Abyssal Pelagic of the Ayu Trough (Figure 3). An east-west trending steep escarpment topographic perpendicular to the abyssal high axis suggests due to the convex growth towards the Pacific Ocean during the occurrence of obliquely convergence and structural response to increase the Late Miocene compression varies along the Waigeo High.

According to Charlton *et al* (1991), in the northern Waigeo the beginning of impact between the Australian and the Pacific Plates has resulted in a reverse fault and back arc basin inversion. Towards the north offshore area of Waigeo, the increased size of obliquely convergence causing the lifting and folding on a large scale of sedimentary basin located at the outer troughs slope (represented by Ayu High/Archipelago ?). The Waigeo-Ayu Trough arc system limited by the traverse heights beyond the arc basin in the form of Ayu Islands with having east-west direction without the presence of fault offset of the main shear. This structural high is the limit with Ayu Trough System. This structural high turned into an east-west direction in the north Ayu Islands and marks the transition between the intra-oceanic arc system in the north and continental collision zone in the south.

CONCLUSION

Seismic reflection data obtained from the offshore northern Waigeo gives an idea of tectonic processes at least during Plio-Quaternary. Subsidence of the Waigeo Trough during the Plio-Quaternary suggested to have resulted in some sedimentary facies changes in the trough. Differential uplift of the Ayu Islands form a consistent submarine ridge to the north and act as a dike of the outer submarine ridge and tectonic border of the terranes.

Seismic record indicates that these units were likely deposited by gravitational movement spreading from the upper slope of the trough, probably triggered by ground shaking and/or uplift of the Waigeo Island. Such thicknesses of sediments filling in the Waigeo Trough are relatively normal on a strike-slip Ayu Islands beneath Waigeo Accretionary Prism (?).

The unconformities formed during Plio-Quaternary in the Waigeo Trough clearly shows differential uplift processes within the trough. Vertical movement of the base of the northern flank of the trough and the variations of sedimentary units that cover the unconformities suggests to be undergone various tectonic cycle events during the Plio-Quaternary. Relatively thick sediments in the trough at many ways are Plio-Quaternary slump-turbidites that mutually crop by slumping processes of sub-sequences thereon.

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