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Depositional Modification in Seram Trough, Eastern Indonesia

Modifikasi Pengendapan di Palung Seram, Indonesia Timur

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Abstract - Seismic reflection profiles considered to represent the morphotectonics of the study area and verified by surficial sedimentary data presented in this paper directed to understand the sedimentary depositional dynamics. Seismic data interpretation results show the gradation and sediment facies cycles in accordance with the episode of tectonic activities, which is characterized by the avalanche of the Seram Trough base-of slopes materials. Seismic data reveal more than 1250 meters acoustically chaotic to laminated, indicate fine-grained sediments between slumps at its base of slope and fine marine sediments at the trough floor. Thus, it suggests that the Seram Trough is in the process of differential vertical movement causing depositional modification due to the accretionary prism growths.

Keyword - Seram Trough, accretionary prism, depositional modification, slumps, turbidites, vertical movement.

Abstrak - *Penampang rekaman seismik yang dianggap mewakili morfotektonik daerah studi dan diverifikasi dengan data sedimen permukaan yang disajikan dalam tulisan ini diarahkan untuk memahami dinamika pengendapan sedimen. Hasil penafsiran data seismik menunjukan gradasi dan siklus fasies sedimen sesuai dengan episod aktivitas tektonik yang dicirikan oleh longsoran material lereng Palung Seram. Data seismik menunjukan lebih dari 1250 meter sedimen secara akustik kaotik hingga berlapis, mencirikan sedimen berbutir halus antara slam pada lereng bagian bawah dan sedimen marin halus pada lantai palung. Dengan demikian, diduga bahwa Palung Seram berada dalam proses pergerakan vertikal diferensial yang menyebabkan terjadinya modifikasi pengendapan karena adanya pertumbuhan prisma akresi.*

Kata kunci - *Palung Seram, prisma akresi, modifikasi pengendapan, slam, turbidit, pergerakan vertikal.*

INTRODUCTION

The Indonesian archipelago is located at the convergence of three major tectonic plates, the Indian-Australian Plate in the south, the Eurasian continental plate in the north, and the Pacific Plate to the east. Morphotectonically, the Indonesian land and waters is known as the Sunda-Banda Arc trench system dominated by a deep sea trench and outer arc/ accretionarry prism system which extend from west of Sumatra, south of Java and Nusa Tenggara until North Maluku. The arcs characterized by a series of morphologies such as submarine outer slopes, trench/trough, outer arc ridge/accretionary prism, fore-arc basin, volcanic arcs and back-arc basin.

One of the interesting submarine morphology in Indonesia is the present of a series of trench-accretionary prism system that extend from the Andaman Islands in the north-west, to the islands of Simeulue and Nias-Enggano west of the island of Sumatra. This system becomes a submarine system that extends at the southern waters of Java and Nusa Tenggara. However, this outer arc ridge raised above sea level and being part of the collision system between the Australian continental plate and the Banda Arc such as the islands of Timor and Seram (Kusnida *et al*, 2009). General geological characteristics of the Banda Arc consists of volcanic and non-volcanic arcs in the form of islands that formed especially of sedimentary, igneous and metamorphic rocks of Permian-Quaternary. The Banda Trough extends more than 2000 km from the Timor Trough in the west and then swing towards the northeast at the Kai Islands sector, turns to the west and ended in Seram Trough. The present of Seram Trough is still in debate whether it is a subduction zone that separates the Australian plate and the Eurasian or it is a foredeep (Pairault *et al,* 2003). However, there is also an opinion that the Seram Trough is a fault zone and a place of subduction of Bird Head to the south beneath Seram (Nugroho *et al,* 2009; Harris, 2011; Riandini *et al,* 2012).

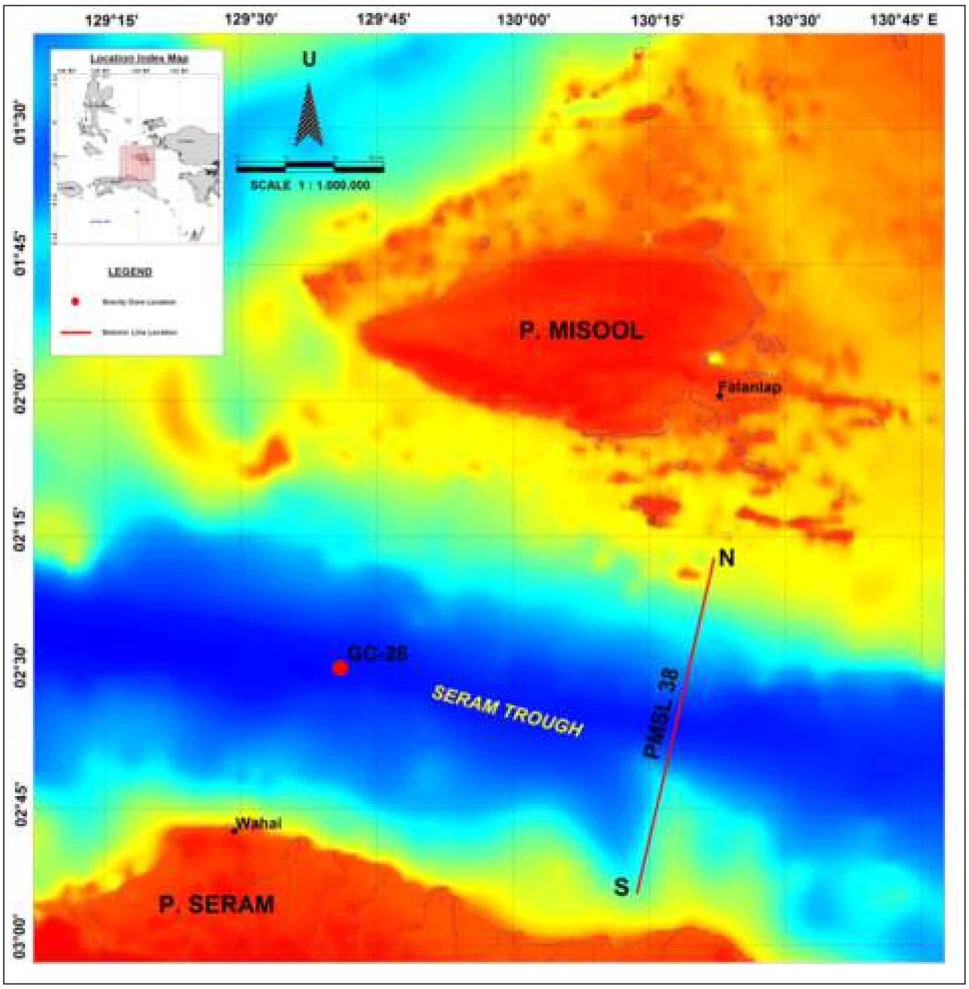
The Seram Trough precisely located between Seram and Misool Islands in the west of Papua Island. Seram itself suggested derived from Sula Spur continental crust in the form of a promontory located at the front of the Australian Plate that collided with parts of Sulawesi after Ceno-Tethys subduction beneath the eastern part of North Sulawesi Volcanic Arc-Philippines-Halmahera (Spakman and Hall, 2010). Colliding of Australia-Southeast Asia began 25 million years ago (Hall, 2011) and has continuing today. However, there are many different models of Neogene tectonic evolution of this 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 (Darman and Reemst, 2012; Pownall *et al,* 2013). Current seismicity and structure on the island of Seram and Seram Trough showed a reverse fault activity to the north, which began since the Pliocene (Liu and Harris, 2013; Pownall and Hall 2014). Furthermore, Pownall and Hall (2014) stated that the Seram keeping records of extreme stretching process during the Neogene up to 2 million years ago. The evidence of these stretch events indicated by the presence of unusual very young igneous and metamorphic rocks, and at the offshore characterized by the present of basins that filled by deep-sea sediments.

In the area of convergence between the earth's plates as well as in Indonesia, both the convergence of tectonic subduction or of tectonic collision, trough or trench is an important element of submarine morphotectonic because it is the place of the very strong accumulation of frontal deformation (Nguyen *et al,* 2013; Moore and Karig, 2015). In this trough, a very complex interaction between sedimentation and tectonic processes occurred that often become the object of research both for scientific and academic interests. In the Seram Trough system where the sedimentary rocks of the Australian continental shelf being eroded and grow at the base of the inner slope of the trough forming a Seram Accretionary Prism. During the ongoing deformation in the bottom of the trough, there are also some moving reverse faults that become passive and buried by sediments filling. The sedimentary rocks deposited and covered this mélange, tectonically hypothesized as ancient trough slope deposits (Hall and Spakman, 2015).

In the framework of marine geological and geophysical mapping, Marine Geological Institute carried out a study in the Misool-Seram waters in 2014, precisely at the coordinates between 1°00'00"- 3°00'00" S and 129°00'00 "- 130°30'00" E (Figure 1). The aim of this study is to obtain a marine geological and geophysical database. The main purpose of this paper is to know the characteristics and depositional cycles in the Seram Trough and its geological factors.

METHODS AND TECHNIQUES

Marine multichannel seismic reflection data acquisition carried out by using SERCEL Seal Streamer with a length of 600 meters, which is composed of four active sections (ALS) with 48 active channels.



Source : Map source, Gebco 2014

Figure 1. Map of the study area indicate seismic line PMSL-38 and core sample GC-26 locations

Sleeve I/O capacity of air-gun array 530 cu.inch with a power output of 1000 psi, which supplied by the Marine Controller Geometric Computer used as a sound source. Quality control of recording during the survey carried out by using the IBM workstation software eSQCPro System. Seismic data recording parameters applied are the Low Cut Filter 3 Hz; High Cut Filter 400 Hz; Sampling Rate of 2 milliseconds; and Record Length 12 seconds. Seismic data processing executed by using promax 2D software version 3.3.2003. Stratigraphic framework divided into several seismic interval based on the sequence boundary and facies analysis. Surficial sediments sampling taken by using gravity corer equipped with machines and rollers winch wire sling size of 12 inch. The navigation system in the study area carried out by the Differential Global Positioning System (DGPS) using software EIVA A/S NaviPac. The transducer using Chirp Sub-bottom Profiler Bathy 2010 frequency 3.5 kHz measured the water depth and Sub-Bottom Profiling (SBP).

RESULTS AND DISCUSSION

Figure 2. indicates that the Misool Platform edge bends and subducted beneath the Seram Accretionary Prism. The Seram Trough floor lies at a water depth of more than 2000 meters with a width of 5000 meters and the thickness of trough sediment fill of about 1250 meters. The outer slope of the trough seem to very gentle until the edge of the Misool Platform subducted, in contrast, the inner slope of the trough seem to very steep. Seram Accretionary Prism forms a wedge with its angle leaned southward. A small portion of the uppermost sediment layer of the Misool Platform scarped and lodged in the frontal deformation zone, while almost the entire of the Misool Platform subducted beneath Seram Accretionary Prism and slip into the mantle. This accreted materials not only fill the Seram Trough but also in time is uplifted above sea level to be a part of mainland of Seram.

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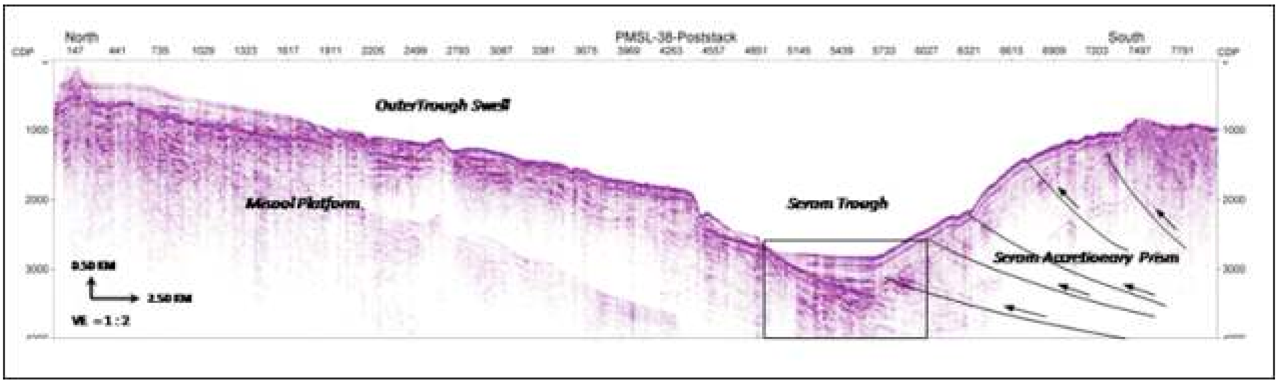

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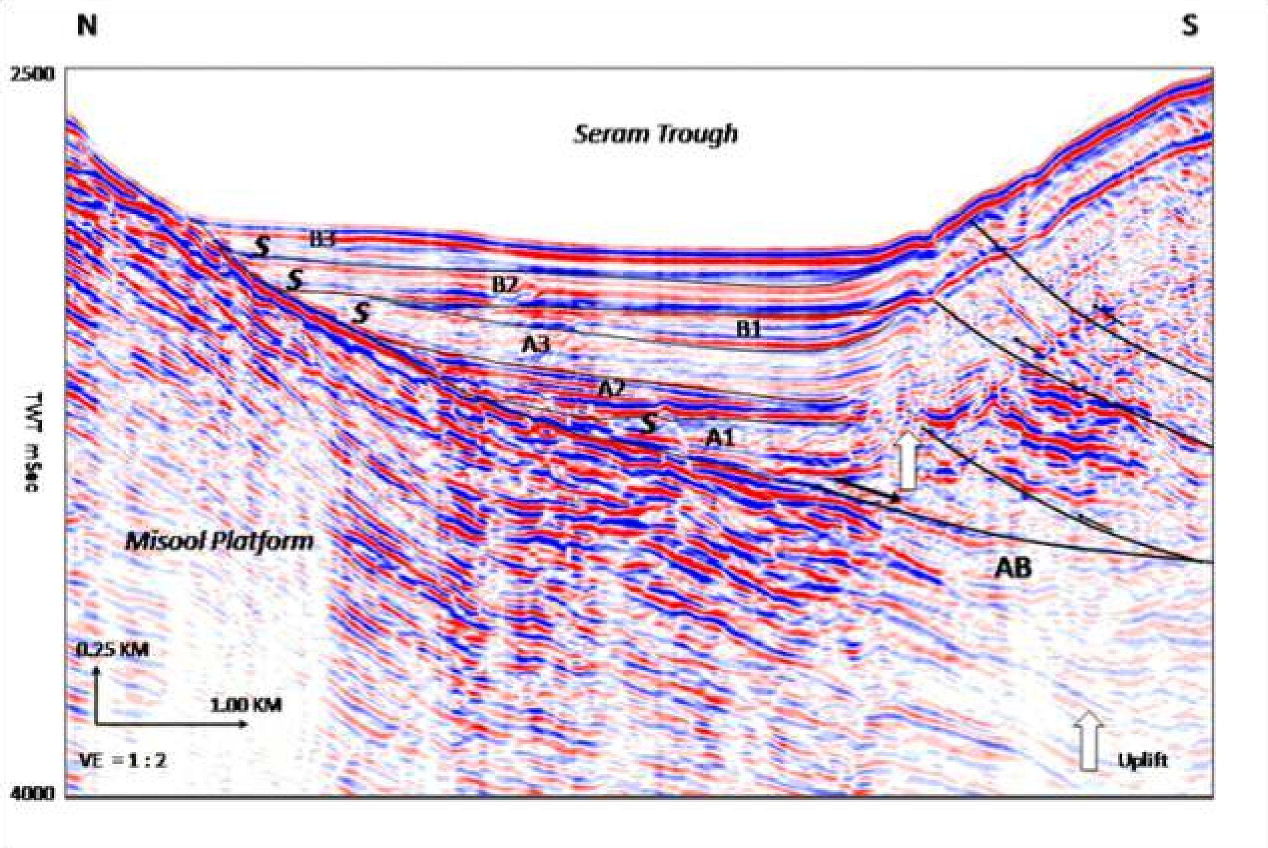
Figure 2. Seismic line PMSL-38. Rectangular box indicates detail seismic produced in Figure 3.

At the upper part of submarine slope of the Misool Platform (Figure 2.), an east-west orientation of submarine ridge form a diapiric structure with a reflection pattern of mound is present. Mound reflection pattern seem to be isolated body, as a dyke and locally grow up to 100 meters from the surrounding sea floor. In some parts, this phenomenon lies at a depth of maximum 750 meters below sea level. General explanation of this phenomenon is that the possibility outer trench/trough swells at the surface of the sea floor. Outer trench swell is a small ridge at the sea floor close to the trench/trough where the continental plate began to bend, downward and faulted in the framework of subducting towards mantle at the subduction zone (Ogawa *et al*, 2011; Moore and Karig, 2015).

Seismic reflection profile (Figure 3.), in general provides information on stratigraphy of sediment fill of the Seram Trough and its relationship with geological factor that control it. Based on the order, the seismic sequence *AB* characterized by strong, continuous reflectors that passes up into sediments with strong, regular, and laterally continuous reflectors. In the Seram Trough, at least two main seismic sequences are identified those are sequence *A* and *B* suggested of Plio-Quaternary. All seismic sequences in the Seram Trough seem to undergo a differential uplifting especially at onlap/downlap contact at both flanks of the trough. Detail examination of the seismic record shows that differential uplit processes take place continuously since seismic sub-sequence *A1* until sub-sequence *B3* deposited where it characterized by divergent reflector configuration within all seismic sub-sequences filling the Seram Trough.

At the lower slope of the Seram Trough, seismic sequence *AB* overlain by seismic sequence *A* that has accoustic characteristics nearly the same with seismic sequence *B*. Accoustically, seismic sequence *AB* from this zone is a rock strata of relatively massive and faulted, representing the acoustic basement. Rock units of each sub-sequence *A1-B3* suggest the gradation of slump (S) at the slope of the trough into turbidite deposits up to possibly pelagic deposits at the center of the trough floor. Rock unit that possibly correspond to trough slope deposits is lumpy-blocky elements. The sequence of slump deposits at the outer slope of the trough, which is proximal facies in each sub-sequences *A1-B3* characterized by a high frequency turbidite deposits, possibly as the respond of uplift activities of trough floor due to the accretionary prism growths, which then resulted the instabilities at trough flanks. Blocky and lumpy slumps deposits are sediment facies that dominate the lower part of the outer slope of the Seram Trough.

Seismic sequences *A* and *B* comprise ± 1250 meters with stronger chaotic reflections that concentrated at base-of-slope of the outer slope and continuous regularly reflecting sediment towards the center of the trough. In the trough, seismic sequence *A* represents older and sequence *B* represents younger trough sediments. At the inner base-of-slope of the trough, seismic sequence *A* and *B* characterized by a high degree of deformation, which is possibly consistent with its long history of vertical differential movement, burial, and deformation where its internal structures in these units are poorly preserved. The concave-upward segments of void reflector in the southern flank of trough intrude seismic sequences *A* and *B* where some of which represent reflections of uplift zones. Seismic sequence *A* comprises a repetition of sub-sequences *A1-A3* as units of accoustically intercalated sediment with markedly a weakly and chaotic reflectors at base-of-slope segments and a distal unit of stronger, more continuous reflectors showing repetition of possibly intercalated by a fine grained sediment at the floor of the Seram Trough. In the outer slope area, sub-sequence *A1* characterized by



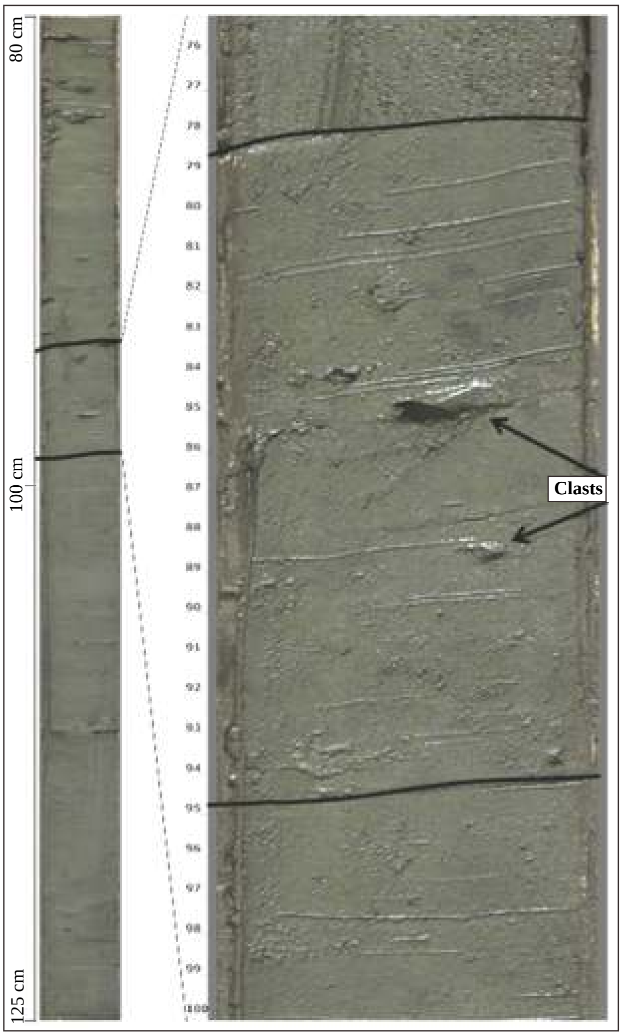
source : Marine Geological Institute of Indonesia 2016

Figure 3. Close up of seismic section pointed in rectangular box in Figure 2. Note ***S*** letters indicate cycles of sedimentary units consist of slumps facies; AB is referred to the uppermost strata of Misool Platform; A1-A3 and B1-B3 are referred to seismic sub-sequences of the Seram Trough sediment fills discussed in the text.

chaotic-transparent to laminated reflectors at deepest floor of the trough. In some area pockets of slumps are present. The system of slump deposition of sequence *A1* at lower of outer slope of the Seram Trough is controled by vertical differential movement of Seram Accretionary Prism (thrusting). *A* clear, continuous, paralel and southward downlap of internal reflectors of sub-sequence *A2*, indicates that seismic sub-sequence *A2* is a gradation of slump at northern base-of-slope to debrite/turbidite and pelagic deposits at the center of the trough. The whole sub-sequence *A3* is characterized by a continuous chaotic reflectors and in some areas suggest as buried lumpy block sediments. Sub-sekuen *A3* suggests as deposit characterized the end of high tectonic activities which took place within a long period of time that possibly also marked of the end of Pliocene.

Seismic sequence *B* in general is characterized by parallel and continuous reflectors, but at the lower slope of the trough is found a weakly to chaotic reflector pockets. Seismic sequence *B* comprises a repitition and nearly uniform of sub-sequence thickness in the entire area, but it thickened and in the form of parallel to divergent reflector facies particulary at the center and deepest part of the trough. Reflector facies relatively parallel and in some areas in the form of repitition of continuous layers suggest as a fine grained sediment. In some areas, seismic sequence *B* can be divided into sub-sekuen *B1*, *B2* dan *B3*. The third sub-sequence is a succsesion of repitition of slump-turbidite deposits. Seismic sub-sequence *B3* is the lowest which characterized by a prograded chaotic and wedged reflectors. Several packages of filler reflectors lies unconformably on seismic sequnce *A* with a various elevation of isolated base-of-slope sediments.

A gravity core of GC-26 (Figure 4.) with a length of 210 cm obtained from the floor of the trough at a water depth of 2320 meters and at coordinate of 129°04'00.47" E, 02°29'30.80" S, shows that the surficial sediments generaly consists of dark greenish grey 10Y 4/1 soft sandy clay. At a various core depth is found a bioclastical clasts of possibly part of debris; carbonaceous and contains mafic mineral of < 5%. Slump clast is found at a core depth between 79-95 cm in the form of greenish gray 2/1 stiff and plastic wedge of clay.



source : Marine Geological Institute of Indonesia 2016

Figure 4. Core GC-26 shows a slump facies at depth 79-95 cm from the trough floor, composed of greenish gray 2/1 stiff and plastic wedge of clay. Note bioclastic clasts within slump deposits

The slump avalanche of seismic sequence *A* of Quaternary which incised and burried seismic sequence *B* of Pliocene underneath, relativelly indicates both subsidence of base of trough and uplift of accretionary prism processes. Quaternary regressive surface of base of trough (sub-sequence *B1*), represents a regional and continuous unconformity above the Pliocene deposits in the Seram Trough suggesting dominantly caused by a tectonic uplift rather than by ice-dynamical response as occurred in most regions such as studied in Disko Trough (Hogan *et al*, 2015). Offlap above Pliocene sediment eroded by a Quaternary sequence may be a part of the uplift tectonic system that occurred in the Seram Trough. The Quaternary deposit is a fairly thick sediment covering in most of the floor trough as wide as 5 km southward. Unconformity separating the sequences A and B may indicate a regressive or uplift of base of the trough that separates Pliocene and Quaternary sediment units which are continuously until now.

CONCLUSION

Seismic reflection data obtained from the Seram Trough give an idea of sedimentation processes during Plio-Quaternary. Vertical movements of the trough during the Plio-Quaternary suggested to have resulted in some unconformities and sedimentary facies changes in the trough. Differential uplift of the Seram Accretionary Prism formed a consistent submarine ridge in the southern flank of the trough and acts as a dike and the border of onlap/downlap sediment filling into the trough.

Sediment core record indicates that these units were likely deposited by gravitational movement spreading from a base of slope, probably triggered by ground shaking and/or uplift of the Seram Accretionary Prism. Such thicknesses of sediments fill in the Seram Trough are relatively normal on a downgoing the Misool Platform beneath the Seram Accretionary Prism and indicate a significant turbidities masses production in the central of the trough floor.

The unconformities formed during Plio-Quaternary in the Seram Trough clearly shows a differential uplift processes within the trough. Vertical movement of the base of the southern flank of the trough and the variations of sedimentary units that cover the unconformities suggested to be undergo various tectonic cycle events during the Plio-Quaternary. Relatively thick sediments in the trough in many ways are Plio-Quaternary turbidites that mutually cropped by slumping processes of sub-sequences thereon.

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