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Sediment Core from the Seafloor of Aru Trough, West Papua - Indonesia

Inti Sedimen Dasar Laut Palung Aru, Papua Barat - Indonesia

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Abstract - Results of multi-sensor core logger (MSCL) measurement on single sediment core from Aru Trough are presented to depict the general pattern of seafloor sediment to its physical and chemical characteristics. Microscopic observations of the core generally show the presence of shell fragments and foraminiferas, mafic minerals and organic residuals of blackish-brownish lignite. The physical characteristics of sediment core shown by natural gamma and magnetic susceptibility values indicate that the sediment fill derived and associated with the terrigenous sediment type. The gradually change of velocity gradient of the core may reflect a change from a relatively consolidated sediments at the upper part to poorly consolidated sediments at the lower part. The sediment characteristics of core sample with L* (lightness) data are mainly related to iron oxyhydroxides zones. The occurrence of relatively high terrestrial elements in sediment core sample (in ppm) i.e. Ti, Fe, K, Mn and K/Ca, indicate a darker sediments. XRF data shows that Th/U ratios and high K content in the Aru Trough seems to the presence of potassium feldspars or micas and the occurrence of black shale deposits.

Keyword : Sediment core, MSCL, lithostratigraphy, natural gamma, electrical resistivity, magnetic susceptibility, P-wave velocity, color spectrophotometry, XRF

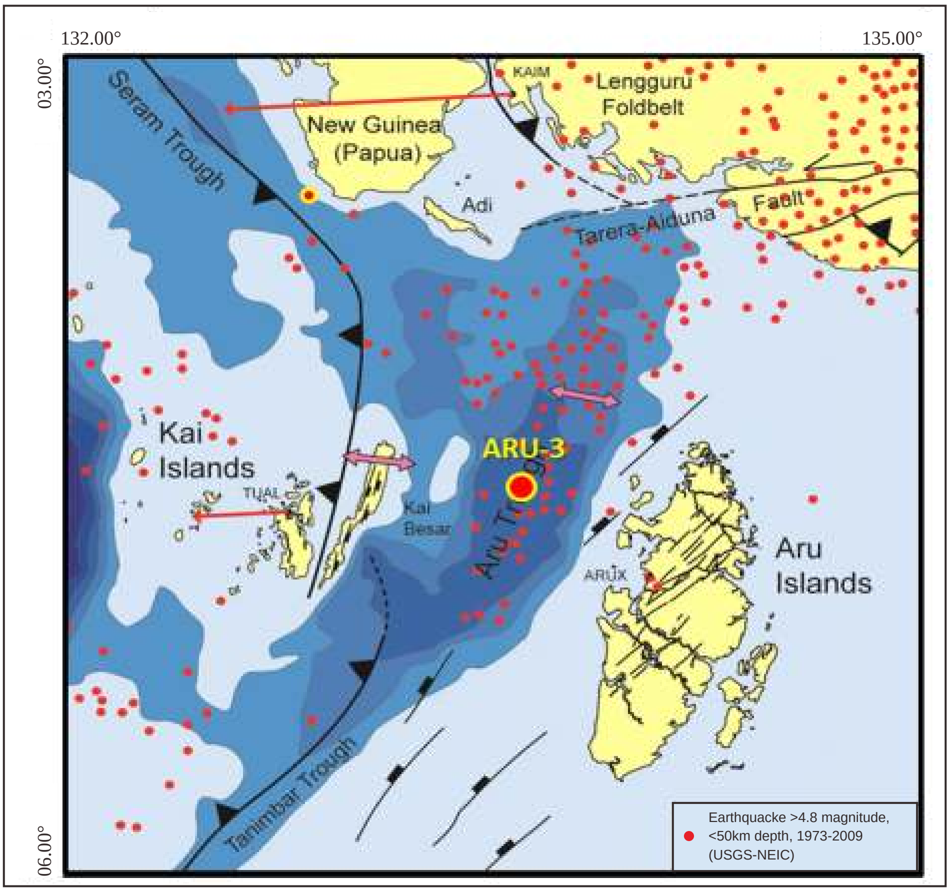
Abstrak *- Hasil pengukuran multi-sensor core logger (MSCL) inti sedimen tunggal dari Palung Aru disajikan untuk menggambarkan pola sedimen terhadap sifat fisika dan kimianya. Pengamatan mikroskopis inti sedimen umumnya menunjukkan adanya fragmen cangkang kerang dan foraminiferas, mineral mafik dan residu organik dari lignit berwarna coklat kehitaman. Karakteristika fisika inti sedimen yang ditunjukkan oleh nilai natural gamma dan kerentanan magnetik mengindikasikan bahwa kandungan sedimen berasal dan terkait dengan jenis sedimen daratan. Perubahan gradual gradien kecepatan rambat gelombang pada inti sedimen mencerminkan perubahan dari sedimen yang relatif terkonsolidasi di bagian atas menjadi sedimen yang kurang terkonsolidasi di bagian bawah. Karakteristika sedimen pada sampel inti dengan data L* (lightness) utamanya terkait dengan zona oksida besi. Kemunculan unsur terestrial yang relatif tinggi pada sampel inti sedimen (dalam ppm) yaitu Ti, Fe, K, Mn, dan K/Ca, menunjukkan sedimen yang lebih gelap. Data XRF menunjukkan bahwa perbandingan Th/U dan kandungan K yang tinggi di Palung Aru kemungkinan terdapatnya feldspar atau mika dan endapan serpih hitam.*

Kata Kunci: *Inti sedimen, MSCL, stratigrafi batuan, natural gamma, tahanan listrik, kerentanan magnetik, kecepatan gelombang P, spektrofotometri warna, XRF.*

INTRODUCTION

Eastern Indonesia with the Arafura Platform acting as continental core and so called as the Banda Arc Complex is generally of dominated by deep waters systems, where among those the Aru Trough is located. The Aru Trough (Figure 1) is characterized by a bathymetric low of a slightly below 3500 meters water depth. Physiographically, to the west the trough is bordered by Kai Islands, to the east it is bordered by Aru Islands and to the north-northeast by Kamarau Bay of the mainland Papua. The Aru Trough is a complex basin of nearly semi-cycle shaped depocenter, which extend northeast-southwest orientation. It lies in the deformation complex region, within a junction of the Tarera-Aiduna fault in the north, the Banda collision zone in the west represented by the north-south orientation of Kai Ridges. The Aru Trough is geologically considered less studied and relatively unknown particularly on seafloor sediments and so far never has been studied and discussed in detail and it is remains poorly understood. Study of Jongsma *et al*. (1989) has recognized it is an extensional rather than compressional origin for the Aru Trough. However, according to Charlton *et al*. (1991), the Aru Trough can be considered as part of four outer trough segments extends from the Timor, Tanimbar, Aru and Seram Troughs, where in cross-section they have many structural characteristics of subduction trenches, and have generally been interpreted in terms of subduction processes.

Marine geological survey in the Aru Trough has been executed by Marine Geological Institute of Indonesia in 2016. The purpose of this study is to conduct geological and geophysical mapping in the Aru Trough as a frontier area to obtain preliminary geological resource data. The aim of this study is to examine the physical and chemical characteristics of deep seafloor sediments of the Aru Trough with considerable interest for scientific and academic purposes such as studies of Debret *et al.* (2006), Balsam *et al*. (2007); Hendrizan *et al*. (2016) and Nurhati (2016) who's particularly using high - resolution spectro photometry. For these reasons the core ARU-03 was taken at site on the sea floor of the basin at a water depth of approximately 3543 m from a coordinate 5°24'07.48" S; 133°46'25.02" E, with core length reaches 226 cm.



Map source: http://www.timcharlton.co.uk/other-projects/regional-tectonics

Figure 1. Map of Aru Trough and location of sediment sample ARU-03.

DATA ACQUISITION AND METHODS

Seafloor sediment samples from the Aru Trough were obtained in 2016 by using gravity corer assembled on RV Geomarine III. Bathymetric measurement in the study area was carried out by using sub-bottom profiling (SBP) Chirp Sub-bottom Profiler Bathy 2010, which works at frequency of about 3.5 kHz as echo sounder. The navigation system during the survey in the study area was carried out by mean the Differential Global Positioning System (DGPS) C-NAV using EIVA A/S NaviPac software. Multi Sensor Core Logger (MSCL) that applied on sediment core sample ARU-03 consist of natural gamma, electrical resistivity, magnetic susceptibility, P-wave velocity, color spectrophotometry and XRF. Measurements with natural gamma and electrical resistivity sensor were performed on the core, while four other sensors logging applied on sample that has been splitted. Megascopic description was intended to find out the sediment type whether it is clastic sediments or it is not. Microscopic description however, has been done on board during the cruise both from the top and bottom of the core samples to sharpen the megascopic description especially to obtain a more detail of major components of the sediment, such as mineral content (light and mafic minerals) and carbonate content in the form of shell or fossil fragments.

RESULTS

Lithostratigraphy of the Seafloor Sediments

Gravity core shows that the surficial sediments generaly consists of dark greenish gray 10Y 4/1 soft silty-clay. Microscopic observation of sediments extracted from the top and bottom of core Aru-03 (Figure 2) in general include fine-grained sediments, particularly silty clays and locally found dark silty clays. The sediments examined from core ARU-03 can be classified as terrigenous, or as pelagic sediments that consists mostly of skeletal remains of microorganisms both terrigenous and biogenic. At a various core depth the bioclastical clasts of possibly part of detritus (?) are found; carbonaceous and content of mafic mineral < 5%. Smear slide of top of core ARU-03 characterized by gray, dominantly clays of about 80%, and 20% of fine-grained fragments, loose, weathered, consist of mafic minerals (*m*) and shell fragments (*f*). While the bottom of core ARU-03 is characterized by gray, dominantly clays (0.5 - 1 nm) of about 99%, and 1% of fine-grained fragments consist of foraminiferas (*f*), mafic minerals (*m*) and residual lignite (*l*).

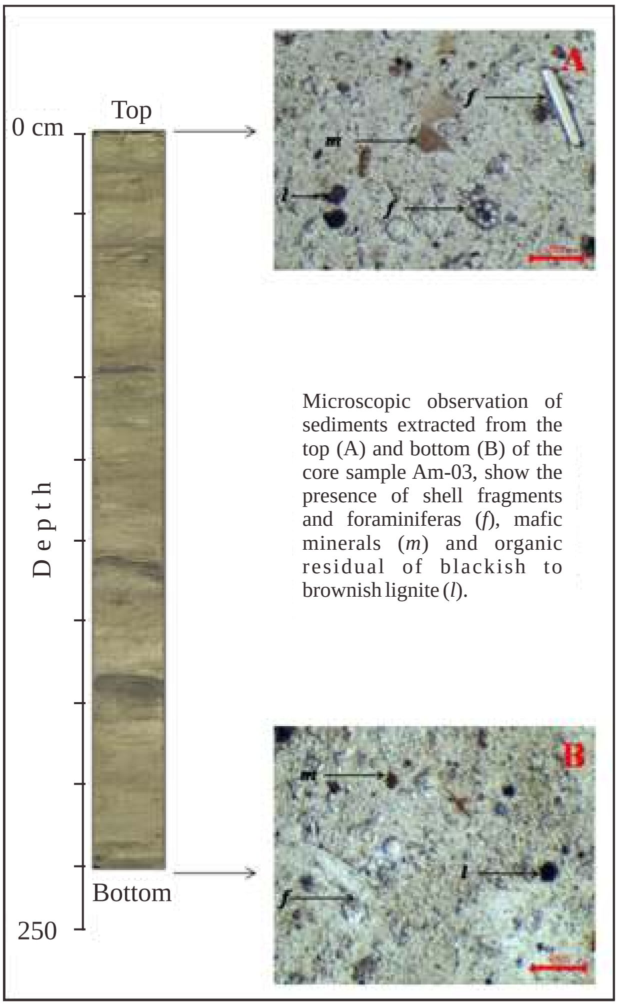


Figure 2. Smear slide of top (A) and bottom (B) of core Aru-03

Multi Sensor Core Logger Records

The result of natural gamma measurement on sediment core ARU-03 (Figure 3b) indicates a uniform values and trend, those in the range of 32-38 cps (count per second). Meanwhile, the resistivity measurement in core Aru-03 (Figure 3c) shows a range of values from 0-0.006 Ohm-meters with the mean ranges of values per samples not much different. At core depth of 0.05; 1.2 and 2.2 meters respectively show that the values of electrical resistivity (ER) are 0.01; 0.012 and 0.007 Ohm-meters. Furthermore, results of magnetic susceptibility measurements on the core ARU-3 (Figure 3d) show a fairly varied range of values those are - 0.86–40.53 Six10^{-5}. The difference of maximum value of magnetic susceptibility in sample ARU-03 occurs at depth of 180-185 cm and 195-200 cm, indicated by high magnetic susceptibility spikes (for detail the reader is referred to Figure 4).

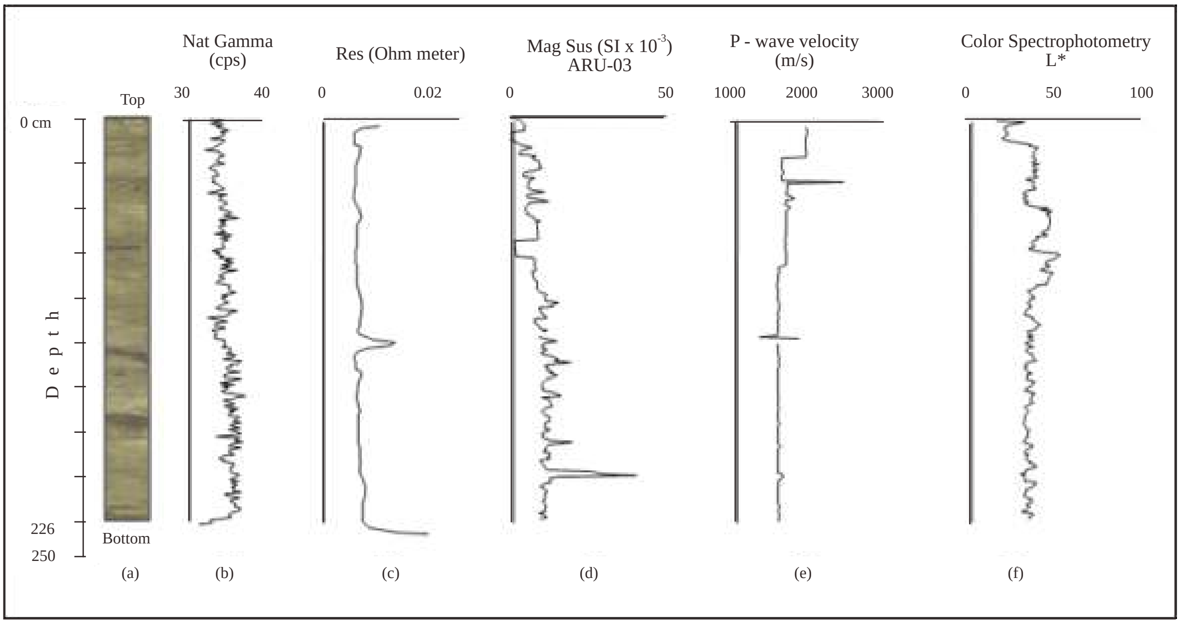


Figure 3. Graphics combination of core ARU-03, natural gamma, electrical resistivity, magnetic susceptibility, P-wave velocity, and color spectrophotometry respectively.

Table1. Maximum content of XRF measurement elements

Element (ppm)	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As
	8227.2	70052.5	11756.7	35061.6	2314.25	47.17	188.59	492.92	18361.5	9.31	64.81	74.96	191.75	7.57

Element (ppm)	Se	Rb	Sr	Y	Zr	Mo	Ag	Cd	Sn	Sb	W	Hg	Pb	Bi	Th	U
	2.01	68.58	302	17.54	568.05	6.35	57.96	24.21	22.44	28.38	9.77	5.62	470.25	13.91	14.44	10.07

Results of P-wave velocity measurement on sample ARU-03 from depth of 20-226 cm (Figure 3e) indicate the relatively uniform of values that is about 1500-1800 m/sec. However at depth of 0-20 cm it shows a velocity of 2000 m/sec and about 2600 m/sec at depth of 35-40 cm. Therefore, density level of sample at these depths possibly is much higher than the other depth levels. On the graph can also be observed the presence of anomaly with value of 1850 m/s that possibly caused by the cavity at depth between 120 cm 125 cm which then causing the P wave velocity decreased dramatically.

In our study, the color spectrophotometry graph of sample ARU-03 (Figure 3f), shows that L* values tend to increase from core depth 0 cm down to 75 cm, from 20 to 55. Furthermore, from core depth of 75 cm down to 226 cm, the L* values tend to decrease from 55 to 35 in average.

XRF

The number of elements measured by XRF method were 31 elements (Table 1), with units of ppm (part per million) measurement. From all elements measured, only the P (Phosphor) element that cannot be detected by the sensor and this is due to limits of detection in detecting elements that have low atomic mass, so that the reading of P element content is negative. In core ARU-03, the concentrations of U = 10.07 ppm (>5ppm), K = 12006.7, Th =14.44 and Th/U ratios = 14.44/10.07 = 1.44 (<2).

DISCUSION

The brownish gray surficial sediments from the Aru Trough composed largely of clay minerals possibly can be classified as terrigenous. As pelagic sediments, it consists mostly of skeletal remains of microorganisms both terrigenous and biogenic. Microscopic observations of sediments extracted from the top and bottom of the core ARU-03 (Figure 2) shows the presence of shell fragments and foraminiferas (*f*), mafic minerals (*m*) and organic residuals of blackish-brownish lignite (*l*).

Two thin dark sediment layers found at depth 180-185 cm and at depth of 195-200 cm in sample ARU-03 (Figure 4) suspected to be volcanic ash deposits are possibly derived from the adjacent island arcs and marginal trough. These dark layers are found as stiff and plastic wedge of dark clays may correspond to iron oxide minerals (?Schon, 2015). These volcanic ashes are mostly deposited as tephras where the ash that has been ejected during an eruption and carried by wind and settled out through the atmosphere and oceans as pelagic sediment. According to Griggs *et al*. (2015), tephra (vitreous volcanic ejecta) deposits have been identified in a number of disparate sedimentary contexts and when traced between sequences, act as time-synchronous marker horizons to establish independent and precise tie points between paleoenvironmental records. Hendrizan *et al*. (2017) in their studies of sediment characteristics of the Sulawesi Trough using MSCL method also indicate two darker-colored sediments at depths of 70-100 cm and 135-195 cm interspersed within the brighter colored sediments. However, these authors do not mention the possibility of such sediment intersperse as the tephras neither the ages nor the origin.

Meanwhile, the natural gamma-ray (NGR) spectrometry that allows estimation of the elemental concentrations of K, U, and Th, confirmed the cps value with range of 32-38 cps of core ARU-03. It is interpreted associated with terrigenous sediment type or weathered rocks dominantly that were transported and deposited on the seafloor (Rothwell and Rack, 2006). Most interpretations of spectral-gamma ray logs focus on the relationships between the three elemental concentrations; in particular, Th/K and Th/U are often used for petrophysical interpretation and log correlation (Hall, 2012). In calculating Th/K and Th/U ratios, Schlumberger (2017) uses the following cut-offs: if uranium < 0.5 then uranium = 0.5; if potassium < 0.004 then potassium = 0.001. According to Hall (2012), high K values may be caused by the presence of potassium feldspars or micas. Glauconite usually produces a spike in the K log. High Th values may be associated with the presence of heavy minerals, particularly in channel deposits. Increased Th values may also be associated with an increased input of terrigenous clays. Increases in U are frequently associated with the presence of organic matter. For example, according to the ODP, particularly high U concentrations (> 5 ppm) and low Th/U ratios (< 2) often occur in black shale deposits. Since in core ARU-03 the concentrations of U = 10.07 ppm (>5ppm), K = 12006.7, Th =14.44 and Th/U ratios = 14.44/10.07 = 1.44 (<2), then it seems to correspond with the ODP of Hall (2012) which indicate the occurrence of black shale deposits, or it is possibly related to the occurrence of suspect "shale volcanic" beneath the Aru Trough interpreted from seismic reflection profiles and magnetic records (Subarsyah, pers.com., 2017).

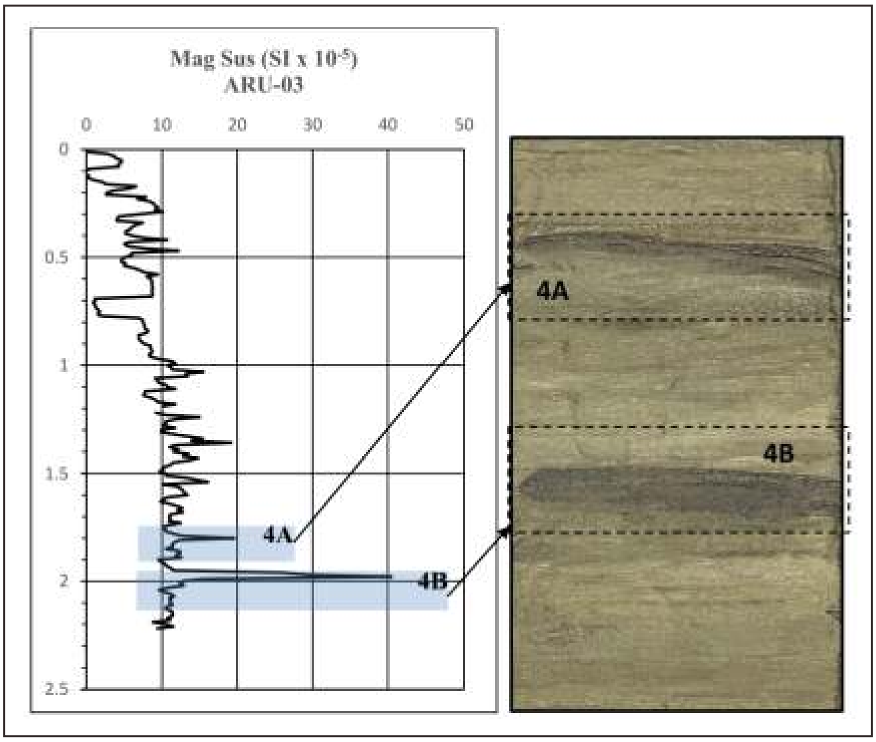


Figure 4. Correlation between magnetic susceptibility spikes with suspect dark minerals lenses (probably iron oxide minerals?) (4A and 4B) in core samples.

MSCL record also indicates the values of spikes that gradually downwards that may indicate interspersion of sedimentary layers with relatively high resistivity properties associated with clay layers with high levels of consolidation and compaction. The high resistivity value of sample of ARU-03 also corresponds to the results of the megascopic description, *i.e.* clays dominant. Besides that, the gradually change of velocity gradient in core ARU-03 may reflect a change from a relatively consolidated sediments above 45 cm to poorly consolidated sediments below 45 cm. Variations in P-wave velocity (P-wave) are affected by the lithology, porosity and density of the measured material, the material's ability to receive pressure, rigidity, and fracture conditions. In marine sediments, velocity is also controlled by levels of consolidation and sediment litification (Schon, 2015). Results of P-wave velocity measurement on core ARU-03 indicate the relatively uniform and correspond with general value of velocity of recent–subrecent sedimentary rocks of the seafloor (Harry and Batzle, 2004).

Spectrophotometric measurements of core ARU-03 indicate that the L* data show a range of 20-55. According to LibreTexts (2017), the lightness, L*, represents the darkest black at L* = 0, and the brightest white at L* = 100. The darker sediments are characterized by the physical properties *i.e.* lower L* value, high magnetic susceptibility, low normalized ratio of (K/Ca), and lower P-wave velocity. In contrast, the brighter sediments show the physical properties i.e. high L* value, low magnetic susceptibility, high normalized ratio of (K/Ca), and low P-wave velocity as well as higher characteristic of terrestrial elements. L* (lightness) data = 20 are mainly related to iron oxyhydroxides zones where chemical compounds that commonly form in aqueous regions and subaqueous areas isolated from the oxic atmosphere of earth (Guimarães *et al*., 2013). Therefore, spectrophotometric measurements in the Aru Trough possibly provide significant information about substrate conditions and the formation of sediment deposits. Based on spectrophotometric measurements, the sediment color of core Aru-03 possibly directly related to its mineralogical and chemical composition including Ti, Fe, K and Mn. The occurrence of relatively high terrestrial elements in core Aru-03 (in ppm) *i.e.* Ti = 2314.25; Fe = 18361.5; K = 11756.7; Mn = 492.9 and ratio of K/Ca = 11756.7/35061.6 = 0.335, indicate low characteristics in the darker sediments. The sediment characteristic at core ARU-03 is supposed due to the amount of terrestrial input from Papua, Aru Islands and Kai Islands.

CONCLUSION

The physical and chemical characteristics of sediment core from the seafloor of the Aru Trough revealed by multi sensor core logger (MSCL) lead to the opinion that it possibly can be classified as terrigenous, derived from mainland Papua, Aru Islands and Kai Islands. Interspersion of sedimentary layers with relatively high resistivity properties associated with clay layers with high levels of consolidation and compaction seems to indicate the occurrence of black shale deposits. Two thin dark sediment layers found as stiff and plastic wedge of dark clays at depth 180-185 cm and at depth of 195-200 cm suspected to be volcanic ash deposits (tephras) derived from the adjacent island arcs and marginal trough and may correspond to iron oxide minerals. Spectrophotometric measurements L* (lightness) data are mainly related to iron oxyhydroxides zones and provide significant information about substrate conditions and the formation of sediment deposits. In contrast, the brighter sediments show the physical properties *i.e.* high L* value, low magnetic susceptibility, high normalized ratio of (K/Ca), and low P-wave velocity as well as higher characteristic of terrestrial elements. The occurrence of relatively high terrestrial elements in core Aru-03 (in ppm) *i.e.* Ti, Fe, K, Mn and K/Ca, indicates low characteristics in the darker sediments.

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