CHARACTERISTICS OF GAS SHALE IN DAKEBO FORMATION, AT WAGHETE AREA - PAPUA PROVINCE

KARAKTERISTIK SERPIH GAS DI FORMASI DAKEBO, DAERAH WAGHETE, PROVINSI PAPUA

Robet Lumban Tobing
Center for Geological Resources
Jl. Soekarno-Hatta No.444 – Bandung, Indonesia
Email: trebor_dim@yahoo.co.id

Diterima : 26 Februari 2015 *Direvisi : 22 April 2015* *Disetujui : 4 Mei 2015*

ABSTRACT

Dakebo Formation is found in Akimeugah Basin. The formation is interpreted as Pliocene in age and it is sedimented on alluvial fan and flood plain environment, composed by conglomerate, sandstone, sandy shale, mudstone and lignite. In megascopic view, samples of rock in this area are blackish gray. Among shale beds there are thin sandstones and limestones layers as well as remains of brownish to blackish plants. The organic geochemistry and maceral analyses indicate that samples of rock contain organic material with fair to very good classification as source rocks, and consist of vitrinite and liptinite macerals. The presence of vitrinite maceral is 'rare to major' and liptinite is 'rare to common'. Based on the TOC analysis, abundance of the organic material is about 3.11% to 12.62% with type II and type III kerogen. T_{max} value is about 401ºC to 431ºC and Rv is 0.28% to 0.31% indicated that organic material is immature. Kerogen type II has prone to produce oil and type III has prone to produce gas.

Keywords: organic geochemistry, organic petrography, TOC, kerogen type, maturity.

ABSTRAK

*Formasi Dakebo berada di dalam Cekungan Akimeugah. Formasi ini diperkirakan berumur Pliosen, terendapkan pada lingkungan kipas aluvial dan dataran limpah banjir, tersusun oleh batuan konglomerat, batupasir, serpih pasiran, batulumpur dan lignit. Secara megaskopis, conto batuan berwarna abu-abu kehitaman. Di antara lapisan serpih, setempat-setempat terdapat sisipan tipis batupasir dan batugamping serta sering ditemui sisa tetumbuhan berwarna coklat dan hitam. Dari hasil analisis geokimia organik dan maseral yang dilakukan pada conto batuan mengindikasikan adanya kandungan material organik dengan kategori sedang hingga sangat baik sebagai batuan sumber. Material organik tersebut terdiri dari maseral vitrinit dan liptinit. Maseral vitrinit hadir dengan jumlah rare hingga major dan liptinit hadir dalam jumlah rare hingga common. Berdasarkan data hasil analisis TOC, conto batuan memiliki kelimpahan material organik berkisar 3,11% hingga 12,62% dan merupakan kerogen Tipe II dan Tipe III. Nilai T_{maks} sebesar 401°C hingga 431°C dan nilai Rv sebesar 0,28% hingga 0,31% mengindikasikan material berada pada tahap belum matang (*immature*). Kerogen Tipe II memiliki kecenderungan menghasilkan minyak dan Tipe III memiliki kecenderungan menghasilkan gas.*

Kata kunci: *geokimia organik, petrografi organik, TOC, tipe kerogen, kematangan.*

INTRODUCTION

Gas shale is considered to be an unconventional resource, in the same category as coal bed methane (CBM) and tight gas reservoirs (Etminan, *et al*., 2014). Unconventional gas is a hydrocarbon resource found in low to ultra-low permeability sediments that can be produced economically if the well is stimulated by hydraulic fracture treatment or accessed by horizontal wellbore, multilateral wellbores or some other technique, which is used to unleash locked

natural gas out of the reservoir (Boyer *et al.*, 2011; Holditch Madani, 2010; in Bocora, 2012).

In Indonesia, gas shale spread in many places, one of which is in Waghete and surrounding area (Figure 1). At the study area, the gas shale was discovered on Dakebo Formation, Upper Miocene to Pliocene in age (Panggabean and Pigram, 1989). Yen and Chilingarian (1976) mentioned that formations containing shale deposits are generally deposited at a slow condition, in the salt and fresh water, lakes, delta and marsh environment. The content of organic material usually derived from algae and the remains of plant.

The research area is at Waghete area, in Deiyai Regency, Papua Province. It's geographically located at 4°00' to 4°10' south latitude and 136° 10' to136° 20' east longitude.

This study is aimed to investigate the characteristics of gaseous shale in Dakebo Formation to determine the potential and production of gas shale deposits.

METHODOLOGY

Methodology in this research consists of compilation, analysis and data estimation of organic geochemical, petrographic and retort sample of rocks. The geochemical and petrographic organic analyses were conducted to unravel the abundance, type, maturity, as well as the origin of organic material that contained in sample of rocks. Whilst, the retort analyze is a method to estimate the oil content of rock through the process of heating up to 550°C.

REGIONAL GEOLOGY

Based on the Map of Indonesian Sedimentary Basin that issued and published by the Centre for Geological Survey in 2009, it was reported that the research area of this study is included in the Akimeugah Basin (Panggabean et al., 1989).

Morphology of the study area is a hilly region with slope about 20º to 80º and an altitude 700 meter to >1000 meter above sea level. The pattern of river flow is sub-dendritic.

According to Panggabean dan Pigram (1989), regional stratigraphy of the study area consists of Kembelangan Group that composed by Woniwogi sandstone aged Early Cretaceous (JKw), Paniya mudstone aged Middle Cretaceous (Kp) and Ekmai sandstone aged Late Cretaceous to Paleocene (Kue).

Paniai Group consists of Waripi Formation with Paleocene to Middle Eocene aged (KTew) and Yawee Formation with Middle Eocene to Early Miocene aged (Temy). And then, on the Yawee Formation was deposited in conformity Buru Formation aged Early Miocene to Pliocene (Tqbu) which interfingering contact with Dakebo Formation aged Pliocene (Qpd) (Figure 2).

Geological structure that thrive in the research area is syncline and anticline by bedding dip about 3° to 20° and normal faults.

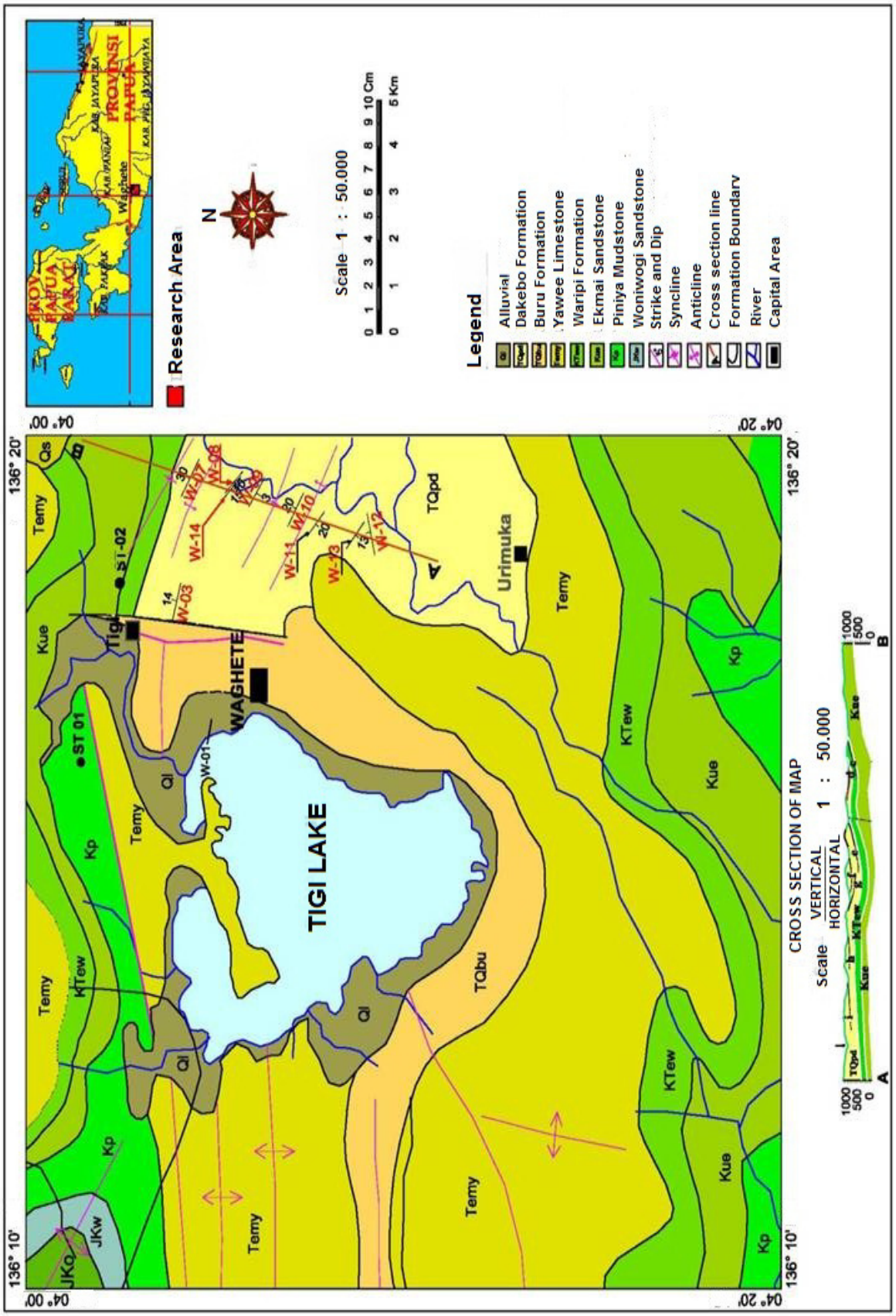

Figure 1. Geological map at Waghete and around areas (modified from Panggabean and Pigram, 1989).

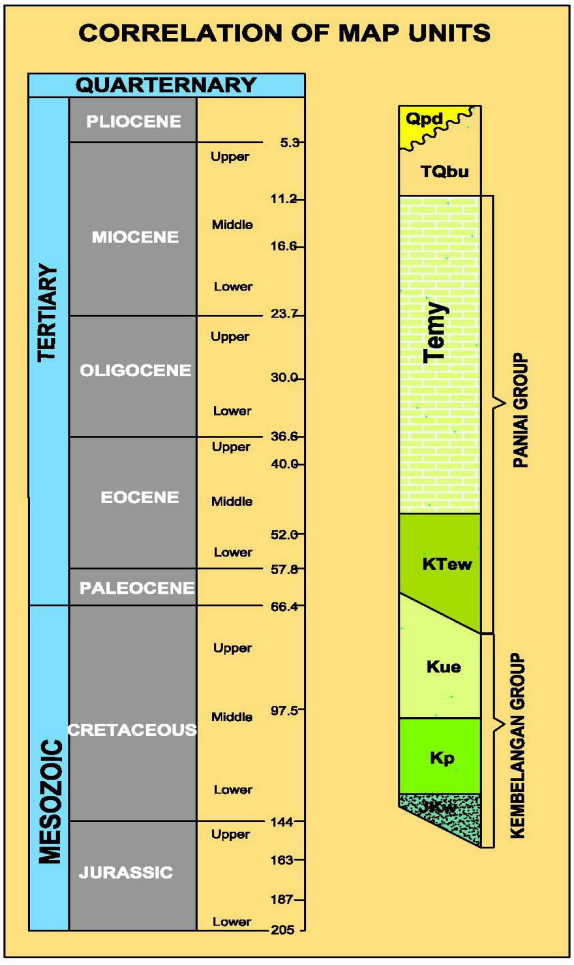

Figure 2. Stratigraphy of Waghete and surrounding area (modified from Panggabean and Pigram, 1989).

DATA ANALYSIS

The results from the geological mapping in the field have been found 14 outcrop and notated W-01, W-02, W-03, W-04, W-05, W-06, W-07, W-08, W-09, W-10, W-11, W-12, W-13 and W-14. The obtained sample of rocks is gray to black. In some places there is a thin bedding of sandstone and limestone with thickness about one until ten centimeter, also found remains of plant, which are brownish and blackish in color. Nine samples of rock were analyzed using organic petrographic and retort methods, while four samples were using organic geochemical analysis (Table 1).

Based on data from the TOC analysis (see Table 1), it is estimated that content of the organic carbon is from 3.11% to 12.62%. According to the terminology of organic maceral (Cook, 1982), microscopically, organic maceral from sample of rocks are dominated by vitrinite maceral about <0.1 % to 50% (rare to major) while liptinite and inertinite are <0.1% to 2.0% (rare to common). Mineral components consists of pyrite about <0.1% to 0.5% (rare to sparse) and iron oxide is about <0.1% to 10.0% (rare to abundant).

Tabel 1. Result of the geochemical and petrographic organic analysis and *retort* from the samples of rock at the research areas.

No.	Sample Code	TOC (%)	Retort Oil (liter/ton)	Retort SG	Organic petrographic Rv (%)	V (%)	L (%)	I (%)	FeS_2 (%)	Fe_2O_3 (%)	Organic Geochemical S1 (mg/gr of rocks)	S2 (mg/gr of rocks)	S3 (mg/gr of rocks)	Tmax (°C)	PI	PY	HI	OI
1	W-03	-	3	2.33	0.28	<0,1	<0.1	<0.1	<0.1	0.1-0.5	-	-	-	-	-	-	-	-
2	W-07	3.11	0	2.14	-	-	-	-	<0.1	0.1-0.5	0.08	1	7.67	431	0.07	1.08	32	247
3	W-08	-	2	2.16	-	<0.1	<0.1	-	<0.1	<0.1	-	-	-	-	-	-	-	-
4	W-09	7.59	10	2	0.31	10.0-50.0	0.1-0.5	-	0.1-0.5	2.0-10.0	1.32	10.68	9.9	401	0.11	12	141	130
5	W-10	12.62	10	1.77	0.31	10.0-50.0	0.1-0.5	0.1-0.5	0.1-0.5	2.0-10.0	1	16.52	29.16	406	0.06	17.52	131	231
6	W-11	-	20	2	0.31	2.0-10.0	0.5-2.0	0.5-2.0	<0.1	0.5-2.0	-	-	-	-	-	-	-	-
7	W-12	-	0	1.54	-	-	-	-	<0.1	0.5-2.0	-	-	-	-	-	-	-	-
8	W-13	-	20	2.16	0.33	10.0-50.0	-	0.1-0.5	<0.1	0.5-2.0	-	-	-	-	-	-	-	-
9	W-14	3.75	10	2	-	<0.1	0.1-0.5	-	-	0.1-0.5	0.24	1.65	9.15	425	0.13	1.89	44	244

Keterangan:

TOC :Total organic carbon
Rv :Reflextance vitrinite
V :Vitrinite
L :Liptinite
I :Inertinite
FeS_2 :Pyrite
Fe_2O_3 :Oksida Besi
SG :Sspecific gravity
Tmax :Maximum temperature
PI :Production Index
PY :Potensial *Yield*
HI :Hidrogen Index
OI :Oksigen Index

Using of the TOC and PY (S1 + S2) parameter in the form a cross plot between PY vs TOC at the diagram (Figure 3) shows that abundance and potential from organic material to produce hydrocarbon are included in the criteria for fair to very good as a source rock.

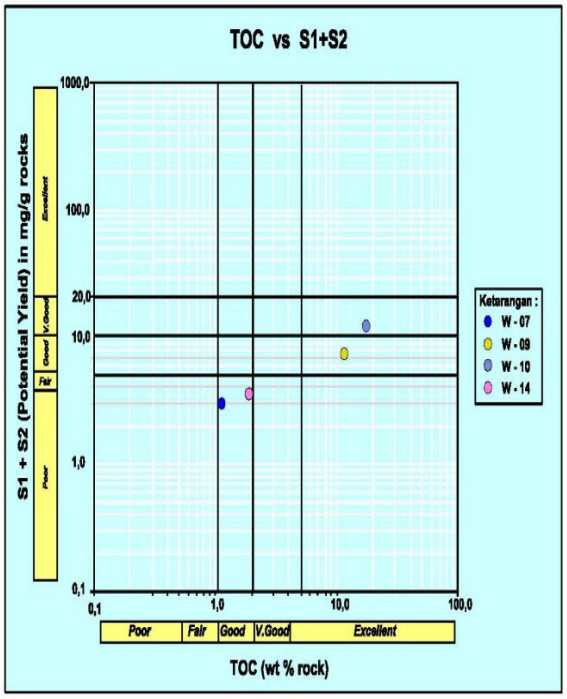

Figure 3. Cross plot between TOC vs PY.

Type of organic material is determined based on the data from maceral analysis, that is HI (hydrogen index) and OI (oxygen index). Type of organic materials is a reflection of maceral component in sedimentary rocks. Cross plot between HI vs OI on the van Krevelen diagram (Figure 4) shows that organic material in the samples of rock indicates type III kerogen.

Based on result from the maceral analysis, sample of rocks are dominated by vitrinite and liptinite.

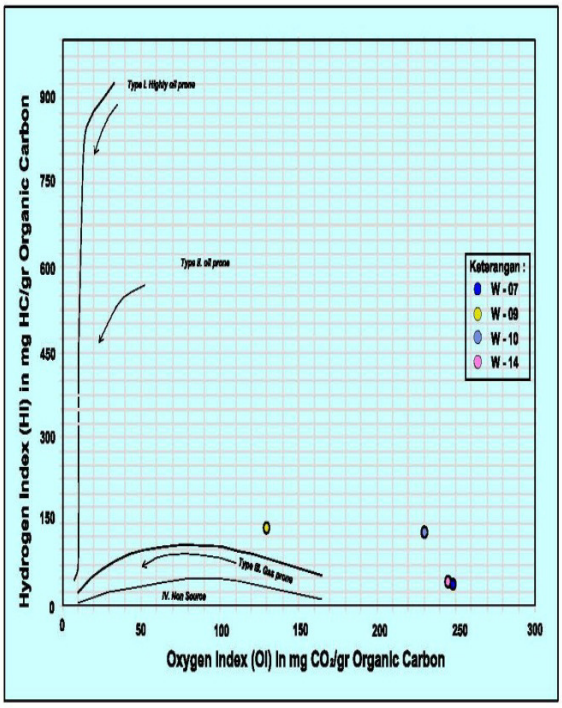

Figure 4. Cross plot between HI vs OI.

Maturity of the organic material in samples of rock is determined based on the T_{max} (maximum temperature) and Rv (vitrinite reflectance) value.

Based on the result from pyrolisis analysis, T_{max} value is about 401°C to 431°C. This value indicates that organic material is immature. Cross plot between T_{max} vs HI on diagram shows that samples of rock are at the stage of immature (Figure 5).

Rv measurements were performed on sample of rocks about 0.28% to 0.33% (Table 1), this indicates that the organic material is categorized as immature.

From the retort analysis (Table 1), it shows that seven samples of rock will produce oil about 2 to 20 liters of oil/ton of rocks and two samples (W-07 and W-12) will not produce oil. The average amount of oil content can be generated from nine samples of rock is 10.7 liters of oil/ton.

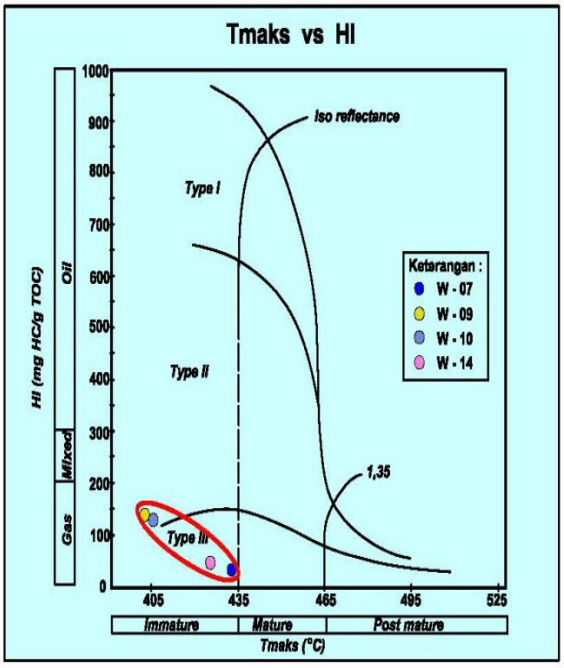

Figure 5. Cross Plot between T_{max} vs HI.

DISCUSSION

Dakebo Formation is in Akimeugah Basin that deposited in alluvial fan environment at the bottom and flood plain at the top. This formation is Plio-Pleistocene in age, composed of conglomerate, sandstone, sandy shale, mudstone and lignite (Panggabean and Pigram, 1989).

Megascopically, shale rock at the study area is blackish gray. In the shale bed, locally, there are thin sandstone and limestone layers as well as remains of plant in brownish and blackish color.

Based on the data of the TOC analysis, it is known that abundance of organic material from the sample of rock is in the range of 3.11% to 12.62%. According to Peters and Cassa (1994), sedimentary rock that contains the TOC about 1.0% to 4.0% is classified as likely good to very good potential as hydrocarbon source rock and greater than 4.0% is potential as a source rock.

The result of organic petrographic analysis (Table 1) from rock samples contains the organic material which is dominated by vitrinite and liptinite. Maceral vitrinite is an organic material derived from higher plants that is a type III kerogen which have a tendency to produce gas, while maceral liptinite derive from plant fats that is type II kerogen which have a tendency to produce oil (Waples, 1985).

According to Peters and Cassa (1994), the value of HI smaller than 50% mg HC/g TOC it is a type IV kerogen and at the peak of maturity will not produce hydrocarbons (none), otherwise, the HI values ranging from 50 mg to 200 mg HC/g TOC is kerogen type III and at the peak of maturity has a tendency to produce gas.

Based on the pyrolisis analysis, the obtained values of T_{max} from the samples are about 401ºC to 431ºC and categorized as immature. The early and peak phase maturity of the organic material is greater than 435°C to 445°C (Peters and Cassa, 1994).

From analysis of the vitrinite reflectance, the obtained Rv values are about 0.28% to 0.33%, these values also indicate organic material considered immature. The early phase mature of organic materials based on the value of Rv is equal to 0.6% and peak maturity is 1.35% (Peters and Cassa, 1994).

In some sample of rocks with notation W-07, W-08, W-12 and W-14 (Table 1), the value of Rv can not measured by microscope because there is no finding of the incision vitrinite maceral in the polish sample of rocks. According to Subroto (2004), vitrinite reflectance analysis has weakness in determining the level of maturity of source rocks caused maceral vitrinite that found in shales were smooth and generally it has been re-arranged or other materials (not vitrinite) which has been compacted.

Based on the results of retort analysis, obtained average oil content is as much as 10.7 liter oil /ton. The amount of oil that obtained is not proportional to amount of TOC value in the sample of rocks. This case indicates that the organic material is more dominated by kerogen type III which has a tendency to produce gas and a little oil.

CONCLUSION

In the study area, Dakebo Formation is thought to be carriers of gas shale that accumulated in shale and sandstone rocks. Maceral content from samples of rocks is dominated by vitrinite (rare to major), a little liptinite and inertinite (rare to common) maceral. Values of the TOC are about 3.11% to 12.62% and T_{max} range from 401ºC to 431ºC indicate that the organic material constitute type II and Type III kerogen with immature category. Rock samples in the study area were estimated to have a tendency to produce gas (gas prone) and a little oil.

ACKNOWLEDGEMENT

The author wishes to thank the head of Center for Geological Resources and also to Asep Suryana and Agus Subarnas who have given support and input to complete this paper.

REFERENCES

Anonymous, (2011): Preliminary Investigation on Gas Shale in Waghete and Surrounding Area, Deiyai Regency, Papua Province, Unpublished report of Center for Geological Resources, Bandung (In Indonesian).

Bocora, Jan, (2012), *Global prospects for the development on unconventional gas*, International Congress on Interdisciplinary Business and Social Science, Sydney.

Cook, A.C. (1982), *The origin and petrology of organic matter in coal, oil shales and petroleum source rocks*, University of Wollongong, Australia.

Etminan, S., Reza, Javadpour, F., Maini, Brij, B., Chen, Zhangxin, (2014), *Measurement of gas storage processes in shale and of the molecular diffusion coefficient in kerogen*, International Journal of Coal Geology, vol. 43

Harahap, Bhakti, H., Syaiful B., Baharuddin, Suwarna N., Panggabean H., Simanjuntak T.O. (2003), *Stratigraphic Lexicon of Indonesia,* (Special Publication No. 29), Geological Research and Development Centre, Bandung.

Hutton, A.C. (2006): Organic petrography and classification of oil shales: *Oil shales workshop*, University of Wollongong, Australia.

Panggabean, H. and Pigram, C.J., (1989): Geologic Map of Waghete Quadrangle, Irian Jaya, , Geological Research and Development Center, Bandung, Indonesia

Peters, K.E., and Cassa, M.R. (1994): Applied source rock geochemistry: *The petroleum system from source rock to trap*, AAPG Memoirs # 60.

Subroto, E.A. (2004) Introduction to Petroleum Gechemistry, Departemen Teknik Geologi, ITB, Bandung (in Indonesian).

Taylor, G.H., Teichmuller, M., Davis, A., Diessel, C.F.K., Littke, R., Robert, P. (1998): *Organic petrology: A new handbook incorporating some revised parts of Stach's textbook of coal petrology*, Gebruder Borntraeger, Berlin, Stuttgart.

Tissot, B.P.,and Welte, D.H. (1984): *Petroleum formation and occurence*, Springer Verlag, Berlin.

Waples, D.W. (1985): *Geochemistry in petroleum exploration*, International Human Resources Development Corporation, Boston.

Yen, T.F., and Chilingarian, G.V. (1976): *Oil shale*, Elsevier, Amsterdam.