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Geochemical Properties of Heavy Oil in Central Sumatra Basin

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ABSTRACT - Heavy oil commonly occurs due to biodegradation, which made the lighter fraction disappears and then leaves the heavier fraction. Heavy oil is characterized by asphaltic, solid, and viscous because it contains asphalthene. Chemically, heavy oils contain fewer hydrogen atoms than light oils. Bulk properties of heavy oil in addition to having a specific gravity of less than 25° API gravity, high viscosity, and often contain (concentration) of heavy metals (vanadium, nickel) which is higher than light oil (normal oil). Geochemical analysis based on the gas chromatography (GC) chromatogram of heavy oil in the Central Sumatra Basin shows a different pattern. The chromatogram pattern eliminates the light molecular fractions of the compounds in biodegraded oil and tar sand/bitumen. According to their geochemical properties, there are 4 (four) types of heavy oil in the Central Sumatra Basin namely: Type 1 come from shallow reservoir, water wash, and full biodegradation/all alkane depleted); Type 2 come from shallow reservoir, meteoric water, and light biodegradation, only low molecular weight alkane depleted); Type 3 come from deep reservoir, vertical gravity segregation, decreased weight fraction, can be caused by oil conditions in thick reservoirs, covered by impermeable lithology and usually located on the edge of the field (flank). Type 4 which contains medium-heavy oil (27°API) and is difficult to produce.

Keywords: Heavy oil, gas chromatogaphy, Central Sumatera Basin

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INTRODUCTION

Heavy oil can be formed from immature oil, from water washing, evaporation, and degradation by bacteria if the oil reservoir is exposed to the surface, and can also form in reservoirs below the surface due to biodegradation at depths at temperatures less than 176°F (80°C) or maximum temperature bacteria can live (Meyer, et al., 2007). Biodegradation by bacteria can occur under both aerobic and anaerobic conditions.

Biological activity in water reservoirs (free water), so that the presence of water in petroleum reservoirs in principle causes biodegradation of petroleum (Head, et al., 2003). Based on the relationship between the degree of degradation and the oil composition of many oil fields, as shown in Figure 1, it is known that the most degraded oil is near the oil-water contact (OWC), so the most degraded place is the bottom of the oil column. Biodegradation can also occur in the initial phase of filling the reservoir in the trap, when there were many OWC (Head, et al., 2003).

The concentration of heavy molecular hydrocarbon compounds such as asphaltene and polar compounds showed a gradual increase from light oil to tar sands. Gas chromatography (GC) on

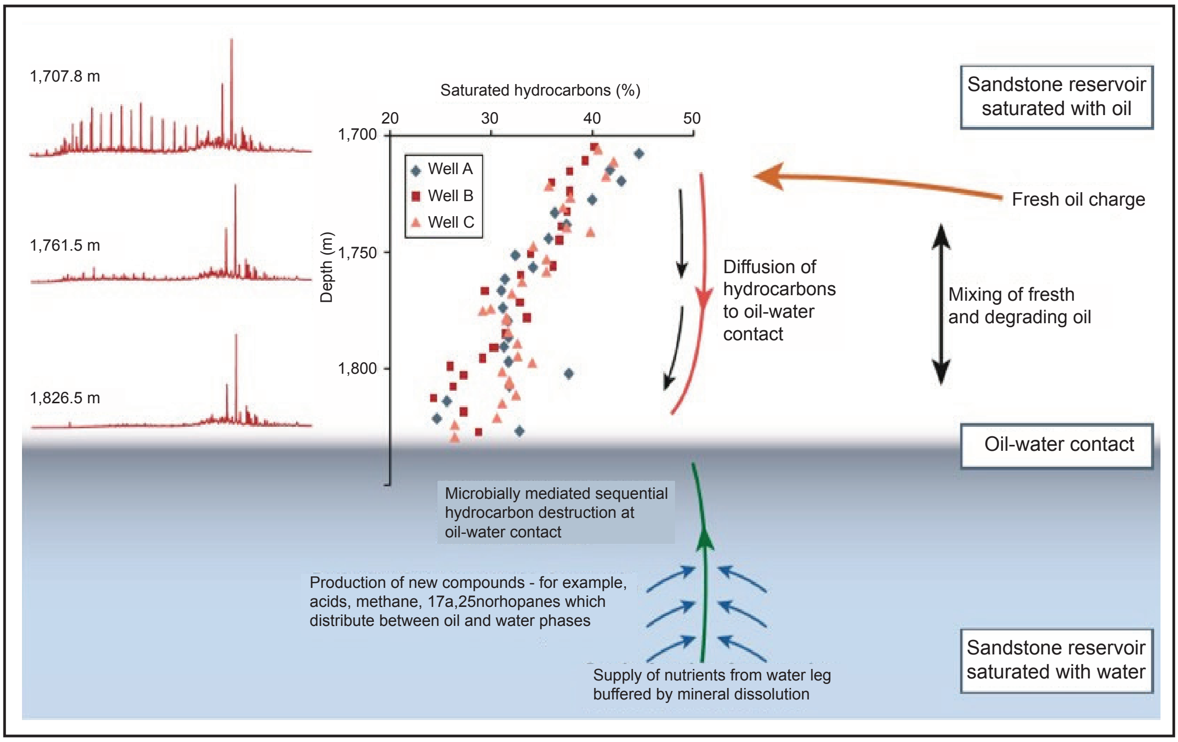

Figure 1
Hydrocarbon saturation and chromatograms of different depths in 3 (three) wells which represents higher level of biodegradation toward oil water contact in reservoir (Head, et al., 2003).

heavy oil shows a different pattern between normal oil (32°API) and biodegraded oil (12°API), and tar sand/bitumens. The chromatogram pattern shows the loss of light molecular fractions of hydrocarbon compounds in biodegraded oil and tar sand/bitumen (Miiller, et al., 1987).

In the Central Sumatra Basin, the areas which have shallow reservoirs are generally in the West or Northeast due to lifting of the Plio-Pleistocene tectonic phase. Geologically and geophysically, these areas can be identified as being in zones above relatively shallow basements.

Geochemical analysis in this study is mainly used to determine the source of heavy oil and determine the amount and type, by using their geochemical properties data.

DATA AND METHODS

The bulk properties heavy oil can be determined by API gravity of the oil such by API gravity and viscosity analysis. While the geochemical characteristics of the heavy oil can be describes by GC analysis to determine the level of biodegradation, and Gas Chromatography Mass Spectrometry (GCMS) analysis to determine the characteristics of petroleum biomarkers (source facies, depositional environment, thermal maturity).

A. API Gravity

The degree of API (API Gravity) is a unit used to express the specific gravity of oil and is used as the simplest basis for classification of petroleum. Based on the degree of API, crude oil is divided into five types of crude oil, namely: light crude oil, light medium crude oil, crude oil medium heavy crude, heavy crude, very heavy crude (Geologi Indonesia, 2011).

Determination of specific gravity of oil (crude oil) is done with a hydrometer, where the specific gravity indicator can be read directly on the tool. For temperatures that are more than 60° F, it is necessary to make corrections using the existing chart. The quality of the oil (heavy oil and light oil) is determined one of them by specific gravity. Crude oil temperature can also affect the viscosity of the oil. This is the basis for the need for correction to the standard temperature of 60° F.

B. Gas Chromatography

Gas Chromatography analysis of whole oil is carried out using an Agilent 6890N GC coupled to a flame ionization detector (FID). The GC is fitted with a 20m x 0.21mm i.d. DB-1 (J&W) fused-silica capillary column. Samples are injected using an Agilent 7673 auto sampler, with split/splitless mode injector.

C_{15} chromatograms are inspected for the distributions of n-alkánes, and the presence and abundance of isoprenoids (particularly pristane and phytane), chromatography may reveal information about the kerogen type of the source rock, its maturity and condition of deposition and if migrant oil is present, whether this has been water flushed or biodegraded.

C. Gas Chromatography Mass Spectrometry (GCMS)

Routine GC-MS analyses of saturate and aromatic fractions are performed using an Agilent 6890 GC coupled to an Agilent 5973 series Mass Selective Detector (MSD)–computer data system (Chemstation). The GC is fitted with a 60m x 0.25mm i.d. DB-5 (J&W) fused-silica capillary column. Samples are injected using an Agilent 7673 auto sampler, with split/splitless mode injector. The MS condition is ionization mode: electron impact (EI), EM voltage

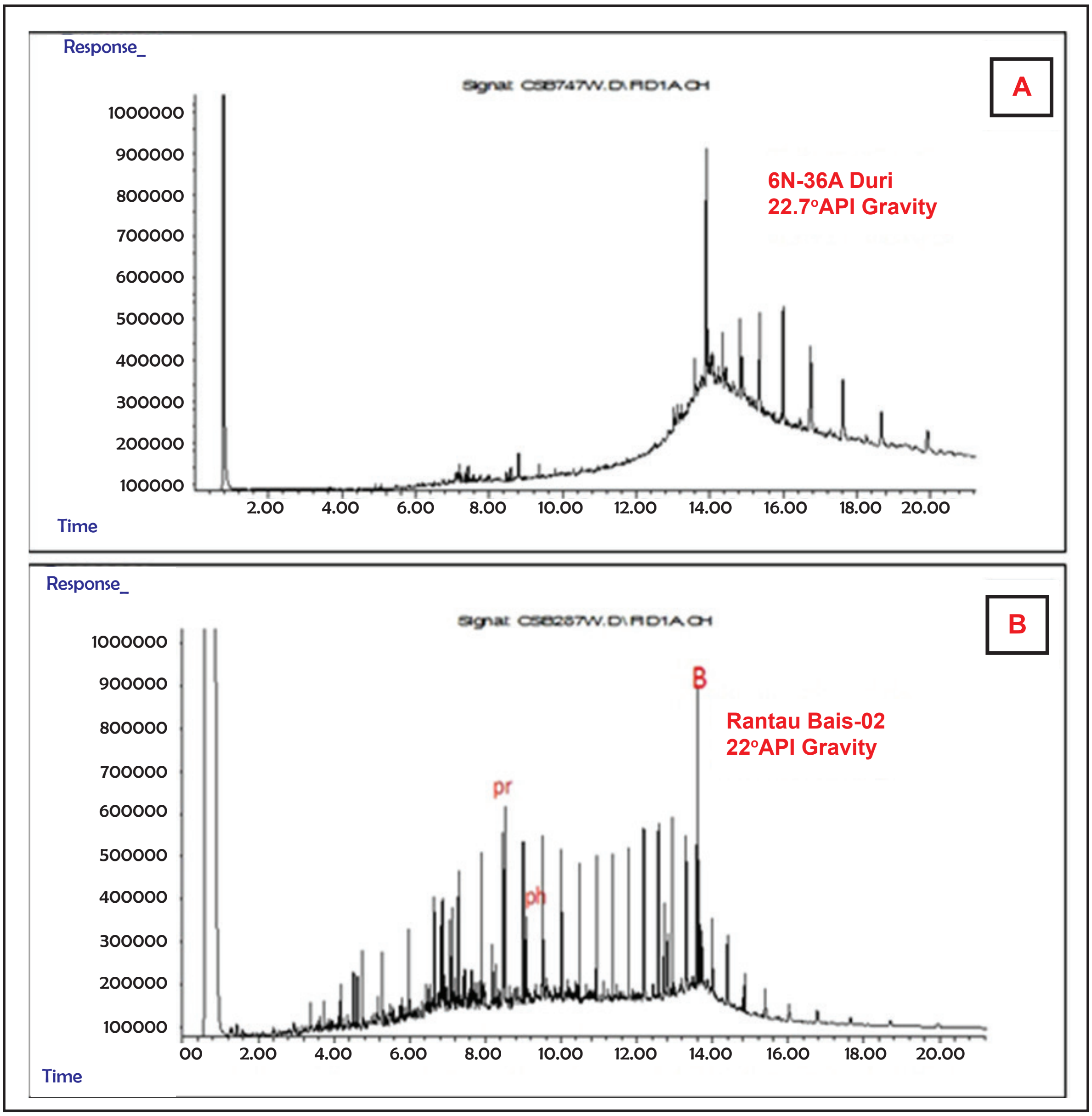

Figure 2
Chromatogram of (GC) analysis show a biodegraded crude oil sample in the Central Sumatra basin. The samples came from the fields: (A) Duri and (B) Rantau Bais.

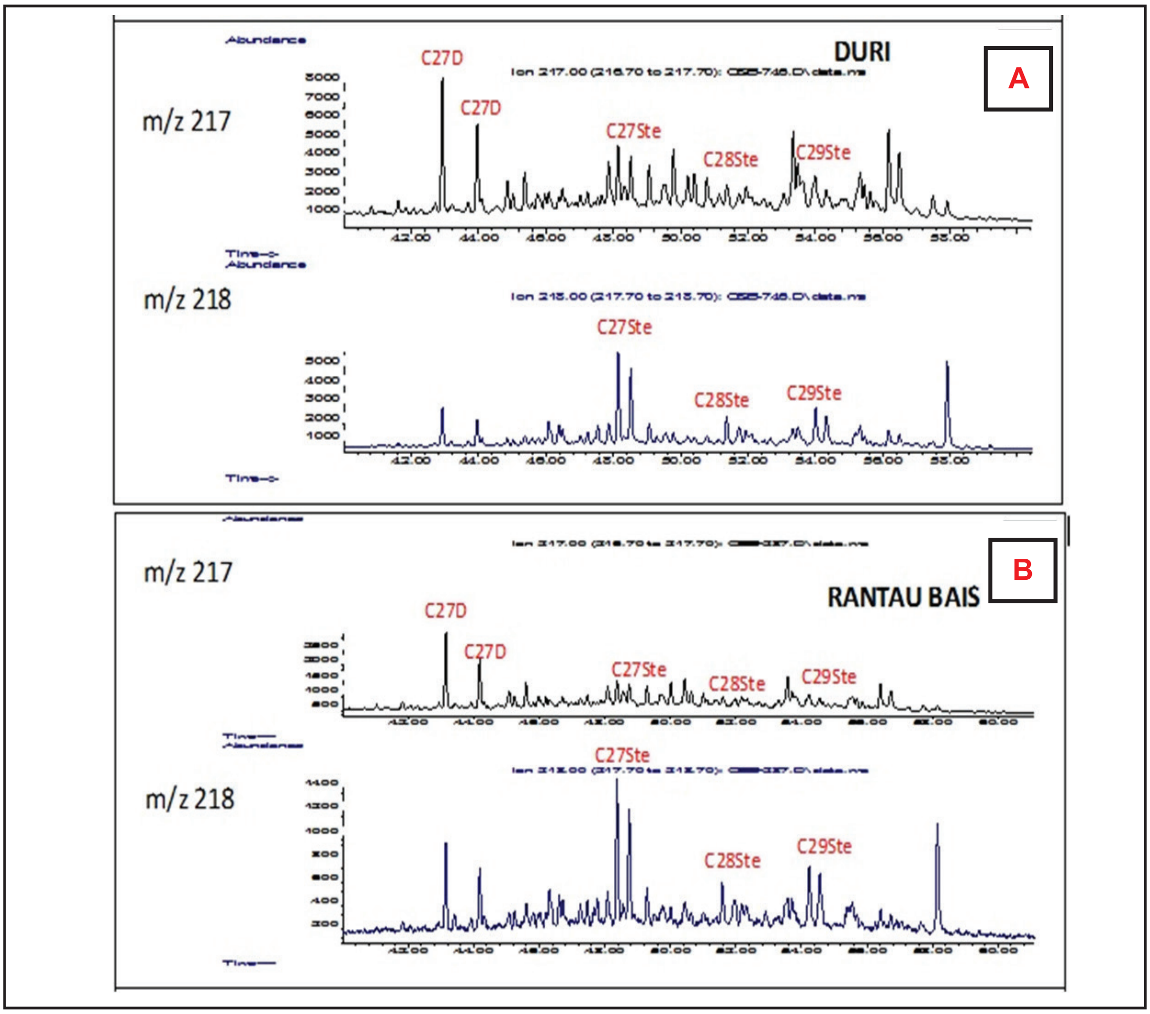

Figure 3
Steranes distribution (m/z 217 and m/z 218) from (A) Duri, (B) Rantau Bais crude oils.

is 1800 Volt; electron energy is 70 eV and source temperature 250^{o}C. Mass spectrometry is a technique in which molecules are bombarded with high energy electrons causing ionisation and fragmentation of the molecules into ions of varying mass (m) and charge(z). The way in which a molecule fragments into ions of various *m/z* values is known as its fragmentation pattern or mass spectrum and is unique

Examination of fingerprint signatures for all the samples are based on partial chromatograms of steranes and pentacyclic triterpanes (saturate), alkyl phenanthrenes, alkyl naphtalenes and tri-aroamatic steranes (aromatic) of biomarker groups. Selected fingerprinting of each group is normalized by the known biomarker within the group. For example, hopane is used to normalized for pentacyclic triterpanes.

The crude oil samples from central Sumatera Basin are injected into the GC device to obtain a chromatogram of the alkane distribution. Oil sample was analyzed using a Fast GC prior to separate into saturated hydrocarbon, aromatic hydrocarbon, and non-hydrocarbon fraction (polar compounds) by preparative column chromatography. The hydrocarbon fractions were carefully evaporated then transferred to sample vials. Isolation of branched and cyclic fraction from saturated hydrocarbons was done using a packed activated silicalite chromatographic column based on method described. The branched and cyclic fraction was introduced to a GCMS instrument.

RESULTS AND DISCUSSION

Duri and Rantau Bais crude oil sampel was introduce to GC and GCMS instrument. The result of GC analysis shows in Figure 2. The Duri crude oil chromatogram indicated biodegradation oil which the lighter fraction disappears and leaves the heavier fraction. Whereas The Rantau Bais crude oil chromatograms shows the *n*-alkanes start to depleted.

The sterane chromatogram (m/z 217) from GCMS analysis show sterane and diasterane distributions which presented in Figure 3. The dominant diasterane composition at m/z 217 indicates that the oil comes from clay rich source rock. The composition of sterane with $C_{27}>C_{29}>C_{28}$ content indicates that the input of organic matter dominated by algae which deposited in a lacustrine depositional environment.

The triterpane chromatogram (m/z 191) of Duri and Rantau Bais crude oil in Figure 4 shows distribution of tricyclic and pentacyclic hopane, which C_{30} Hopane is maximum peak. This indicates that the oil originates from the clastic facies. The abundance of

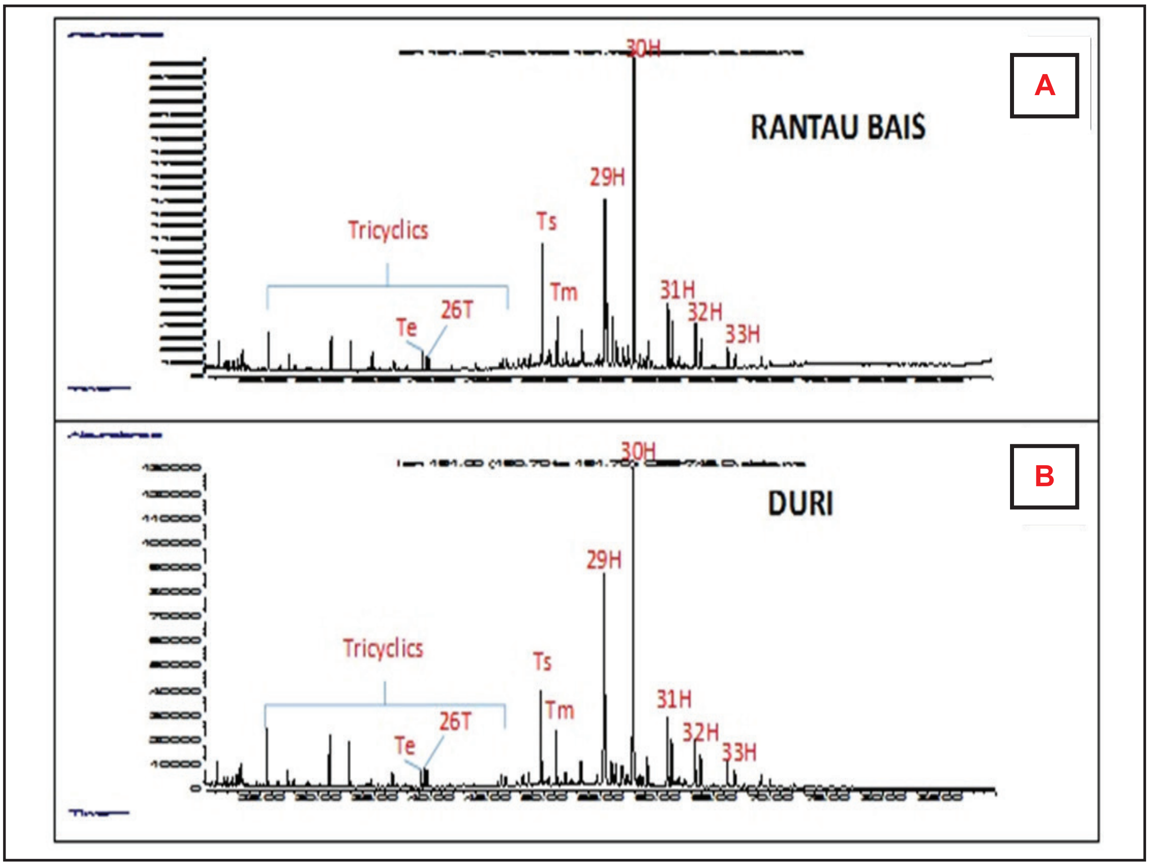

Figure 4
Triterpanes distribution in m/z 191 for Rantau Bais (A) and Duri (B) crude oils.

Table 1
General properties of oil quality parameters based on source rock origin and depositional environment (Wenger, et al., 2002)

Generative Value*	Marine Algal Clastic (Shale)	Marine Marl	Marine Carbonate	Marine Shale with Terrestrial Organic Matter	Saline Lacustrine	Freshwater Lacustrine
API Gravity	30-38	27-32	15-25	35-40	25-35	35-45
% Sulfur	0.3-0.8	0.6-1.2	1.5-4.0	<0.2	0.3-1.0	<0.2
GOR (scf/STB)	500-1.200	400-800	200-500	2.000-5.000	100-400	200-500
Mainstage Oil-Maturity Level	Mid	Early to Mid	Early	Mid	Mid to Late	Late

*Approximate generative value ranges at mainstage oil-generation maturity (varies depending on source type)

Relative mainstage oil generation level varies depending on source type (scf/STB x 0.1781076 = m^3/m^3)

oleanane is very little or almost none, indicating that the organic matter in the oil is dominated by algae. The Tetracyclic/26Tricyclic ratio with a value of approximately 1 indicated lacustrine environment.

The heavy oil in the Central Sumatra Basin can be divided into four (4) types (Figure 5), namely: Type 1 which found in shallow reservoir undergoing water washing, and the GC chromatogram show full biodegradation where all alkanes were depleted; Type 2 which found in shallow reservoir with meteoric water, and the GC chromatogram show partial/light biodegradation, only low molecular weight alkane were depleted; Type 3 which found in deep reservoir, have been vertical gravity segregation, decreased weight fraction, can be caused by oil conditions in thick reservoirs, covered by impermeable lithology and usually located on the edge of the field (flank). For the case of Kotabatak no oil-water contact is found. Lateral boundary in the form of changes in facies to be smoother, and Type 4 (Sijambu and Pusing Fields) which contains medium-heavy oil (27°API) and is difficult to produce. The process cause of the formation of medium-heavy oil is not yet known.

According data from the geochemical data analysis in LEMIGAS and data from SDMS SKK Migas obtained a list of oil wells that are categorized as having heavy oil content because they have a gravity API value less than 25° and the types of heavy oil based on their geochemical character (Table 2).

Theoretically, petroleum whose environment of origin is known to have an estimated generative value of API Gravity according to the environment of deposition (Wenger, et al., 2002). Crude oil in the Central Sumatra Basin deposited in a freshwater lacustrine environment is estimated to have an original API gravity value of around 35° - 45° or includes light oil. If you find oil with an API gravity value of less than 35° - 45°, it is likely that the oil has already been biodegraded depending on its level.

Biodegradation of crude oil within reservoir has been taking place when micro-organism (bacteria) and encroaching water are in contact with crude oil. This original crude oil was usually light or medium in weight. Hotspot area for biodegradation in reservoir occurs around oil water transition zone (OWTZ) that separates water and oil legs. The biodegradation process also occurs within ranges of temperature of less than maximum temperature under which bacteria can live (LEMIGAS, 2020).

According to scale of Wenger, et al., 2002, the type I heavy oil was biodegraded to level 4 where

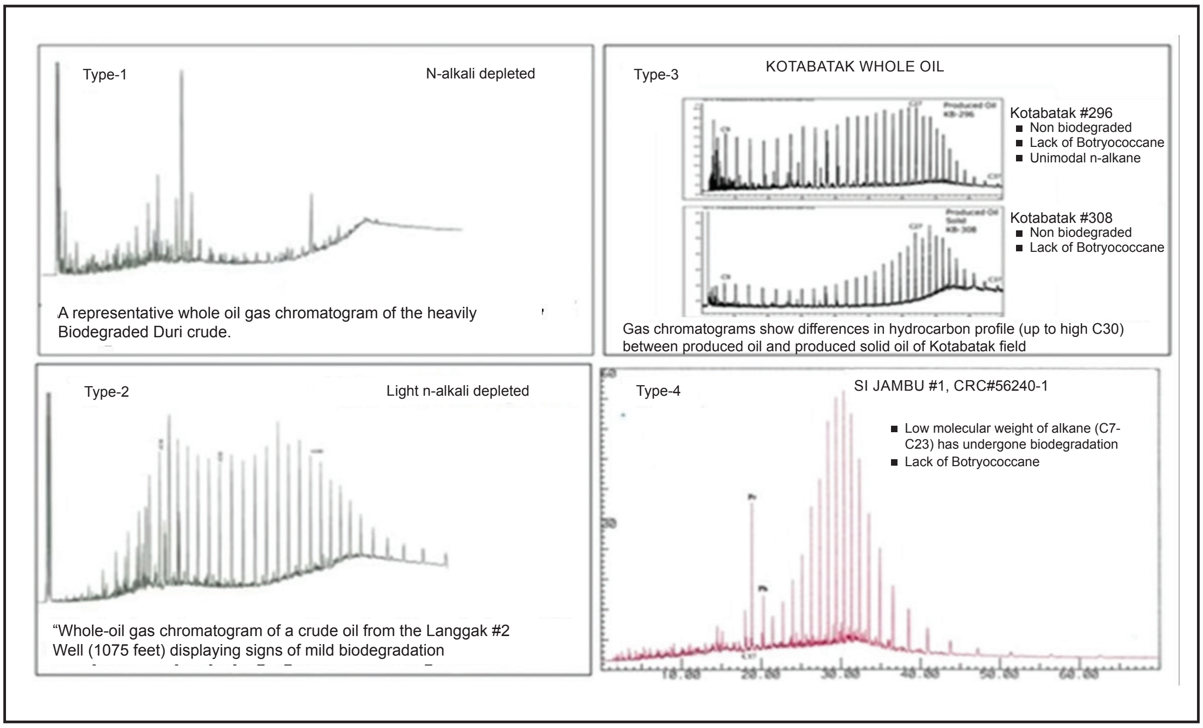

Figure 5
GC chromatogram show the difference of four heavy oil type in Central Sumatra Basin.

Table 2
List of oil wells in the Central Sumatra basin indicated to
have heavy oil content and the type of heavy oil based on their geochemical character

No	Well Name	Well Status	Field	Block	Type	API
1	Batang	Oil Well	Batang	Rokan	1	17
	Batang 42					22.2
	Batang 6					21.8
	Batang 17					22
	Batang 30					21.6
	Batang 05	Oil prod				20.8-21
	Well 18 DRI					22.5
	Wel 24 BKS 440					23.1
	Well 34 DRI/BKS					18.6
	Wel 6 BKS					21.7
	Well 30 DRI					23.8
2	Duri	Oil Well	Duri	Rokan	1	15-17
						19.9-22.7
3	North Duri			Rokan	1	18.25
4	Genting-1	Oil Well	Genting	Rokan	1	21
						23.2
						24.8
						21
5	Kota Lama#3	Oil Well	Kota Lama	Siak	1	19-20.1
6	Ked-01	Oil Well	Kulin	Rokan	1	18.1
	Ked-05	Oil Well				18.8
7	Langgak #1	Oil Well	Langgak	Siak	2	30.7
	Langgak 23					19.8-22.0
	Langgak 02					24.7
	Langgak 14					25.2
	Langgak Block B					19.8-24.2
8	MSJ-27	Oil Well	Melibur (Offshore)	Malacca Strait	1	22.2
	MSJ-29	Oil Well				22.1
	MSJ-30	Oil Well				25.1
	MSJ-33	Oil Well				24.5
	MSJ-3	Oil Well				22.3
	MSBH-1	Oil Well				24.2
	MSBH-3	Oil Well				24.2
9	Well #08	Oil Well	Rantau Bais	Rokan	1	16.2
10	Well 18	Oil Well				22.2
11	Selatan A3		Selatan	Malacca Strait	1	18
12	Sebanga North-03	Oil prod	Senbanga North	Rokan	1	18.6
13	Kumis-01		Kumis	Siak	1	19
14	Pendalian			Kampar Kanan	1	
15	Akar-1		Akar	Rokan	1	17.2
16	Daludalu-1		Dalu Dalu	Siak	2	?
17	Sebanga-6		Sebanga	Rokan	1	
18	Sebanga-11					
19	Kasikan-1		Kasikan	CPP	2	30
20	Paitan-01		Paitan	CPP	2	?
21	Kotagaro-1		Kotagaro	CPP	3	?
22	MSTA-2		Kurau (Offshore)	Malacca Strait	1	22.1
	MSBZ-1					26
	MSAC-1					?
23	Langgai			Kampar Kanan	1	
24	Pusing	Oil Well	Pusing	Rokan	4	25.6

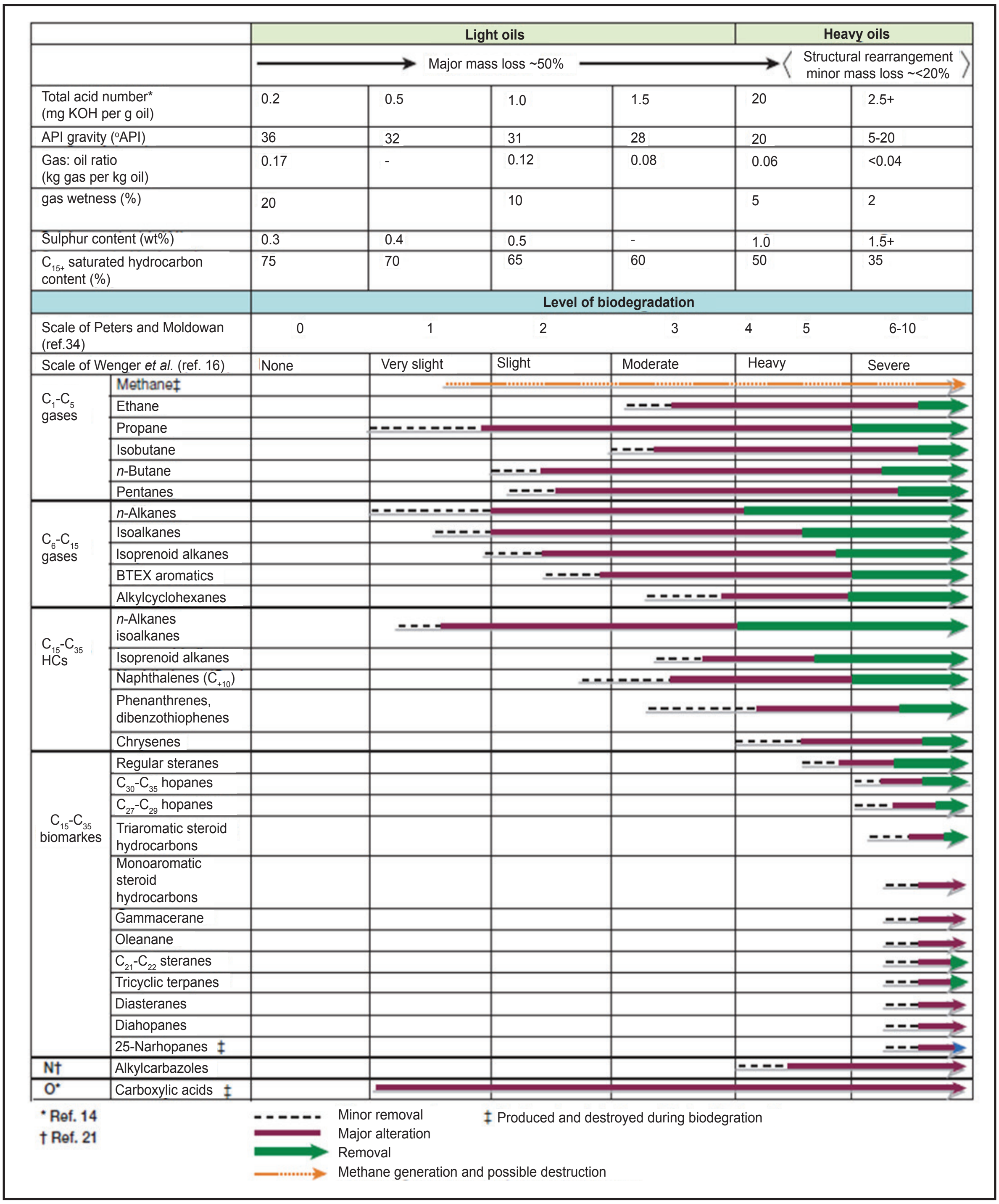

Figure 6
Schematic of the relationship between the degree of biodegradation
and changes in the physical and chemical properties of oil and gas (Head, *et al.*, 2003).

all the alkanes and isoprenoids were disappear but not regular sterane and hopane. The heavy oil type 2 and 3 has undergone biodegradation at level 3 (moderate) which all alkanes and isoprenoids are start to depleted. The difference is seen in the presence of botryococane in type 2 and not in type 3. Type 4 heavy oil, only low molecular weigh alkane (C_7-C_{23}) has undergone biodegradation (level 1-2).

CONCLUSIONS

According to their geochemical properties, there are 4 types of heavy oil in the Central Sumatra Basin, namely:

Type 1, come from shallow reservoir, water wash, and full biodegradation/all alkane depleted, level 4 biodegradation

Type 2, come from shallow reservoir, meteoric water, and light biodegradation, only low molecular weight alkane depleted, including biodegration level 3.

Type 3, come from deep reservoir, vertical gravity segregation, decreased weight fraction, can be caused by oil conditions in thick reservoirs, covered by impermeable lithology and usually located on the edge of the field (flank); and the biodegradation is level 3.

Type 4, which contains medium-heavy oil (27° API) and is difficult to produce. This heavy oil is categorize level 1-2 biodegradation.

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GLOSSARY OF TERMS

Symbol	Definition	Unit
Geavy Oil	Heavy oil is a crude oil that has a viscosity typically greater than 0.01 Pa. s [10 cP] and a high specific gravity. The World Petroleum Congress classifies heavy oils as crude oils that have a gravity below 22.3 degree API	
Biodegradation	Biodegradation is the breakdown of organic matter by microorganisms, such as bacteria and fungi	
GC	Gas chromatography is the process of separating compounds in a mixture by injecting a gaseous or liquid sample into a mobile phase, typically called the carrier gas, and passing the gas through a stationary phase. The mobile phase is usually an inert gas or an unreactive gas such as helium, argon, nitroge n or hydrogen	
GCMS	When gas chromatography is combined with mass spectrometry, its power is greatly enhanced. The separated components can be analysed by a mass spectrometric detector (GC-MS) for maximum sensitivity and selectivity.	
API	The degree of API (API Gravity) is a unit used to express the specific gravity of oil and is used as the basis for the simplest classification of petroleum.	

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