Carbon Isotope Analysis of Oil Samples from the Utsira High Area in Norway

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Summary

Crude oil originated from organic matter deposited in sedimentary basins, which is mostly from marine environment (Stahl, 1977). However, some sediment transported by wind, rivers, and even continental runoff and buried in marine environment were considered as source materials for oil and gas (Stahl, 1977). Since organic matter is very rich in carbon, it is significant and useful to apply carbon isotope analysis to oil samples. Generally, there are two applications in analyzing carbon isotopic values, which are used to indicate depositional environment and to correlate oil-oil and oil-source rock relationships (Sofer, 1984). This study is aimed at verifying the source rocks of oil and its depositional environment based on stable carbon isotope analysis. In addition, it will be helpful to prepare biodegraded connections with nondegraded counterparts for future studies.

Introduction

The samples are collected from the Utsira High area, which is located in the Norwegian North Sea between the Viking Grabben to the west and the Stord Basin to the east (Figure 1a) (Isaksen & Ledje, 2001). According to previous studies, abundant hydrocarbon has been found in the Utsira High area where the potential reserve is approximately 1.0-1.5 billion standard bbl (Isaksen & Ledje, 2001). Source rocks of important oil and gas discoveries are mostly coming from submarine-fan sands that belong to Upper Jurassic Draupne and Heather formations (Isaksen & Ledje, 2001). However, we need more details to reveal the source rock quality and depositional environment in our specific area, so that we can appraise well for the producible reserves.

The 12 core-extracted samples in the Utsira High area are from Avaldsnes, Edvard Grieg, LunoII, and Luno Extension discoveries separately that were confirmed by Lundin Petroleum, which are presented in Figure 1b (Lundin Petroleum Norway Operations). Based on Lundin Petroleum wells information, it can be inferred that these discoveries are from Triassic to Jurassic ages with a depth range from 1900m to 2700m. Additionally, the reservoirs consist of alluvial, eolian and shallow marine conglomerates and sandstones. (Lundin Petroleum Norway Operations)

Method

Oils samples preparation

Before the stable carbon isotope analysis, the bitumen is solvent extracted from reservoir cores using Soxhlet extraction with dichloromethane (DCM), and is put under a Nitrogen atmosphere in a fume hood for about 10 hours to evaporate the DCM. After that, one drop of each sample is loaded by a 'Zero Blank' auto sampler on to a quartz tube combustion column and packed in tin cups (ISL-AGG). These are prepared for using Continuous Flow-Elemental Analysis-Isotope Ratio Mass Spectrometry (CF-EA-IRMS) technology, while analyzed by Costech 4010-C only elemental analyzer (ISL-AGG).

Measurement

The column prepared is kept at 1020°C, and 'flash-combustion' is achieved by injecting a pulse of O_2 at the time of sample drop (ISL-AGG). "δ^{13}C values are determined by comparing the respective sample peak areas, as [Vs], to reference gas peaks inlet through the open split (ISL-AGG)." In this lab, the ratios are interpreted in per mil notation relative to the V-PDB (Vienna Pee Dee Belemnite). We also use internal lab standard reference material NBS-22, which has δ^{13}C=-30.03 ± 0.2 ‰, to calibrate carbon isotope ratios and correct for instrument drift and to normalize the data to internationally accepted standards (ISL-AGG). According to the ISL-AGG techniques, the calculation equation for δ^{13}C value is: δ^{13}C={[(^{13}C/^{12}C)$_{sample}$/(^{13}C/^{12}C)$_{V-PDB}$]-1}*1000, and the accuracy and precision are δ^{13}C$_{organic}$ ± 0.2 permil (n=10 internal lab standards).

Examples

From the data obtained, δ^{13}C-$_{orgnc}$ shows only small variations in values from -28.7‰ to -27.8‰, and δ^{13}C/^{12}C is from -26.64‰ to -27.54‰ (Table 1). The well drilled in Edvard Grieg reservoir has a total depth of 1900 metres, and a depth of 2100 metres in Avaldsnes, and a depth of 2700 metres in Luno II. The δ^{13}C-$_{orgnc}$ and δ^{13}C/^{12}C values versus the locations are shown in graph below.

As was indicated by Meyer (2016), it is said that crude oils have similar carbon isotope ratios with those of their source material, because carbon isotope ratios of organic matter change less than 3% during kerogen formation and subsequent maturation alteration. Therefore, we can interpret the source materials based on the results we got from the oil samples.

Generally, δ^{13}C-$_{orgnc}$ values of oils fluctuate between -18 and -34 ‰, most of which are close to -30‰. (Mayer, 2016) The carbon isotopic composition of crude oil can be different, which can be attributed to their different sources. Although, it is concluded that δ^{13}C is about -27‰ if source materials are either terrestrial organic carbon or marine organic matter in recent geological past (Mayer, 2016). Generally oils derived from terrigenous organic matter are isotopically more negative than marine oils (Mayer, 2016; Craig, 1953). Furthermore, δ^{13}C value of organic carbon has a decreasing tendency from marine organisms to sedimentary rocks, while the value of the recent sediments is between them (Fuex, 1977). In addition, as a major form of biomass in oceans, oceanic plankton has a mean value of δ^{13}C that is around -22‰. However, it can be different due to various climates, which have values of -18‰ to -30‰ from tropical to arctic region separately. (Mayer, 2016)

As indicated by studies, we can see that δ^{13}C-$_{orgnc}$(‰) values are very similar in three oilfields, which are around 28.2‰. Hence, it indicates that these samples are derived from the same source rock, which should buried in marine environment. Beyond that, because of latitude effects, the temperature is very low and this leads to more fractionation, so the δ^{13}C-$_{orgnc}$(‰) is more negative. For example, Norway has a latitude degree about -59, and the results are consistent with the data presented in Figure 3. While the δ^{13}C-$_{orgnc}$(‰) values in Luno II are a little lower compared to those of the other locations, this could be due to the reason that the source materials are contaminated by terrestrially derived carbon, which is more rich in ^{12}C.

Furthermore, some measurements reveal distributions of ^{13}C values with possible geological age. Their 623 post-Ordovician marine oils illustrate that: δ^{13}C with a value of -32‰ to -28‰ indicate marine shale oils older than Oligocene; δ^{13}C with a value of -28‰ to -23.5‰ indicate deltaic oils of different geologic age or Mesozoic carbonate oils; δ^{13}C with a value of heavier than -23.5‰ indicate marine shale oils of Miocene age (Chung, 1992). As a result, the age of 12 samples in the study area should be around Late Mesozoic to Early Oligocene. The decreasing δ^{13}C values caused by decreased atmospheric CO_2

concentration, which led to decreased isotope fractionation during photosynthesis by marine plankton. (Stahl, 1977)

Conclusions

In conclusion, based on the precious studies and experiments, Utsira High Area has similar $\delta^{13}C$ values of around 28.2‰ in different oilfields. These values indicate that source rocks could be derived from cold marine environment in Late Mesozoic to Early Oligocene time. Some slight variations could be effected by contaminated terrestrially derived carbon, or due to latitude effects resulted in different isotope fractionation. For future studies, we should analyze carbon isotope ratios based on individual hydrocarbon compounds, which could be separated and converted to CO_2. After that, we will get more information of the carbon composition and it will be helpful for oil-oil correlation.
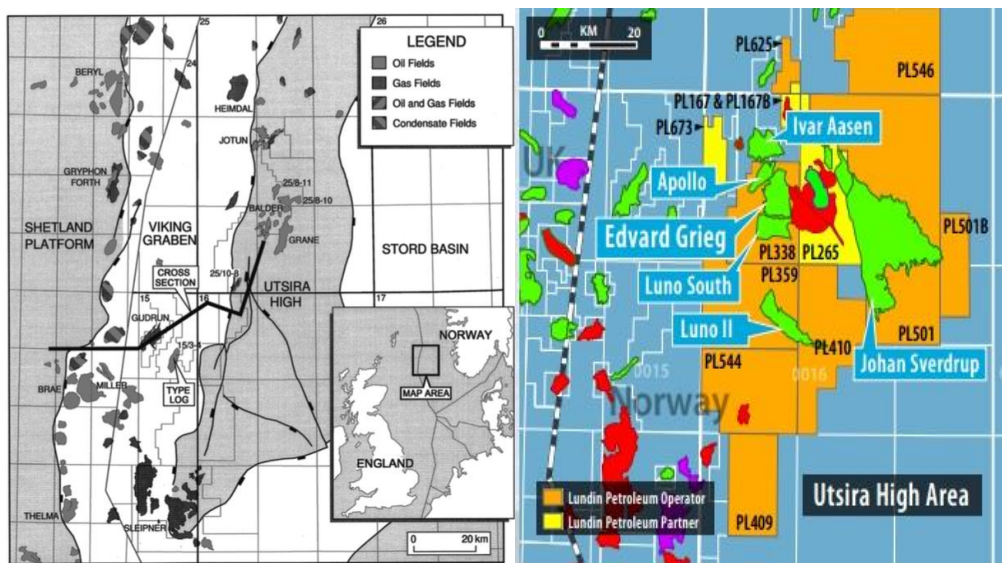

Fig 1.(a) Location map of study area (b) Location of oil samples' Formations (Isaksen, 2001; Lundin Petroleum Norway Operations)
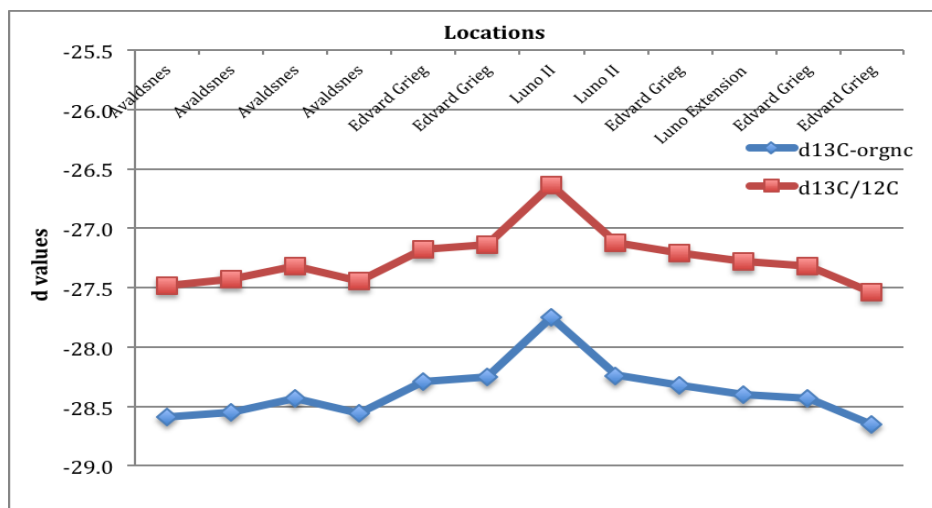

Figure 2. $\delta^{13}C\text{-}_{orgnc}$ and $\delta^{13}C/^{12}C$ values versus different locations of the analyzed extract samples
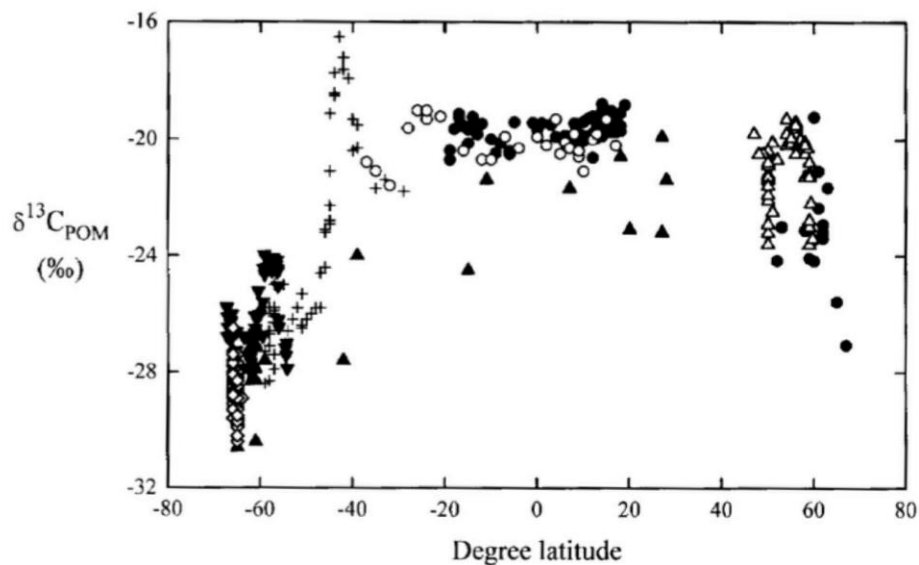
Figure 3. Variation in $\delta^{13}C_{POM}$ plotted against latitude (Johnston & Kennedy, 1998)

Table 1. Carbon isotope values of core-extract samples from Utsira High Area

Well No.	LIMs ID	Sample ID	Location	$\delta^{13}C\text{-}_{orgnc}$(‰)	$\delta^{13}C/^{12}C$
16/3-4	G-13586	14124.0	Avaldsnes	-28.6	-27.48
16/3-4	G-13587	14125.0	Avaldsnes	-28.6	-27.43
16/2-6	G-13588	14127.0	Avaldsnes	-28.4	-27.32
16/2-7A	G-13589	14128.0	Avaldsnes	-28.6	-27.44
16/1-14	G-13590	14130.0	Edvard Grieg	-28.3	-27.18
16/1-14	G-13591	14131.0	Edvard Grieg	-28.3	-27.14
16/4-6S	G-13592	14132.0	Luno II	-27.8	-26.64
16/4-8S	G-13593	14133.0	Luno II	-28.2	-27.12
16/1-18	G-13594	14134.0	Edvard Grieg	-28.3	-27.21
16/1-12	G-13595	14135.0	Luno Extension	-28.4	-27.28
16/1-15	G-13596	14136.0	Edvard Grieg	-28.4	-27.32
16//1-8	G-13597	14140.0	Edvard Grieg	-28.7	-27.54

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