



T A B L E O F C O N T E N T S

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1. Introduction

The gas samples from the mud line and one FMT gas sample were received in January 1984. These samples were analyzed during February, 1984.

Due to low hydrocarbon concentration in the vacutainers, it was only possible to determine the  $\delta^{13}\text{C}$  methane value of one sample.

Headspace cans from about the same depth as the vacutainers were received late March 1984, and were analyzed early April 1984. The  $\delta^{13}\text{C}$  value is measured on methane and when possible on ethane and propane from the headspace cans.

It has only been possible to determine the  $\delta\text{D}$  methane value of the FMT gas sample.

2. Analytical procedure

The natural gas has been separated into the different gas components by a Carlo-Erba 4200 instrument. The hydrocarbon gas components were oxydized in separate CuO-ovens, which enables us to collect several times when the concentration of a gas component is low. The combustion products  $\text{CO}_2$  and  $\text{H}_2\text{O}$  were frozen into collection vessles and separated. The isotopic measurements were performed on a Finnigan Mat 251 mass spectrometer. Our  $\delta^{13}\text{C}$ -value on NBS-22 is  $-29.77 \pm 0.06$  ‰.

3. Results

The stable isotope results are given in table 1.

The composition of the headspace gases are given in table 2 and the composition of the vacutainers are given in table 3.

#### 4. Interpretation

As seen from table 1, thermogenic methane migrated and was mixed with biogenic methane at least to about the 1000 m level. The sealing efficiency of the cap rock may therefore not be complete with respect to methane.

The FMT sample (1475 m) shows a rather heavy  $\delta^{13}\text{C}$  propane value. This is in accordance with the data reported from the reservoired gases of well 31/3-1 and well 31/5-1, 31/5-2. The heavy  $\delta^{13}\text{C}$  propane value can in our view only be explained by effects of bacterial degradation. This is also in agreement with the high  $i\text{C}_4/n\text{C}_4$ -ratio of the samples from this zone, table 2.

The methane and most of the ethane have, however, not been effected by the bacterial degradation. If this was the case, we should according to our previous experience have seen much heavier  $\delta^{13}\text{C}$  methane and - ethane values.

New methane and ethane, or a dry gas with only small amounts of wetter components, must therefore have migrated into the reservoir after the bacterial degradation had stopped. The new gas could, particularly if the geological situation of the reservoir is complex, have been mixed with varying amount of the already biodegraded hydrocarbon gas components in the reservoir. It is in this connection interesting to note the sample from the 1550-1575 m level. This sample should according to the high  $i\text{C}_4/n\text{C}_4$  ratio belong to the zone where most of the biodegradation appears to have occurred. The rather heavy  $\delta^{13}\text{C}$  methane and -ethane values of this sample suggest that a relatively smaller amount of the new gas have been mixed with the earlier biodegraded hydrocarbons of this zone. From this depth and downwards to at least 1680 m increasing amounts of new gas appears to have been mixed with the earlier biodegraded gas, or the gases in this zone were only slightly biodegraded.

The samples from the (1830-1845)m level and downwards have a normal trend in the distribution of the  $\delta^{13}\text{C}$  values of methane, ethane and

propane. This normal trend between the hydrocarbon gas components may according to the  $\delta^{13}\text{C}$  propane value (- 28) even extend upwards to the 1770-1785 m level. The normal trend samples, (1830-1845) m and (1980-1995) m, are plotted in the maturity diagram by James (1983).\*

These samples indicate a high maturity source situation eq. to the condensate field of the oil window (Figure 1). These gases may represent ; a) The generation of gas (or gases) which occurred in the reservoir prior to the bacterial degradation, or b) they may represent the gases which migrated into the reservoir after the bacterial degradation had taken place and may thus represent the gases which are presently migrating into the reservoir.

The carbon and hydrogen isotopic composition of the FMT sample are plotted in a  $\delta^{13}\text{C}$  methane vs  $\delta\text{D}$  methane cross plot (Schoell 1983 \*\*), Figure 2.

As seen from Figure 2 b, the methane appears to have a small component of biogenic origin. This is, however, not considered likely. Relatively light methane values can also occur at a high maturity situation when cracking of oils and organic material occur.

## 5. Conclusion

The interpretation given for the reservoired gas of well 31/3-1 and well 31/5-1, 31/5-2 would also fit the present situation. Biodegradation of hydrocarbons in the reservoir was followed by a period of renewed supply of predominantly dry gas.

The gas samples taken underneath the reservoir {(1830-1845)m level and (1980-1995)m level} have been formed at a high maturity situation, eq. to the condensate field of the oil window.

These gases are not affected by bacterial degradation, and may therefore represent the gases (or gas) which are presently migrating into the reservoir.

- \* James, Alan T. (1983) : Correlation of Natural Gas by Use of Carbon Isotopic Distribution Between Hydrocarbon Components, A.A.P.G. Vol. 67, No. 7, July, 1983.
  
- \*\* Schoell, M. 1983 : Genetic Characertization of Natural Gases. A.A.P.G. December, 1983.

TABLE 1. ISOTOPIC COMPOSITION OF MUD, RESERVOIRED AND HEADSPACE GAS FROM WELL 31/6-2

IFE No.	Sample depth m	$\delta^{13}C_1$	$\delta D$	$C_2$	$C_3$	$iC_4$	$nC_4$	$Co_2$
	500 *	-64.0						
1482	525 - 540	-62.7						
1483	570 - 585	-73.0						
1484	630 - 645	-70.0						
1485	675 - 690	-74.3						
1486	720 - 735	-72.3						
1487	810 - 825	-63.8						
1476	855 - 870	-53.5						
1478	940 - 960	-60.5						
1479	1020 - 1035	-57.4						
1480	1065 - 1080	-55.9						
1481	1110-1125	-54.1						
1488	1335 - 1350	-50.1						
1489	1365 - 1380	-47.6		-30.1				
1490	1425 - 1440	-44.2		-26.2	-25.4			
	1475 m FMT **	-43.7	-135.4	-26.8	-17.0	-26.6	-23.3	5.9
1492	1560 - 1575	-36.5		-20.4				
1493	1590 - 1605	-38.6		-27.0	-25.5			
1494	1650 - 1665	-43.8		-29.9	-26.5			
1495	1680 - 1695	-42.9		-27.8				
1496	1740 - 1755	-45.0		-25.5				
1497	1770 - 1785	-43.9			-28.0			

IFE No.	Sample depth m	$\delta^{13}\text{C}_1$	$\delta\text{D}$	$\text{C}_2$	$\text{C}_3$	$\text{iC}_4$	$\text{nC}_4$	$\text{CO}_2$
1498	1830 - 1845	-43.9		-28.6	-28.5			
1499	1860 - 1875	-40.0		-29.5	-27.9			
1500	1950 - 1965	-46.8		-28.0				
1501	1980 - 1995	-45.6		-28.6	-28.4			

\* Vacutainer

\*\* Aluminiumbag

Our uncertainty on the  $\delta^{13}\text{C}$ -value is estimated to be  $\pm 0.3$  ‰, and includes all the different analyses steps.

The uncertainty on the  $\delta\text{D CH}_4$  value is about 5 ‰. The isotopic measurements have been performed in Mook's laboratory, Groningen, Netherland.



TABLE 2. COMPOSITION OF HEADSPACE AND RESERVOIRED GAS FROM  
WELL 31/6-2

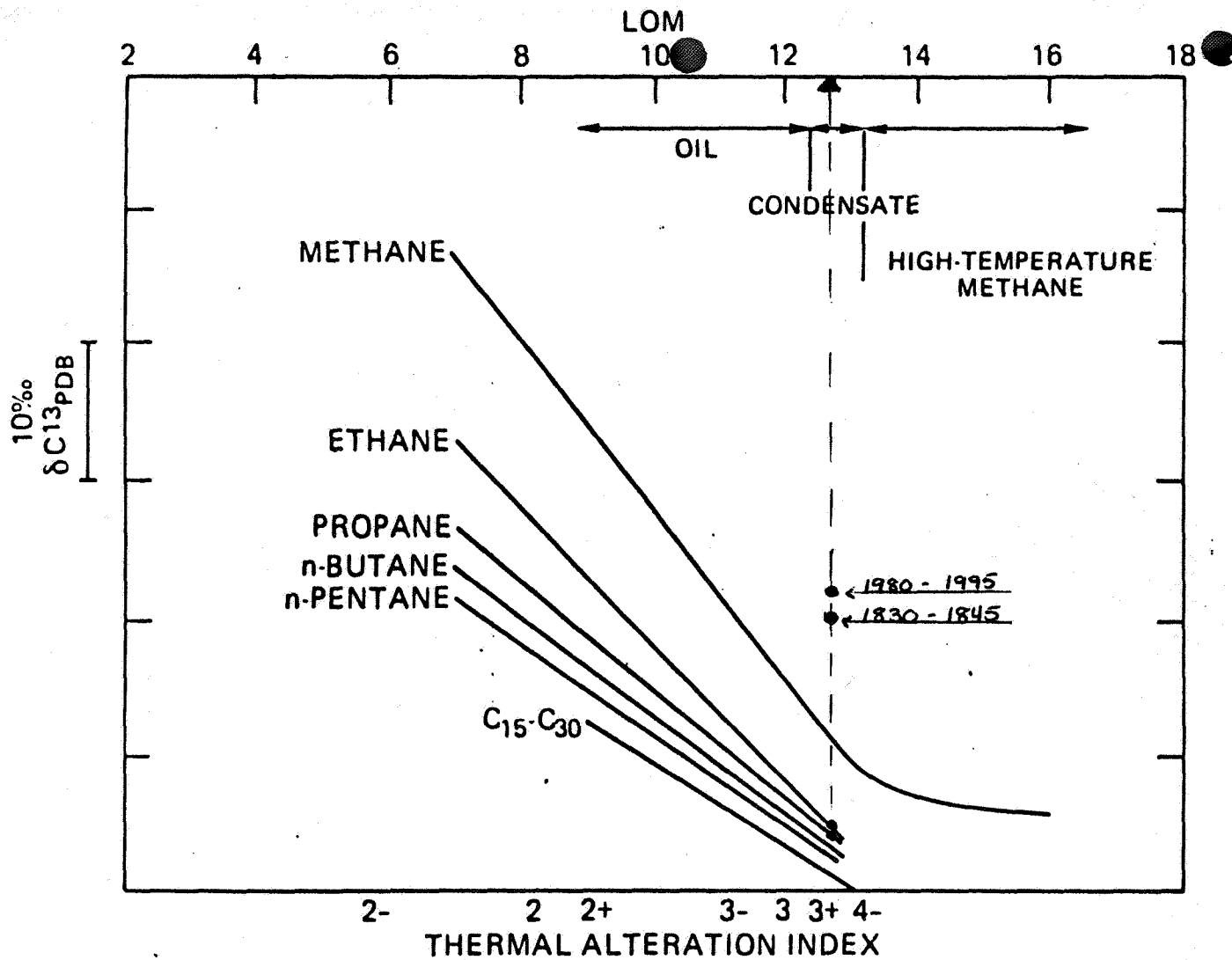
Sample depth m	% of C <sub>1</sub> -C <sub>4</sub>							
	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	iC <sub>4</sub>	nC <sub>4</sub>	CO <sub>2</sub>	$\frac{\Sigma C_2 - C_4}{\Sigma C_1 - C_4}$	$\frac{iC_4}{nC_4}$
525 - 540	3.5	0.01				0.026		
570 - 585	4.4	0.01				0.040		
630 - 645	9.4	0.02				0.019		
675 - 690	14.5	0.02				0.043		
720 - 735	9.2	0.007				0.036		
810 - 825	6.9	0.04	0.001	0.002		0.035	0.006	
855 - 870	4.9	0.03	0.002	0.002	0.002	0.015	0.007	1.0
913 - 930	0.03							
940 - 960	5.7	0.06	0.08	0.052	0.018	0.004	0.036	2.9
1020 - 1035	1.3	0.03	0.05	0.035	0.014		0.090	
1065 - 1080	3.3	0.05	0.02	0.004	0.004	0.002	0.023	1.0
1110-1125	7.1	0.08	0.02	0.011	0.008	0.009	0.016	1.4
1335 - 1350	9.9	0.20	0.07	0.025	0.017	0.007	0.031	1.5
1365 - 1380	21.8	0.60	0.15	0.049	0.032	0.017	0.037	1.5
1425 - 1440	3.7	1.06	0.39	0.105	0.073	0.022	0.31	1.4
1455 - 1470	0.03	0.02	0.02	0.027	0.010	0.005	0.72	2.7
1475 m FMT	67	1.7	0.46	0.31	0.03	0.42	0.04	10.3
1560 - 1575	1.7	0.33	0.12	0.129	0.036	0.024	0.27	3.6
1590 - 1605	1.0	0.30	0.16	0.046	0.032	0.010	0.35	1.4
1650 - 1665	5.8	0.67	0.24	0.050	0.044	0.015	0.15	1.1
1680 - 1695	2.4	0.30	0.16	0.036	0.032	0.021	0.18	1.1
1740 - 1755	2.8	0.32	0.16	0.036	0.032	0.045	0.16	1.1

Z of  $C_1 - C_4$ 

Sample depth m	$C_1$	$C_2$	$C_3$	$iC_4$	$nC_4$	$Co_2$	$\frac{\Sigma C_2 - C_4}{\Sigma C_1 - C_4}$	$\frac{iC}{nC}$
1770 - 1785	1.7	0.30	0.12	0.024	0.027	0.019	0.22	0.9
1830 - 1845	1.7	0.16	0.09	0.020	0.017	0.025	0.14	1.2
1860 - 1875	1.0	0.15	0.09	0.024	0.022	0.054	0.22	1.1
1950 - 1965	4.2	0.50	0.16	0.037	0.029	0.064	0.15	1.3
1980 - 1995	2.2	0.37	0.21	0.052	0.045	0.100	0.24	1.2

TABLE 3. COMPOSITION OF MUD GAS FROM WELL 31/6-2

Sample depth, m	% of C <sub>1</sub> - C <sub>4</sub>					
	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	iC <sub>4</sub>	nC <sub>4</sub>	CO <sub>2</sub>
500	0.13					0.04
600	0.02					0.05
700	0.01					0.03
800	0.04					0.04
920	0.03					0.04
925	0.04					0.04
1000	0.01					0.04
1100	0.03					0.04
-	0.03					0.04
1200	0.03					0.04
1300	0.04					0.04
1400	0.05					0.04
1500	0.03					0.04
1600	0.03					0.04
1800	0.03					0.04
1900	0.02					0.04



**Figure 1.** Carbon isotopic separations of the headspace gases from the (1830-1845) m level and the (1980-1995) m level of well 31/6-2 are plotted on the maturity diagram (after James, 1983). A source LOM of about 13 is indicated for the gas.

The calculated carbon isotopic separations between gas component are plotted on the vertical axis using a sliding scale that is simply the algebraic difference, in parts per mil, between the isotopic compositions of the natural gas components. The scale does not possess a fixed origin, but is oriented with the more depleted  $\delta^{13}\text{C}$  values at the upper end. Use of this sliding scale allows the maturity of a gas to be assessed without prior knowledge of the isotopic composition of the gas' source.

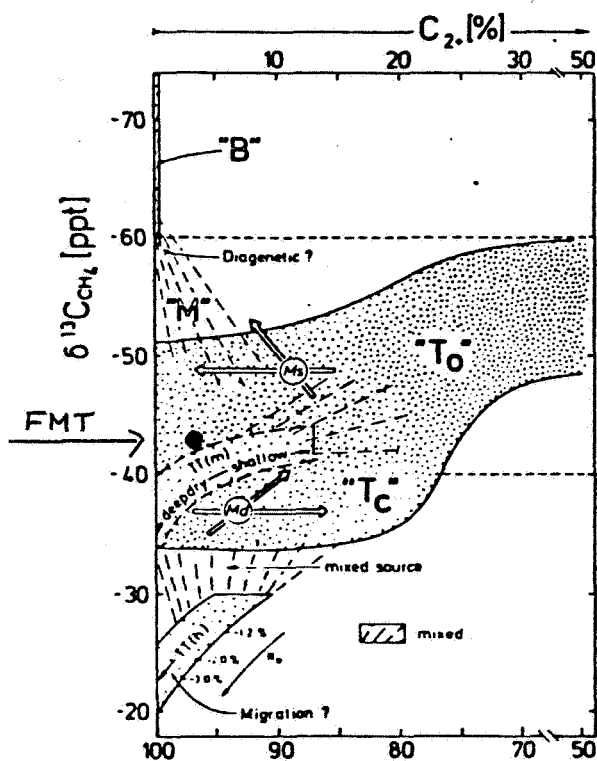


Figure 2 a. Variations of molecular composition in natural gases related to the isotope variations of methane.

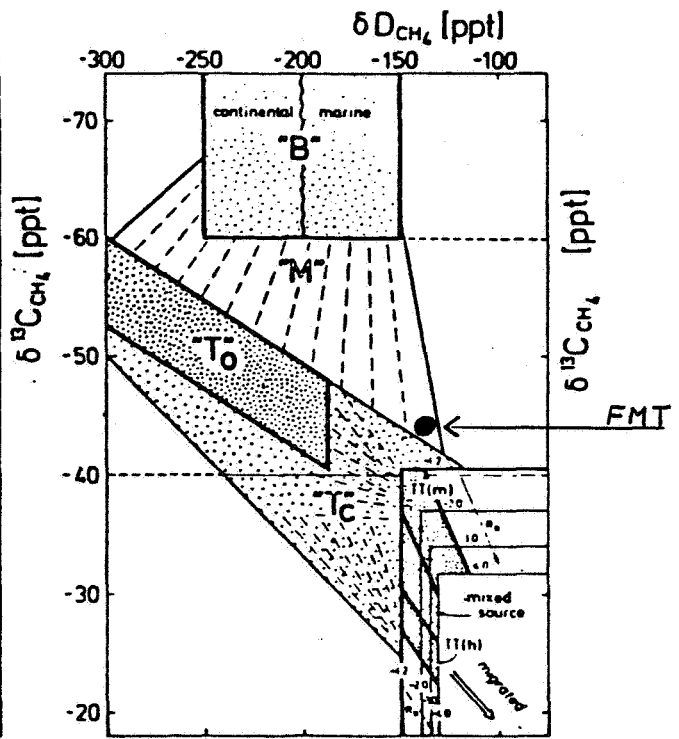


Figure 2 b. Carbon and hydrogen isotope variations in methane.

The principle for the genetic characterization of natural gases is that the primary gases (B-biogenic gas, T-associated gas, TT-non-associated gas) are defined by fields of compositional variations. These primary gases may become mixed and form various mixtures "M" of intermediate composition. "TT(m)" and "TT(h)" are non associated gases from marine source rocks and coal gases from N.W. Germany respectively, compositional shifts due to migration are indicated by arrows Md (deep migration) and Ms (shallow migration) respectively. "T" are gases associated with petroleum in an initial phase of formation. "T<sub>c</sub>" are gases associated with condensates. (Schoell, 1983).