

Denne rapport  
tilhører

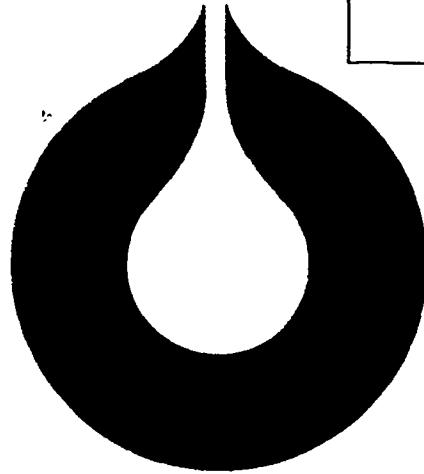
 **STATOIL**

**L&U DOK. SENTER**

L. NR. 30284390011

KODE Well 31/3-1 nr 44

Returneres etter bruk



**statoil**

Tritiated water in the mud by  
drilling well 31/3-1. Estimation  
of formation water from FMT-samples.

STATOIL  
EXPLORATION & PRODUCTION  
LABORATORY

by  
Reidun Kleven

July 1984

LAB

**Den norske stats oljeselskap a.s**



Classification

Requested by

Roald Riise, LET S

Subtitle

Co-workers

Didrik Malthe-Sørenssen, Torgeir Lund, Hans Petter Rønningesen  
Kåre Sørheim

Title

Tritiated water in the mud by  
drilling well 31/3-1. Estimation  
of formation water from FMT-samples.

STATOIL  
EXPLORATION & PRODUCTION  
LABORATORY

by  
Reidun Kleven

July 1984

LAB84.221

Prepared

30/7-84 Reidun Kleven  
Reidun Kleven

Approved

7/8-84 Didrik Malthe-Sørenssen  
Didrik Malthe-Sørenssen

SUMMARY

To determine the migration of mud into the rock structure, mud samples and FMT-water samples were analysed for ion and tritium concentrations. In addition, leakage of cushion water into the sampling chambers was measured.

Tritiated water was injected in the mud during drilling the well 31/3-1, depth 1303-1820 m. Samples of the mud were analysed on the platform for tritium concentration by liquid scintillation counting. Further, samples were analysed on shore under lab conditions by atomic absorption spectroscopy. The data was used to estimate the ion composition of the formation water by using sorption coefficients previously determined. The results obtained were generally in accordance with results from previous wells tested in this area, with the exception which showed higher concentrations than expected of potassium. The calculations have been described in detail in a separate report from IFE (1).

## 1 INTRODUCTION

The purpose of the experiments was to study mudfiltrate invasion into the rock formation. Sorption effects were determined by adding tritiated water to the mud. The initial approach was to measure tritium and ion concentrations in water produced during a drill stem test as a function of time. A similar experiment has previously been performed by drilling and testing on well 30/6-6. (2,3). However, due to the low recovery of oil in the FMT-tests in the oil/water zone it was decided not to proceed with the DST in this zone.

The experiment was concluded by chemical and radiochemical analysis of the FMT-samples. These analysis, together with information on sorption coefficients determined in the evaluation of data from 30/6-6, were used to estimate the ion composition of the formation water.

Tritiated water is an ideal tracer for measuring the mud infiltration in the formation fluid. It is easy to detect, has a good miscibility and does not interfere with the formation.

## 2. EXPERIMENT AND RESULTS

### 2.1 Mud system

Tritiated water was injected into the mud at a rate of 83 ml/min. during one mud cycle (1 1/2 h.). The tritium level was kept constant at  $(65 \pm 4)$  Bq/ml in the mud during drilling through the section 1303-1820 m. This was achieved by adding tritiated water to all pits where mud was mixed. Controlled amounts of tritium were also added directly to the circulating system to compensate for fluid loss.

0,5 litres of drilling mud was sampled from the shaker pit every hour during the drilling period, and processed on the rig. 100 ml of the mud samples were distilled and one ml of the distillate was used to determine the tritium concentration by liquid scintillation counting.

To measure the ion composition in the mud used in the actually zone mud- samples no. 123 (1564 m), no 124 (1571 m) and no. 134 (1613 m) were sent to West Lab for ion analysis. The results of these analyses are summarised in Table 1. The average ion composition of three samples is used to represent the ion composition of the mud filtrate for the interval where FMT-tests were done (1570-80 m).

## 2.2 FMT-samples

Three FMT-tests were performed in the gas/oil/water - zone: FMT 1 (1574,2 m), FMT 2 (1579,5 m) and FMT 3 (1570,0 m). The 10.409 litre chambers were treated off shore and the water samples designated FMT 1b, FMT 2b and FMT 3b were collected in one liter bottles on the rig and shipped to West lab for ion analysis.

The content of the 3,785 litre chamber was shipped to the Statoil laboratory. The water from the chamber was collected in 1 liter bottles and 5 ml conc  $\text{HNO}_3$  was added to prevent salt precipitation. These samples were designated FMT 1a, FMT 2a and FMT 3a. The volume of sample FMT 3a was too small to obtain analytical data.

The following data was obtained for the FMT-samples:

a) Tritium concentrations in the distillate.

The same procedure used to analyse the mud samples was adopted. The ratios of tritium concentration in the FMT-samples to tritium concentration in the mud are given in Table 2. These results are used to determine contamination of the mud in the FMT-water.

b) Cushion water in FMT-samples.

Prior to sampling a known concentration of NaI was added to the cushion water in the FMT-tools (0,82 g / 14,2 l). The contamination of the cushion water is proportional to the concentration of iodine in the FMT-water samples. The volume of cushion water in the FMT-samples is given in

Table 2. A detailed description of the experimental procedure is included in Ref.1 and in appendix.

c) Ion concentrations.

Ion analysis were performed on the filtrates by West Lab. The data is given in Table 3.

### 2.3 Core analysis

To get some additional information about mud filtrate migration into the formation one section of the seal peal 1575.45 -.75 was examined. The core was frozen and a 2 cm thick slice was cut vertically through the middle. One radial section was cut from the slice and then divided into 3 rods (samples 1-3). Each rod was grounded to sand in a precooled mortar.

The water from the core was collected by distillation. Approximately 4 ml of water was extracted from rod no.1 (outer) and rod no.3 (inner). Due to too high distillation temperature, the sample from rod no.2 was destroyed. The distillate was a white turbid solution and 1 ml of the solution was used to determine the concentration of tritiated water by liquid scintillation counting.

The radiochemical analysis of the destillate show 80% tritiated water with no gradient through the core.

### 3 FORMATION WATER COMPOSITION

The ion and tritium concentration measured for the FMT-samples was corrected for the leakage of cushion water by adding sodium iodine.

The corrected values for a mixture of mud filtrate and formation water, have been listed in Table 4 and are shown graphically in Figs. 1 and 2. as a plot of % mudfiltrate versus the ion concentration in FMT-samples. The ion concentration in the formation water is higher than the ion concentration in the mudfiltrate and in Fig. 2 the ion concentration in the formation water is lower. A linear relationship between ion concentration and per cent mudfiltrate (see Figs. 1 and 2) means there is no sorbtion effects between the ions and the rock formation. Linearity is found for  $\text{Na}^+$ ,  $\text{Cl}^-$  and  $\text{Sr}^{++}$  - ions. This result is as expected for sodium and chloride ions, which are generally accepted to be freely movable in aqueous solutions.

The curves for the other bivalent cations, calcium and magnesium deviate from linearity. This might be due to the fact that calcium and magnesium precipitate easier as hydroxydes and coefficcients. Potassium and sulphate also show strong tendencies of sorption.

Sorbtion coefficcents for the ions in the formation water could not be established from the results of the experiment due to the relative high concentrations of mud filtrate in all samples. By using sorbtion coefficients from the previous experiment on well 30/6-6, the present data were used to estimate the formation water ion composition. The results are given in Table 5.



The ion concentrations are generally in agreement with those found in formation water from other wells in this area (ref 4-7). The only exception is the extremely high potassium concentration as mentioned earlier in this report. From the general agreement of concentrations of all other ions, we have indicated a potassium concentration of 500 mg/l being more reasonable.

## 4. RESISTIVITY OF FORMATION WATER AND MUD FILTRATE

The resistivity in the estimated formation water is calculated from the equivalent NaCl-concentrations (see Table 6) based on the variable multipliers method (ref.8-9). Two values for the resistivity are given in Table 6:

- b) based on the estimated potassium concentration and
- c) based on the expected potassium concentration.

As earlier discussed (Chap. 3) the estimated potassium concentration is too high. The more reasonable value is 500 mg/l and the corresponding resistivity in the formation water is 0.118 ohm-m.

## 5 REFERENCES

1. Dahl, J.B and Tollan, O. : Use of tritiated water as a drilling mud tracer in well 31/3-1 in the North Sea. Institutt for energiteknikk Prosjektrapport, des. 1983.
2. Dahl, J.B and Tollan, O : Use of tritiated water as a drilling mud tracer in well 30/6-6 in the North Sea. Institut for energiteknikk, Prosjektrapport, juni 1982.
3. Didrik Malthé-Sørensen: Mudfiltrate invasion in formation fluid studied by isotope tracer-formation water analysis of 30/6-6, LAB 82.25.
4. Norske Shell A/S  
Water analysis well 31/2-11 (Geco)
5. Norske Shell A/S  
Water analysis well 31/2-1A (Geco 13.11.81)
6. Water analysis for Norsk Hydro North Sea well 31/4-2 (Core Lab 19.nov. 1979)
7. Water analysis for Norsk Hydro  
report no. sec 109/6  
well 31/4-3 (Core Lab 2. febr. 1980)
8. Schlumberger Log interpretation chart 1978 edition.
9. CRC Handbook of chemistry and Physics 55th Edition, CRC-Press (1975).

Table 1

Ion concentrations measured in mud filtrate from well 31/3-1. The listed values are the averages from three samples: No 123 (1564 m), no 124 (1571 m) and no 134 (1613 m). The average values are taken to be representative for the mud filtrate composition for the interval where FMT-samples were collected (1570-1580 m)

Ion	Concentration	
	mg/l	meq/l
Na	8200	357
Ca	125	6
Mg	25	2
Ba	4	0
Sr	10	0
K	13900	356
Cl	32700	922
SO <sub>4</sub>	3440	72
CO <sub>3</sub>	0	0
HCO <sub>3</sub>	990	16
Cation/anion-ratio		721/1010
TDS (sum of ion analysis)	59394	
TDS (from density)	69000	
pH (20°C)		8.39
SG (gcm <sup>-3</sup> )		1.045
Resistivity (ohm-m)		0.120

Table 2

Volume of cushion water and % mud filtrate in FMT-water samples from well 31/3-1

Sample identi- fication	Depth (m)	Volume FMT- chamber  (1)	Volume of total FMT-water sample  (1)	Volume cushion water in FTM-sample  (1)	% mud filtrate in total FMT-water sample
FMT 1a	1574.2	3.785	2.15	0.312	45
FMT 1b	1574.2	10.409	6.10	0.673	59
FMT 2a	1579.5	3.785	3.70	0.465	53
FMT 2b	1579.5	10.409	6.70	0.492	77
FMT 3a	1570.0	3.785			35
FMT 3b	1570.0	10.409	1.50	0.033	91

Table 3

Ion concentrations in FMT-samples from well no 31/3-1

Depth FMT no	1574,2 m		1579,5 m		1570m
	1a <sup>1)</sup> mg/l	1b <sup>2)</sup> mg/l	2a <sup>1)</sup> mg/l	2b <sup>2)</sup> mg/l	3b <sup>1)</sup> mg/l
Na	8500	9250	7750	7750	7250
Ca	1080	1010	980	730	365
Mg	235	214	204	147	88
Ba	3	3	5	4	1
Fe	3	2	3	2	2
Sr	141	105	115	75	34
K	5040	7500	5440	6240	6520
Cl	29110	31950	29465	31240	29820
SO <sub>4</sub>	600	900	700	1400	1900
HCO <sub>3</sub>	566	645	554	693	1115
TDS/SUM	452785	51579	45216	48280	47095
pH (20°C)	6.75	7.35	6.78	7.20	7.80
Specific gravity (measured gcm <sup>-3</sup> )	1.034	1.037	1.034	1.037	1.037
Specific gravity from TDS (gcm <sup>-3</sup> )	1.032	1.036	1.031	1.034	1.033
Resistivity (ohm-m)	0.146	0.132	0.143	0.132	0.132

1) a = sample from 3.785 l chamber

2) b = sample from 10.409 l chamber

Table 4

Ion concentrations and % mud filtrate in FMT-samples after correction for cushion water contamination.

Depth FMT no	1574,2 m		1579,5 m		1570m
	1a <sup>1)</sup> mg/l	1b <sup>2)</sup> mg/l	2a <sup>1)</sup> mg/l	2b <sup>2)</sup> mg/l	3b <sup>1)</sup> mg/l
Na	9945	10397	8866	8362	7410
Ca	1264	1135	1121	788	373
Mg	275	241	233	159	90
Ba	3	3	6	4	1
Fe	3	2	3	2	2
Sr	165	118	132	80	35
K	4897	8430	6223	6733	6663
Cl	34059	35912	33708	33708	30476
S <sub>O4</sub>	702	1012	801	1511	1942
Hc <sub>O3</sub>	662	725	634	748	1140
% mud filtrate	52	67	61	83	93

- 1) a = sample from 3.785 l chamber  
 b = sample from 10.409 l chamber

Table 5

Estimated ion concentration in the formation water from well no 31/3-1

Ion concentration		
Ion	mg/l	meq/l
Na	15700	683
Ca	3900	90
Mg	550	22
Ba	150	2
Sr	400	10
K	( <sup>a</sup> 5600) <sup>b</sup> 500	( <sup>a</sup> 143) <sup>b</sup> 13
Cl	44500	1255
SO <sub>4</sub>	30	1
CO <sub>3</sub>	300	5
TDS	( <sup>a</sup> 71130) <sup>b</sup> 66030	
Cation/anion ratio		( <sup>a</sup> 1080/1261) <sup>b</sup> 950/1261

Specific gravity from the <sup>a</sup>TDS: 1.0490 gcm<sup>-3</sup>

Specific gravity from the <sup>b</sup>TDS- value (with expected potassium concentration): 1.0455 gcm<sup>-3</sup>

a) The estimated potassium concentration

b) The expected potassium concentration



Table 6.

"Equivalent NaCl - concentration" in formationwater and mudfiltrate from well no 31/3-1

Ion	a)F	Formation water (mg/l)	Mudfiltrate (mg/l)
Na	1	15700	8200
Ca	0.72	2808	90
Mg	0.8	440	352
Ba	0.3	45	13
Sr	0.4	160	64
K	1.12	<sup>b</sup> 6272 <sup>c</sup> 560	15568
Cl	1	44500	32700
S <sub>O4</sub>	0.32	9	1100
HC <sub>O3</sub>	0.2	60	198
Sum		<sup>b</sup> 69994 <sup>c</sup> 64282	58285

The calculated resistivity in the formation water from the estimated ion concentration: 0.111 ohm-m.

The calculated resistivity in the formation water based on the expected potassium concentration: 0.118 ohm-m

The calculated resistivity in the mudfiltrate 0.129 ohm-m  
The measured resistivity in the mudfiltrate 0.120 ohm-m

a) from ref.8.

b) The estimated potassium concentration.

c) The expected potassium concentration

Fig. 1

THE ION CONCENTRATION IN ESTIMATED FORMATION WATER AS A FUNCTION OF % MUDFILTRATE IN THE SAMPLE.

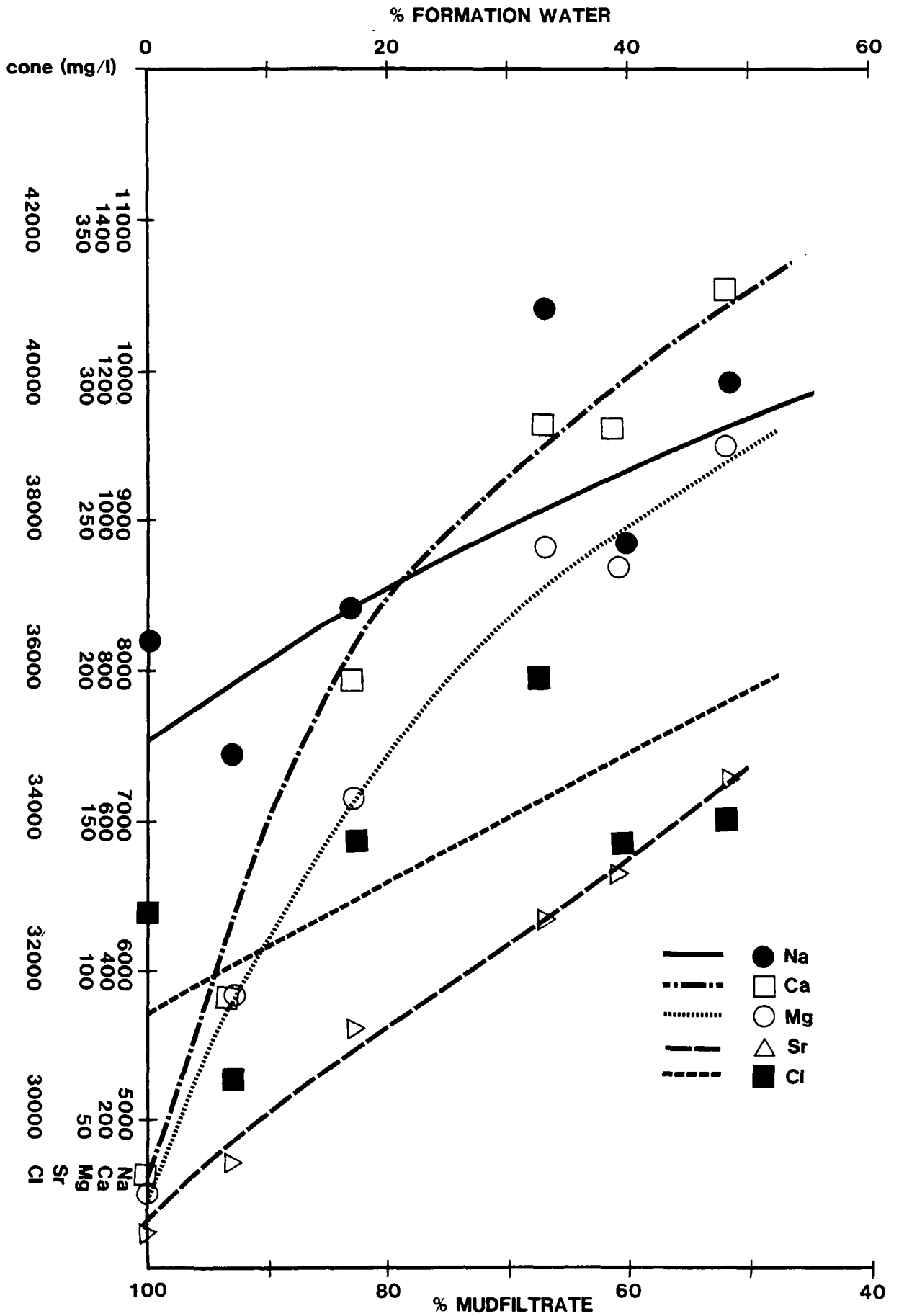
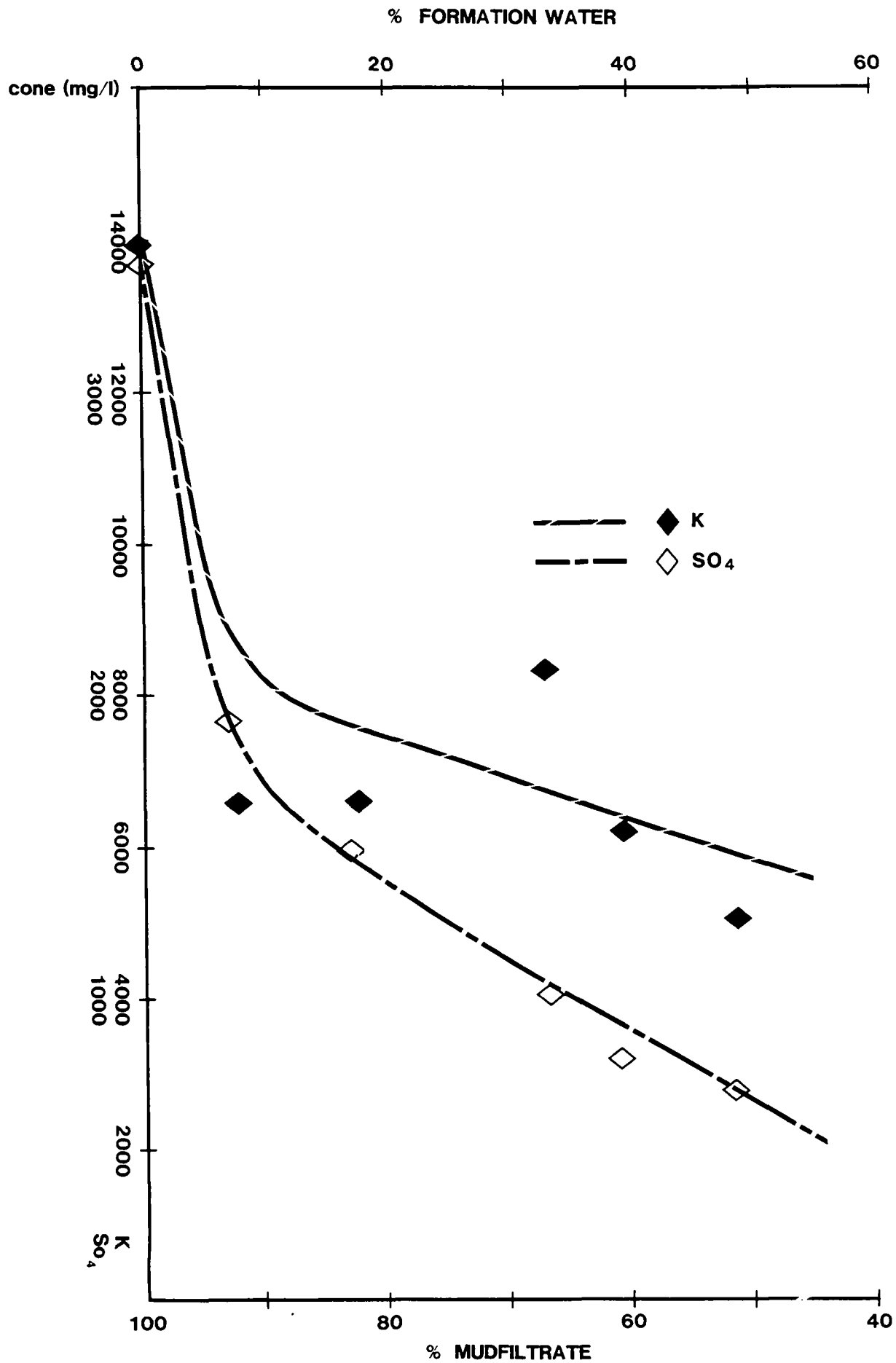


Fig. 2

# THE ION CONCENTRATION IN ESTIMATED FORMATION WATER AS A FUNCTION OF % MUDFILTRATE IN THE SAMPLE





LAB  
AMM/TLF  
15.09.83

N O T A T

TIL: Svein Løining, Troll  
Roald Riise, LET Stav.

				44	

FRA: Arne M. Martinsen, LAB

SAK: FMT PRØVER FRA BRØNN 31/3-1

Laboratoriet fikk 4 en gal. FMT kammer fra 31/3-1.  
Disse kammerne var tatt i henholdsvis 1579.5m, 1574,2m, 1570m og  
1374.2m.

Det avtalte analyseprogrammet gikk ut på å sjekke åpningstrykket  
til hvert enkelt kammer, avgjøre verdien av prøven for fremtidig  
PVT bruk, overføre deler av prøven til egnede høytrykksbeholdere,  
samt tappe av resten av innholdet, og måle mengder gass, olje,  
kondensat, samt evt. vann/mudfiltrat.

**FMT kammer fra 1579.5m.**

Åpningstrykk: 2-3 Bar.

Mengde vann : 3700ml.

Kommentar:

Dette kammeret inneholdt bare vann/mudfiltrat. 2000ml. ble  
beholdt for videre analyse.

**FMT kammer fra 1574.2m.**

Åpningstrykk : 20 Bar.  
Åpningstrykk fra rigg: ca. 90 Bar.

**Innhold:**

Mengde olje: 1270ml.  
Mengde vann: 2150ml.  
Mengde gass: 30.000ml.

En prøve for organisk geokjemi analyser.

**Kommentar:**

Åpningstrykk fra rigg var rapportert til ca. 90 Bar. Kammeret hadde derfor lekket under transport, og kunne ikke gi et riktig bilde av reservoarvæske-komposisjonen i oljesonen. Kammeret ble tappet av, og mengde gass, olje og vann målt. Disse prøvene er nå til analyse ved PRO-LAB.

**FMT kammer fra 1570m.**

Åpningstrykk : 115 Bar.  
Åpningstrykk fra rigg: Ca. 109 Bar.

**Innhold:**

Gass: 700cm<sup>3</sup> overført til flaske nr. 83081712 ved ca. 350 Bar.  
215 l gass blødd av etter overføring.  
2 prøver til organisk geokjemi analyser.

Olje/kond: neg.  
Vann : 165ml.

**Kommentar:**

Kammeret ble trykket opp til ca. 300 Bar, og stod ved dette trykket i ca. 48 timer. 700cm<sup>3</sup> ble så overført til en høytrykkssylinder.  
Denne sylindren vil bli sjekket for komposisjon, og oppbevart inntil videre. Vannet blir også analysert.

FMT kammer fra 1374.2m.

Åpningstrykk : 130 Bar.  
Åpningstrykk fra rigg: Ca. 103 Bar.

Innhold:

Gass: 700cm<sup>3</sup> overført til flaske nr. 83081219 ved ca. 325 Bar.  
405 l gass blødd av etter overføring.  
2 prøver til organisk geokjemi analyser.

Olje/kond: neg.  
Vann : Spor, men for lite til analyse.

Kommentar:

Kammeret ble trykket opp til ca. 300 Bar, og stod ved dette trykket i ca. 52 timer. 700cm<sup>3</sup> ble deretter overført til en høytrykks-sylinder. Den vil bli sjekket for komposisjon, og oppbevart inntil videre.