



<b>BP NORGE - FORUS</b> RECORDS MANAGEMENT AND LIBRARY	
AC/SL	NOCS 2/1-4 W25
HOLIS ID:	<del>101456</del> 100033

copy 2

Copy No. 15

## RESEARCH CENTRE

SUNBURY - ON - THAMES

MIDDLESEX

---

### EXPLORATION AND PRODUCTION DIVISION

#### GEOCHEMISTRY BRANCH

GCB/12/89

JANUARY 1989

---

### THE CONDITIONS OF TRAPPING OF BRINE AND PETROLEUM IN AUTHIGENIC CEMENTS IN THE GYDA SANDSTONE, WELL 2/1-4, NOCS : FLUID INCLUSION RESULTS

By  
N.H. Oxtoby

Sponsored by:

BPPD Norway

Approved by:

M.L. Coleman

B P E X P L O R A T I O N

I N F O R M A T I O N & L I B R A R Y S E R V I C E S

I N D E X S H E E T

Report Number (internal only): GCB/12/88

Title: THE CONDITIONS OF TRAPPING OF BRINE AND PETROLEUM IN AUTHIGENIC CEMENTS  
IN THE GYDA SANDSTONE, WELL 2/1-4 NOCS: FLUID INCLUSION RESULTS

Author(s): N.H. OXTOBY

Company: BP RESEARCH INTERNATIONAL

Date of Report: JANUARY 1989

Keywords: RESERVOIR, ROCK, DIAGENESIS

Country or Area (if applicable): NOCS

Well Name (if applicable): 2/1-4

Oil/Gas field names (if applicable): GYDA

-----  
PLEASE COMPLETE IF REPORT REFERS TO GEOGRAPHICAL/GEOLOGICAL AREA

Area Covered:	Northernmost Latitude	57d	0m	0s
	Westernmost Latitude	3d	0m	0s
	Southernmost Latitude	56d	45m	0s
	Easternmost Latitude	3d	20m	0s

Sedimentary Basin:

Stratigraphy: JURASSIC ONLY (youngest age)  
(oldest age)

Indexer: A.G. ROBINSON

Date: 18/1/88

1805/AGR/AJT

CONTENTS

	<u>Page No.</u>
SUMMARY OF CONCLUSIONS	i
1. BACKGROUND	1
2. IDENTIFICATION OF FLUID INCLUSIONS AND RESULTS	2
2.1 Heating Experiments	
2.3 Freezing Experiments	
3. DISCUSSION	5
3.1 Variations in Brine Composition	
3.2 Estimation of the True Temperature and Pressure of Trapping	
4. CONCLUSIONS	8
5. REFERENCES	9

- TABLE 1 BP Microthermometric Data, Gyda Sandstone, Well 2/1-4, NOCS.  
2 Elf-Aquitaine Microthermometric Data, Gyda Sandstone Well  
2/1-4, NOCS

FIGURE 1 Tm and Th Histograms for Fluid Inclusions, Well 2/1-4, NOCS.  
(BP Data)

2 Histograms of Homogenisation Temperatures for Fluid Inclusions,  
Well 2/1-4, NOCS. (Elf Data)

3 Histogram of Final Solid Melting Temperatures in Fluid  
Inclusions, Well 2/1-4, NOCS. (Elf Data)

4 Tm vs Th for Aqueous Inclusions, Well 2/1-4, NOCS.

5 Histograms of all Fluid Inclusion Data, Well 2/1-4, NOCS.

SUMMARY OF CONCLUSIONS

1. In the Gyda Sandstone in Well 2/1-4, NOCS, coexisting populations of primary, aqueous and petroleum-bearing fluid inclusions in quartz cement show that cementation and filling of the reservoir with oil were synchronous.
2. The fluids were trapped at ca.135-160°C and 40-65 MPa. This estimate was derived by comparison of the contrasting PVT properties of brine and petroleum. These trapping conditions are close to present day burial conditions and imply that quartz cementation and reservoir filling could have occurred recently, if heat flow was only controlled by conduction, or earlier, if temperatures were raised by movement of hot water into the reservoir.
3. Fluids of variable salinity, some containing methane, were trapped, suggesting mixing of a high salinity, basinal brine with relatively fresh water.

1. BACKGROUND

The Gyda field is situated in Block 2/1, NOCS, on the eastern margin of the Norwegian Central Graben. Commercial oil was discovered in late Jurassic sandstones immediately underlying the radioactive mudstone facies of the Mandal Formation (Kimmeridge Clay Formation equivalent) at 3 to 4km depth. Authigenic cements, particularly quartz overgrowths, significantly impair poroperm over the field. It would obviously be of great use to develop models describing the spatial distribution of these cements and to gain an insight into the timing of cementation. This report documents a fluid inclusion study of the Gyda reservoir in well 2/1-4. The data set is a combination of in-house analyses and trade data received from Elf-Aquitaine.

Fluid inclusion microthermometry relies on the presence of optically transparent authigenic phases of sufficient continuity to enable inclusions of over  $2\mu\text{m}$  diameter to be trapped. In the samples analysed in-house only quartz and neomorphic calcite in shell fragments fulfil these requirements. Elf data include some inclusions in feldspar. Quartz provides the bulk of the microthermometric data in both data sets.

## 2. IDENTIFICATION OF FLUID INCLUSIONS

Six doubly polished wafers of sandstones were prepared from core chips spanning the interval 4044m to 4137.8m brt in well 2/1-4. Primary fluid inclusions (i.e. formed during crystal growth) were found in the abundant quartz overgrowths to quartz grains and in the recrystallised cores of large calcite shell fragments. Two populations of fluid inclusions were distinguished; aqueous and petroleum-bearing. The petroleum bearing inclusions fluoresced blue-white under 354nm UV illumination. Both populations were two phase, containing a small vapour bubble in a much larger volume of liquid. BP microthermometric data are summarised in Table 1.

Elf also identified aqueous and petroleum-bearing fluid inclusions in samples from 4038m to 4082.5m (Table 2). Their sample from 4082.5m contains petroleum-bearing inclusions in a carbonate (whether this is an authigenic phase or a shell fragment is not stated), and in feldspar, but they do not state whether these occur in authigenic feldspar or as secondary inclusions in a grain. A point to note is that most of the Elf data come from 4038m, which is above the top of the core as recorded on the composite log and above the main Gyda sand body. I presume that Elf are quoting subsea depths, since adding RTE (25m) to all values gives sample points within the cored interval. Elf microthermometric data are summarised in Table 2.

### 2.1 Heating Experiments

In heating two phase, liquid-dominated inclusions, the vapour bubble becomes smaller and eventually disappears. The temperature of disappearance is known as the homogenisation temperature ( $T_h$ ) and is interpreted as the minimum temperature of trapping of the inclusion. Presumably owing to temperature variation over the period of trapping, most primary inclusions in a homogeneous population show a range in  $T_h$ , which is conventionally plotted as a frequency histogram.

BP data are shown on Figure 1.  $T_h$  for the aqueous inclusions varies between 125 and 155°C with a mean of 144°C.  $T_h$  (the bubble point temperature) for the petroleum-bearing inclusions varies between 90 and 95°C with a mean of 93°C. This difference between  $T_h$  of the aqueous and petroleum-bearing inclusions is expected and results from the considerably different compressibilities of petroleum and water.

Elf data are shown on Figure 2.  $T_h$  for the aqueous inclusions varies between 125 and 150°C with a mean of 137°C.  $T_h$  for the petroleum-bearing inclusions varies between 80 and 110°C with a mean of 92°C.

The difference between the Elf and BP data sets for aqueous inclusions is statistically significant and may be ascribed to the difference in depth ranges sampled: the lower  $T_h$  data from Elf comes from shallower levels. However the absolute difference is small (7 °C) enough for the combined data to be used to estimate the true temperature and pressure of trapping of the fluids (Section 3.2).

Elf also report decrepitation temperatures for some inclusions. This is the temperature at which the pressure inside the inclusion exceeds the strength of the host mineral, causing it to leak. It may be used in the estimation of the true temperature and pressure of trapping of the inclusion fluids and is the preferred method amongst the French oil companies (Pagel *et al.*, 1986). However, the assumptions required by this method are badly constrained and we prefer the method described by Narr and Burruss (1984).

## 2.2 Freezing Experiments

In freezing experiments the inclusion under study is cooled until the contents are completely frozen. Phase changes on warming are then observed and the transition temperatures noted. The easiest measurement to observe is the final melting temperature ( $T_m$ ), which may be used to estimate the salinity of aqueous inclusions (Potter *et al.*, 1978). Occasionally the temperature of first melting ( $T_f$ ) may be observed, which



gives an indication of the cation composition in the fluid (Borisenko, 1977; Roedder, 1984).

BP Tm data are shown on Figure 1. They display a very wide range (-15 to 0°C) which strongly suggests that more than one aqueous fluid was present in the system. One Tf of -21°C was measured in a high salinity inclusion. This suggests that NaCl alone is the dominant solute. In contrast the Elf data (Figure 3), cluster in two fields with means of -12°C and +2.1°C. Here we assume that Elf's "Tapp" (vapour phase apparition) and "Tf" (fusion temperature = BP's Tm) are equivalent. Numerous measurements made in-house in the past would suggest this to be a fair approximation, for aqueous inclusions with small vapour bubbles, on the following grounds. Complete freezing of an aqueous inclusion with a high liquid to vapour ratio usually results in complete disappearance of the vapour bubble, due to the larger volume of ice relative to water. On warming, the sum of the volumes of liquid plus ice must decrease to a volume less than that of the inclusion cavity before the vapour bubble can reappear. This normally takes place within 1 degC of the final melting temperature.

The Tm values above 0°C result from the formation of a gas hydrate, in this case most likely to be natural gas (with CH<sub>4</sub> dominant) since the samples were taken from a petroleum reservoir. We cannot calculate the salinity of the gas-bearing inclusions because such a calculation requires estimates of

- a) the vapour-liquid ratio
- b) the density of methane in the vapour phase at room temperature

in addition to an equation of state for the system H<sub>2</sub>O-NaCl-CH<sub>4</sub>. Neither a) nor b) could be determined from the available sample material (see also discussion in Hanor, 1980).

### 3. DISCUSSION

#### 3.1 Variations in Brine Composition

Figure 4 shows a Th versus Tm crossplot with both Elf and BP data indicated. The lowest Tm measured was  $-14.4^{\circ}\text{C}$ , corresponding to a fluid of 183,000 ppm salinity (NaCl equivalent) with a density of  $1.07\text{g cm}^{-3}$ . The minimum salinity approaches fresh water (i.e. is less than sea water) with a density of  $0.92\text{g cm}^{-3}$ . Elf data indicate that methane is present in some inclusions.

The Th versus Tm data are arranged on a roughly linear trend which could represent a mixing line between high salinity, presumably basinal, brines and relatively fresh water. It is possible that the apparently low salinity inclusions also contain methane in varying, but low, concentrations.

#### 3.2 Estimation of the True Temperature and Pressure of Trapping

The fluids in the inclusions were trapped roughly synchronously as single phase fluids, at a point in P,T space ( $T_t$ ,  $P_t$ ). With a change in conditions, the fluids follow a path in P-T space corresponding to a line of constant bulk density or "isochore". On cooling, the inclusion remains single phase until the point of univariant liquid-vapour equilibrium is reached. This point is at Th (and Ph) for the inclusion fluid. The difference between  $T_t$  and Th is however likely to be small ( $<20^{\circ}\text{C}$ ) in the range of subsurface conditions expected for the genesis of our samples so that the assumption that  $T_h \approx T_t$  is not grossly erroneous. However, we do have enough data to estimate  $T_t$  and  $P_t$  by the method discussed by Narr and Burruss (1984) as follows.

This method utilises the PVT properties of synchronously trapped immiscible fluids of different chemistry, namely petroleum and brine. First the bubble point curve for each fluid is plotted on a P-T diagram.

The homogenisation temperature for each fluid is plotted on the bubble point curve and an isochore projected from these  $T_h$  points. The limiting  $T_h$  values are taken at two standard deviations about the means of the pooled Elf and BP data for brine and petroleum inclusions (Figure 5). The intersection of the isochores gives  $T_t$  and  $P_t$  (Figure 6).

The PVT properties of NaCl brines are relatively simple over a wide range of salinities and are well known (Potter and Brown, 1977). The PVT properties of petroleum are complex, being a function of the composition of the specific petroleum being studied; at present it is easier and more accurate to measure the PVT properties rather than predict them from compositional data. We must assume that the inclusion petroleum is the same as the reservoir petroleum and that the 2/1-8 sample is representative of the reservoir as a whole. The latter is likely as the Gyda oil is relatively homogeneous throughout. The former assumption is probably valid for petroleum composition since the inclusion petroleum showed blue-dominant fluorescence under UV illumination indicative of a light oil (Hagemann and Hollerbach, 1986). However, it is not possible to ascertain whether the PVT properties of inclusion and reservoir petroleum correspond, since the gas-oil ratio of the inclusion petroleum cannot be determined in this case. The major assumption in this calculation is that the PVT properties do correspond.

The bubble point curve for petroleum is constructed from the data given below:

Saturation Pressure (psia)	Temperature ( $^{\circ}$ C)	Density ( $\text{kg m}^{-3}$ )
3143	158	566
2764	93	630
2090	27	688

The petroleum isochores are constructed using Figure 7. The petroleum density according to the PVT analysis is ca.  $630\text{kg m}^{-3}$  at saturation at  $93^{\circ}\text{C}$  which is approximately the mean  $T_h$  for the inclusion

petroleum. The inclusion petroleum has a constant bulk density and thus we can read off a series of P,T pairs for petroleum of this density on the single phase field from the figure. These define the petroleum isochores plotted on Figure 6.

The brine isochores are estimated from the data of Potter and Brown (1977), given  $T_h$  and a salinity estimate (from  $T_m$ ). The isochores are projected from the brine-only liquid-vapour equilibrium curve. If the inclusions contain methane, the liquid-vapour equilibrium will be shifted to higher pressures. In this case  $T_h$  will be closer to  $T_t$ , and  $P_h$  will be closer to  $P_t$ . Because the isochores of aqueous fluids are steep, the effect on  $T_t$  estimation will be small, but the effect on the estimation of  $P_t$  could be large (ca. 10 MPa). These effects must be borne in mind when interpreting the data. Nevertheless, if we assume the PVT properties of aqueous inclusions are due to a brine-only system, we shall derive a maximum temperature (and a maximum pressure) of trapping, to be compared to the minimum temperature of trapping given by  $T_h$  values.

The true temperature of trapping is given at the isochore intersections as 140-160°C, while the true pressure of trapping is given as 40-65 MPa. In view of the uncertainties regarding the presence of methane in the aqueous inclusions, the true temperature of trapping probably lies between 135 and 160°C.

4. CONCLUSIONS

1. Primary aqueous and petroleum bearing fluid inclusions were trapped in authigenic quartz in the Gyda Sandstone in well 2/1-4, NOCS. Their coexistence indicates growth of quartz cement during reservoir filling.
2. Freezing data show that, as expected, methane or homologous compounds occur in some inclusions. The majority however appear to contain only brine. The salinity variation (18.3% to 1.0% NaCl equivalent) suggests mixing of a highly saline, presumably basinal brine with relatively fresh water.
3. Differences in the PVT properties of the petroleum-bearing and aqueous inclusions can be used to estimate the maximum temperature and pressure of trapping; here 135-160°C and 40-65 MPa. These figures are close to present-day values and imply either
  - a) quartz growth and reservoir filling were recent, or
  - b) quartz growth and reservoir filling were earlier, and reservoir temperatures were raised above those predicted by convective heat flow models, by movement of water.

5. REFERENCES

- BORISENKO, A.S. 1977 Study of the salt compositions of solutions in gas-liquid inclusions in minerals by the cryometric method. Soviet Geol. and Geophys. v.18 p11-19.
- HAGEMANN, H.W. and HOLLERBACH, A. 1986 The fluorescence behaviour of crude oils with respect to their thermal maturation and degradation. Org. Geochem. v.10 p.473-480.
- HANOR, J.S. 1980 Dissolved methane in sedimentary brines; potential effect on the PVT properties of fluid inclusions Econ. Geol. v.75 p.603-617.
- NARR, W. and BURRUSS, R.C. 1984 Origin of Reservoir Fractures in Little Knife Field, North Dakota. AAPG Bull. v.68 No.9. p.1087-1100.
- PAGEL, M., WALGENWITZ, F. and DUBESSY, J. 1986 Fluid Inclusions in Oil and Gas-Bearing Sedimentary Formations, in Burrus, J. (ed) Thermal Modeling in Sedimentary Basins. Editions Technip p.565-583.
- POTTER, R.W.II and BROWN, D.L. 1977 The volumetric properties of aqueous sodium chloride solutions from 0° to 500°C at pressures up to 2000 bars based on a regression of available data in the literature. U.S. Geol. Surv. Bull 1421-C, 35p.

- POTTER, R.W.II, CLYNNE, H.A. 1978 Freezing point depression of  
and BROWN, D.L. aqueous sodium chloride solutions.  
Econ. Geol. v.73 p.284-285.
- ROEDDER, E. 1984 Fluid Inclusions. Rev. Mineralogy  
v.12. Min. Soc. America. 644p.
- SHEPHERD, T., RANKIN, A.H. 1985 A practical guide to fluid  
and ALDERTON, D.H.M. inclusion studies, Blackie 239p.

TABLE 1

BP MICROTHERMOMETRIC DATA, GYDA SANDSTONE WELL 2/1-4, NOCS

SHEET 1

Sample ID.	Depth (m)	Th corr (°C)	est isochore [gcm-3 NaCl=]	Tm corr (°C)	Salinity wt%= [NaCl]	Remarks
G882901	4044	151.3 ± 0.5	0.99	-5.4 ± 0.1	9.7	PS, L+V (L), irregular, L-shaped, subang 20x17μm aq
"	4044	145.4 ± 0.5	0.98	-5.4 ± 0.2	8.4	PS, L+V (L), irregular, submd 8x4μm aq
"	4044	128.1 ± 0.5				PS, L+V (L), rectangular negx1, subang 6x4μm aq
"	4044	141.7 ± 0.5				PS, L+V (L), equant, submd 5x5μm aq
"	4044	142.6 ± 0.5				PS, L+V (L) equant, submd, 3x3μm aq
"	4044	145.5 ± 0.5				P, L+V (L) equant, submd 6x4μm aq
G882902	4050	139.3 ± 0.5	1.04	-11.1 ± 0.1	15.1	P, L+V (L), irregular subang, 10x8μm aq
"	4050	153.9 ± 0.5	0.92	-0.8 ± 0.2	1.4	P, L+V (L), trapezoid negx1, submd 7x5μm aq
"	4050	94.4 ± 0.3				P, L+V (L), negx1, ang 19x12μm Paleyel, blue-whfluor. petrol.

WORK BY: N.H. OXTOBY  
DATE: AUGUST 1988



TABLE 1 (Cont'd)

BP MICROTHERMOMETRIC DATA, GYDA SANDSTONE WELL 2/1-4, NOCS

SHEET 3

Sample ID.	Depth (m)	Th corr (°C)	est isochore [gcm-3 NaCl=]	Tm corr (°C)	Salinity wt%=[NaCl]	Remarks
G882904	4078.8	150.1 ± 0.5				P, L+V (L) elliptical, rnd, 3x2µm
"	4078.8	147.8 ± 0.5				P, L+V (L) elliptical, elongate, rnd 2x1µm
G882906	4137.8	ca.141°C	≈1.06	-14.0 ± 0.2	17.9	?P,L+V (L), negxl, ang 8x5µm. Bubble reappeared gradually in rexl. shell fragment.
"	4137.8	ca.156°C	≈1.04	-13.2 ± 0.1	17.2	?P L+V (L), irreg. subong 10x6µm Bubble reappeared gradually in rexl. shell frag. Tf = -21°C.
"	4137.8	ca.146°C	≈1.05	-13.7 ± 0.3	17.6	?P, L+V (L) irregular, submd 12x7µm Bubble reappeared gradually in rexl. shell frag.
"	4137.8			-12.3 ± 0.1	16.3	PS, L+V (L) irregular, submd 12x7µm Unable to renucleate v. bubble after homogenisation.

aq = aqueous    p = primary    L = liquid    (L) = homogenisation into  
 PS = pseudo secondary    V = Vapour    liquid phase  
 S = Secondary

WORK BY: N.H. OXTOBY  
 DATE: AUGUST 1988

TABLE 1 (Cont'd)

BP MICROTHERMOMETRIC DATA, GYDA SANDSTONE, WELL 2/1-4, NOCS

SHEET 2

Sample ID.	Depth (m)	Th corr (°C)	est isochore [gcm-3 NaCl=]	Tm corr (°C)	Salinity wt% [NaCl]	Remarks
G882902	4050	92.0 ± 0.3				P, L+V (L), elliptical, rnd, 8x5µm clear; blue-wh fluor. Petrol.
"	4050	92.0 ± 0.3				P, L+V (L), irregular, rnd 5x4µm clear; blue-wh fluor. Petrol
"	4050	125.7 ± 0.6				P, L+V (L), equant submd 6x5µm aq
"	4050	134.1 ± 0.5				P, L+V (L), irregular, subang 4x2µm aq
"	4050	132.6 ± 0.5				P, L+V (L) triangular, submd, 5x5µm aq
G882903	4053.75	143.2 ± 0.5				PS, L+V (L) elliptical, rnd 2x1µm aq
"	4053.75	148.0 ± 0.5				PS, L+V (L), irregular, elongate submd 5x2µm aq
"	4053.75	147.8 ± 0.5				PS, L+V (L), equant, elong, subang 6x2µm aq
"	4053.75	149.6 ± 0.5				PS, L+V (L), equant, elong, subang 5x2µm aq
"	4053.75	144.6 ± 0.5				PS, L+V (L), triang, subang 2x2µm
"	4053.75	149.7 ± 0.5	0.92	-0.6 ± 0.2	1.0	P, L+V (L), negx1, subang, 8x5µm
"	4053.75	149.0 ± 0.5	0.93	-0.8 ± 0.2	1.4	P, L+V (L), triangular, subang, 5x5µm
"	4053.75	153.7 ± 0.5	0.95	-2.9 ± 0.1	4.8	P, L+V (L) elongate, angular 8x2µm
"	4053.75	148.2 ± 0.5				P, L+V (L) trapezoid, angular 6x3µm

WORK BY: N.H. OXTOBY  
 DATE: AUGUST 1988

TABLE 2

ELF AQUITAINE MICROTHERMOMETRIC DATA, GYDA SANDSTONE, WELL 2/1-4, NOCS

BASIN : NORWEGIAN CENTRAL GRABEN  
LITHOLOGY : SANDSTONE

ANALYSIS BY: N.H. OXTOBY  
ANALYSIS DATE: JUNE 1988

HOST PHASE	DEPTH(m) SAMPLE	INCLUS. NUMBER	HOMOGENISATION TEMP(+or- err.)	FINAL MELTING TEMP(or- err.)	SALINITY (wt % NaCl) eq.	CONTENTS
Quartz	4038	1	97.60			P
"	4038	2	86.20			P
"	4038	3	87.50			P
"	4038	4	99.80			P
"	4038	5	86.50			P
"	4038	6	137.00	-12.70	16.7	B
"	4038	7	139.70	-10.90	14.9	B
"	4038	8	128.80	-14.40	18.3	B
"	4038	9	138.10	-11.40	15.4	B
"	4038	10	135.50	-11.40	15.4	B
"	4038	11	137.60	-11.00	15.0	B
"	4038	12	135.00		B	
"	4038	13	100.20			P
"	4038	14	107.10			P
"	4038	15	86.20			P
"	4038	16	87.40			P
"	4038	17	86.50			P
"	4038	18	86.40			P
"	4038	19	87.70			P
"	4038	20	91.80			P
"	4038	21	91.10			P

TABLE 2 (Cont'd)

ELF AQUITAINE MICROTHERMOMETRIC DATA, GYDA SANDSTONE, WELL 2/1-4, NOCS

BASIN : NORWEGIAN CENTRAL GRABEN  
LITHOLOGY : SANDSTONE

ANALYSIS BY: N.H. OXTOBY  
ANALYSIS DATE: JUNE 1988

HOST PHASE	DEPTH(m) SAMPLE	INCLUS. NUMBER	HOMOGENISATION TEMP(+or- err.)	FINAL MELTING TEMP(or- err.)	SALINITY (wt % NaCl) eq.	CONTENTS
Quartz	4038	22	90.40			P
"	4038	23	89.40			P
"	4038	24	140.00	-13.80	17.7	B
"	4038	25	130.00	-11.20	15.2	B
"	4038	26	137.50			B
"	4038	27	87.30			P
"	4038	28	87.40			P
"	4038	29	89.00			P
"	4038	30	102.70	-95.10		P
"	4038	31	89.60			P
"	4038	32	98.90	-100.00		P
"	4038	33	101.20			P
"	4038	34	91.50			P
"	4038	35	89.60			P
"	4038	36	93.90			P
"	4038	37	92.10			P
"	4038	38	95.30			P
"	4038	39	139.00	-11.20	15.2	B
"	4038	40	137.60	-11.40	15.4	B
"	4038	41	130.10	-12.20	16.2	B
"	4038	42	135.20	-12.60	16.6	B

TABLE 2 (Cont'd)

ELF AQUITAINE MICROTHERMOMETRIC DATA, GYDA SANDSTONE, WELL 2/1-4, NOCS

BASIN : NORWEGIAN CENTRAL GRABEN  
LITHOLOGY : SANDSTONE

ANALYSIS BY: N.H. OXTOBY  
ANALYSIS DATE: JUNE 1988

HOST PHASE	DEPTH(m) SAMPLE	INCLUS. NUMBER	HOMOGENISATION TEMP(+or- err.)	FINAL MELTING TEMP(or- err.)	SALINITY (wt % NaCl) eq.	CONTENTS
Quartz	4038	43	137.50	-14.10	18.0	B
"	4038	44	138.90	-13.00	17.0	B
"	4038	45	133.00	-10.90	14.9	B
"	4038	46	141.70	-12.80	16.8	B
"	4038	47	87.70			P
"	4038	48	86.80			P
"	4038	49	138.50	-11.70	15.7	B
"	4038	50	135.40			B
"	4038	51	131.40	-11.60	15.6	B
"	4038	52	141.50	11.50	15.5	B
"	4038	53	136.40	-11.60	15.6	B
"	4038	54	138.90	-11.50	15.5	B
"	4038	55	136.20	-12.00	16.0	B
"	4038	56	135.50	-11.70	15.7	B
"	4038	57	128.40	-11.60	15.6	B
"	4038	58	135.60	0.00	0.0 (?C)	B
"	4038	59	134.90	5.60	C	B
Quartz	4053	1	138.60	0.80	C	
"	4053	2	138.50	-0.20	0.4	

TABLE 2 (Cont'd)

ELF AQUITAINE MICROTHERMOMETRIC DATA, GYDA SANDSTONE, WELL 2/1-4, NOCS

BASIN : NORWEGIAN CENTRAL GRABEN  
LITHOLOGY : SANDSTONE

ANALYSIS BY: N.H. OXTOBY  
ANALYSIS DATE: JUNE 1988

HOST PHASE	DEPTH(m) SAMPLE	INCLUS. NUMBER	HOMOGENISATION TEMP(+or- err.)	FINAL MELTING TEMP(or- err.)	SALINITY (wt % NaCl) eq.	CONTENTS
Quartz	4053	3	138.70	-0.10	0.2	B
"	4053	4	142.60	3.30	C	B
"	4053	5	136.30	4.40	C	B
"	4053	6	139.50	4.10	C	B
"	4053	7	138.10	3.40	C	B
"	4053	8	147.30	-0.70	1.2	B
Carbonate	4082.50	1	92.50		P	
"	4082.50	2	84.00		P	
"	4082.50	3	92.60		P	
"	4082.50	4	90.00		P	
Feldspar	4082.50	1	91.10		P	
"	4082.50	2	93.90		P	
"	4082.50	3	87.50		P	
"	4082.50	4	94.30		P	
"	4082.50	5	92.70		P	

All temperatures measured in degrees Centigrade. Inclusions sizes measured in micrometres.  
S = Solid, L = Liquid, V = Vapour, P = Petroleum, B = Brine, C = Clathrate melting

# T<sub>m</sub> AND T<sub>h</sub> HISTOGRAMS FOR FLUID INCLUSIONS; WELL 2/1-4, NOCS (BP DATA)

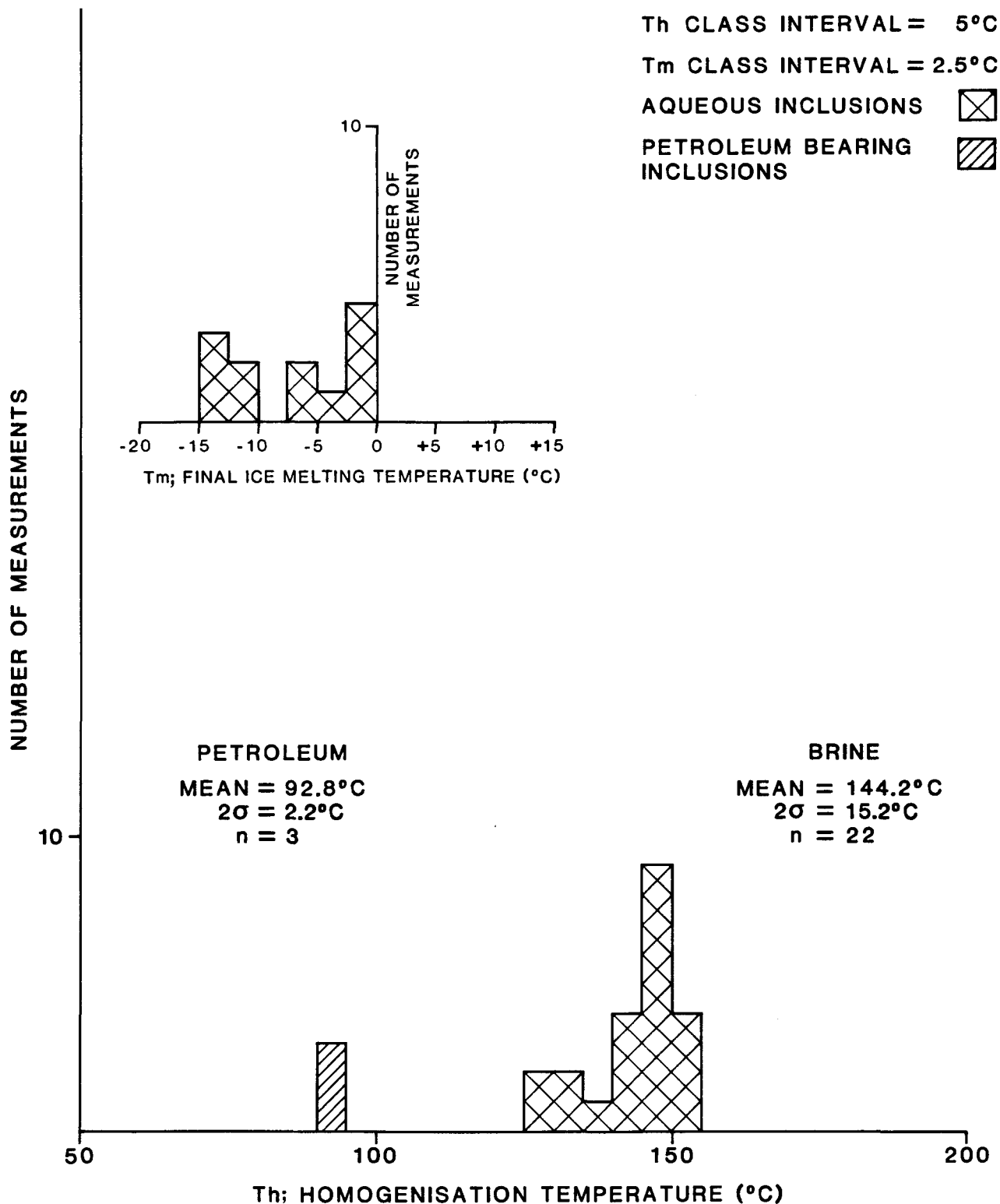


Figure 1

# HISTOGRAMS OF HOMOGENISATION TEMPERATURES FOR FLUID INCLUSIONS; WELL 2/1-4, NOCS (ELF DATA)

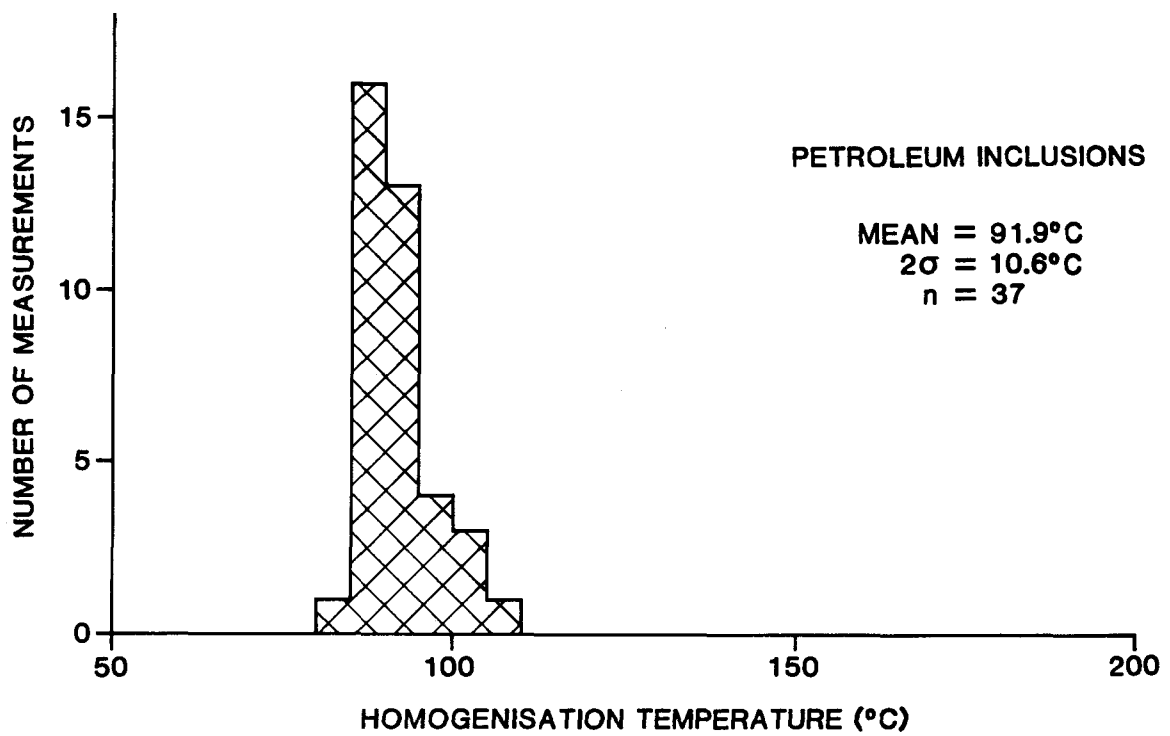
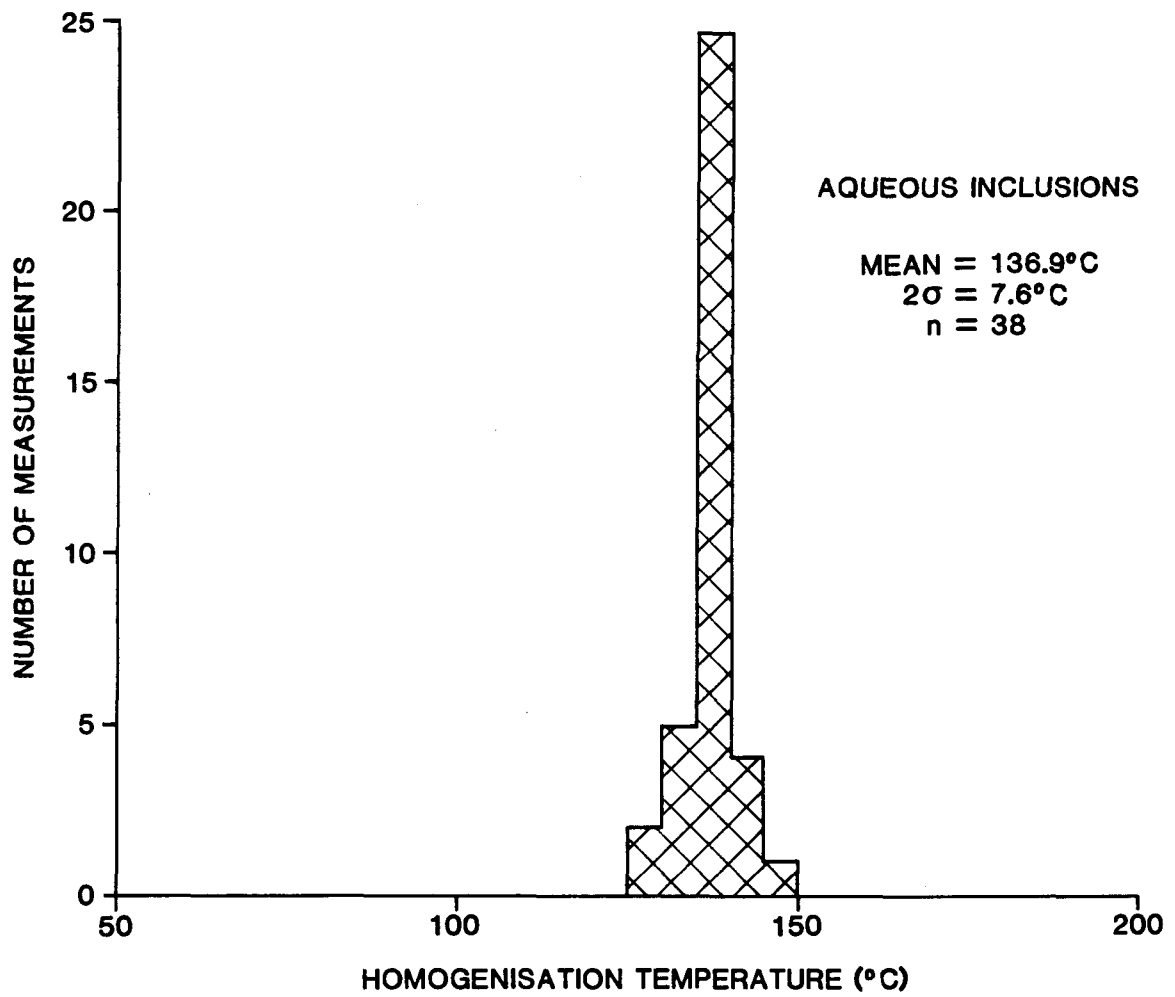


Figure 2



# HISTOGRAM OF FINAL SOLID MELTING TEMPERATURES IN FLUID INCLUSIONS; WELL 2/1-4, NOCS (ELF DATA)

MEAN =  $-12.0^{\circ}\text{C}$   
 $2\sigma = 2.0^{\circ}\text{C}$   
 $n = 23$

MEAN =  $2.1^{\circ}\text{C}$   
 $2\sigma = 4.0^{\circ}\text{C}$   
 $n = 10$

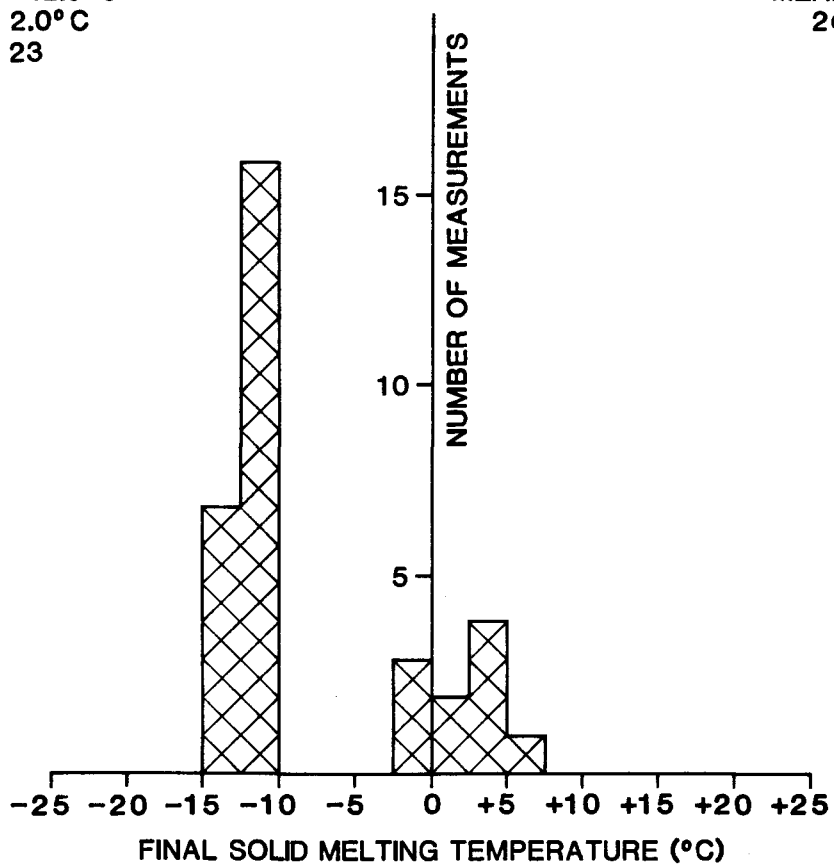


Figure 3

# T<sub>m</sub> vs T<sub>h</sub> FOR AQUEOUS INCLUSIONS; WELL 2/1-4, NOCS

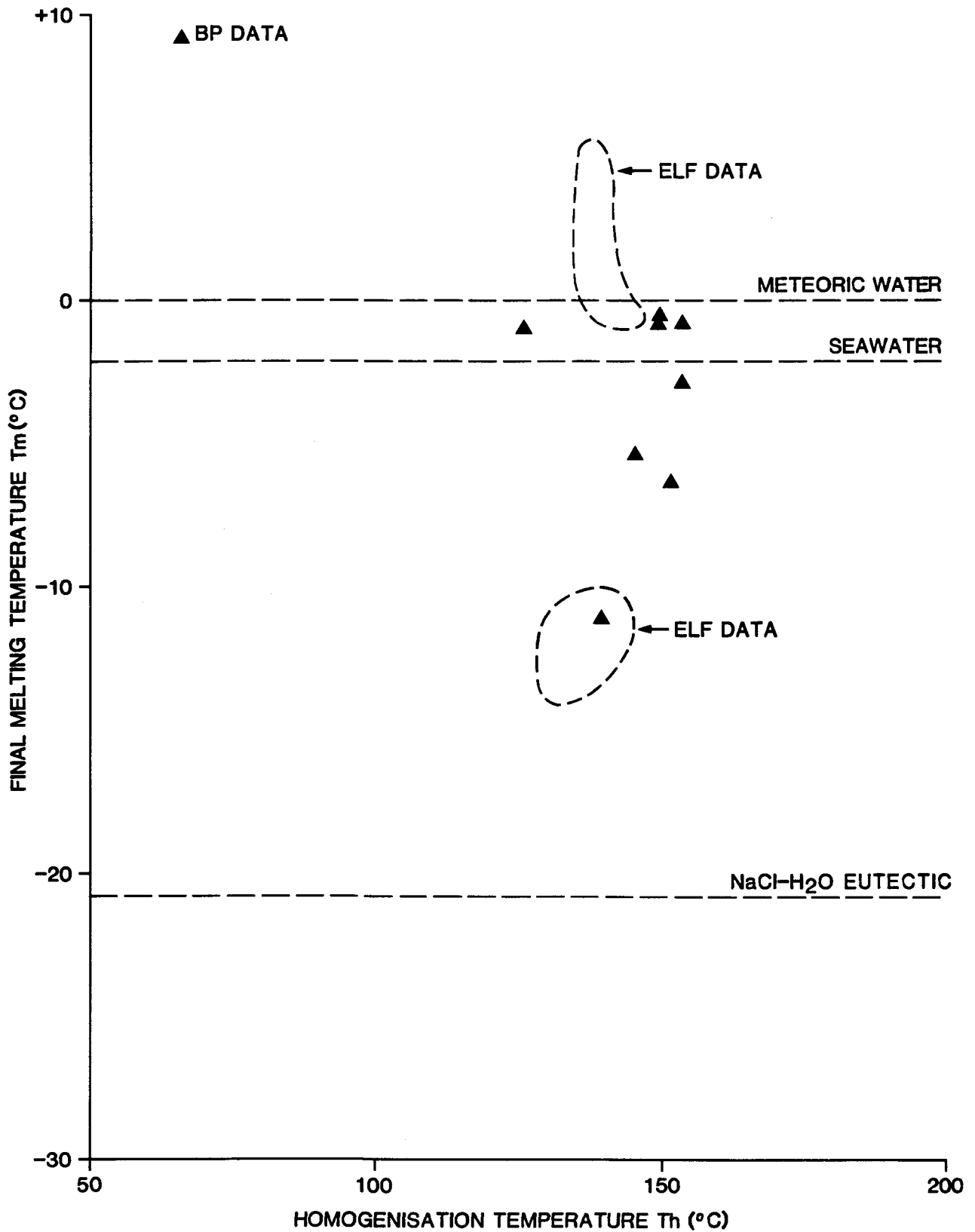
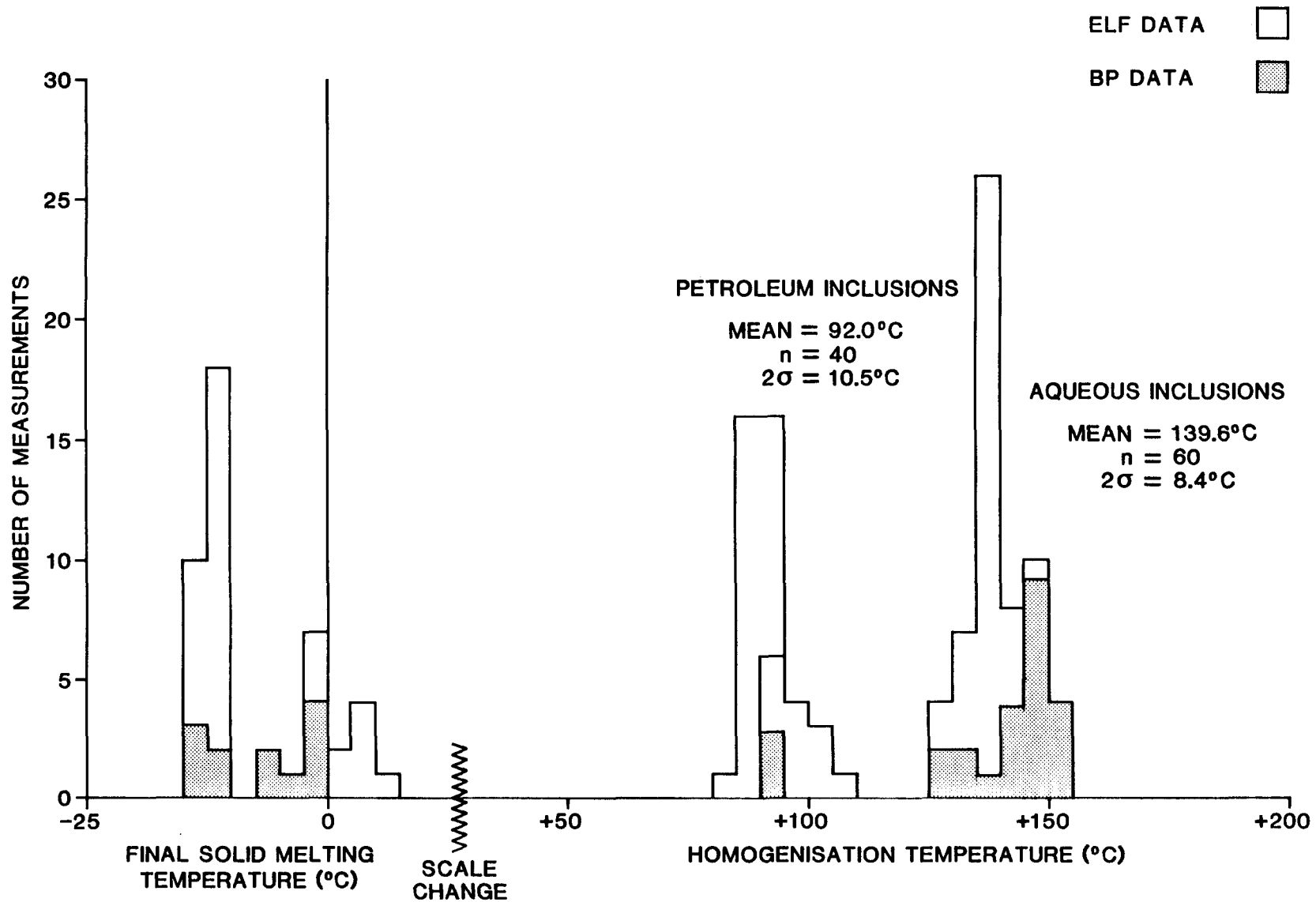


Figure 4

# HISTOGRAMS OF ALL FLUID INCLUSION DATA; WELL 2/1-4, NOCS



RCS 21301  
 BP Research Centre Sunbury  
 GCB/12/89

Figure 5