



Report no.
GEOLAB 93.17
Copy no.
No. of copies 9

SECTOR FOR PETROLEUM TECHNOLOGY
Geological laboratories

Grading

Title A geochemical review of data for petroleum from wells 30/2-1, 30/2-2 and 30/2-3, Huldra Field, and comparison with Veslefrikk Field		
Requested by Bob Firth, UND LS/NN	Project	
Date 11/2/93	No. of pages 169	No. of enclosures

Keywords

Organic geochemistry, gas, oil, condensate, thermal maturity, source rock correlation, Huldra Field, Veslefrikk Field,

Abstract

See Summary, p.iv.

BA-93-545-1

15 MAR 1993

REGISTRERT

OLJEDIREKTORATET

Prepared by

Kristin Skadsem Eikermann, Statoil
Richard Patience, Statoil
IFE

Text operator Richard Patience

Approved by

12/2/93 *G. van Graas*

G. van Graas, Section Manager,
Geochemistry

12.02.93 *T. Meyer*

T. Meyer, Dept. Manager, Geolab

**A GEOCHEMICAL REVIEW OF DATA FOR PETROLEUM FROM WELLS 30/2-1,
30/2-2 AND 30/2-3, HULDRA FIELD, AND COMPARISON WITH
VESLEFRIKK FIELD**

Contents

	p.
Summary	iv
1. Introduction	1
2. Samples and Methods	2
2.1 Samples	
2.2 Methods	
3. Results	3
3.1 Gases	
3.2 Condensates	
3.2.1 Bulk composition	
3.2.2 Molecular composition	
4. Discussion	7
4.1 Inter-DST variations in Huldra Field	7
4.2 Thermal maturity of the Huldra fluids	7
4.3 Source correlation for Huldra fluids	10
4.3.1 Draupne Formation	
4.3.2 Heather Formation	
4.3.3 Brent Group	
4.3.4 Dunlin Group	
4.4 Comparison of petroleum in Huldra with Veslefrikk Field	14
4.4.1 Veslefrikk oils - source and thermal maturity	
4.4.2 DST#1, well 30/3-A1	
5. Conclusions	19
6. References	20
Tables	
Figures	
Appendices	

Tables

- 1 Geological information for gas columns in Huldra Field
- 2 Test and analytical information for gas and condensate samples from Huldra Field
- 3 Bulk compositions for condensate samples from Huldra Field
- 4 Thompson's indices from light hydrocarbons analysis of Huldra Field condensates
- 5 Data from GC analysis of whole condensates and saturates fractions, Huldra Field samples
- 6 Data from GC analysis of aromatics fractions, Huldra Field samples
- 7 Biomarker parameters from GCMS analysis of saturated hydrocarbon fractions, Huldra Field condensates
- 8 Depth intervals for potential source rocks in wells 30/2-1, 30/2-2 and 30/2-3, Huldra Field
- 9 Summary of geochemical data for potential source rocks in wells 30/2-1, 30/2-2 and 30/2-3, Huldra Field
- 10 Test information for oil samples from Veslefrikk Field
- 11 Bulk compositions for oil samples from Veslefrikk Field
- 12 Thompson's indices from light hydrocarbons analysis of Veslefrikk Field oils
- 13 Data from GC analysis of saturates fractions, Veslefrikk Field oils
- 14 Data from GC analysis of aromatics fractions, Veslefrikk Field oils
- 15 Biomarker parameters from GCMS analysis of saturated hydrocarbon fractions, Veslefrikk Field oils
- 16 Carbon isotopic data for whole oils and separated fractions, Veslefrikk Field

Figures

- 1 Geographical location of the Huldra Field
 - a) Regional map
 - b) Well locations
- 2 Plot of carbon isotope composition versus fraction for DST#2, well 30/2-1
- 3 Comparison of GC traces of saturates fractions from source rocks and a DST from Huldra Field
 - a) Draupne Formation
 - b) Heather Formation
 - c) Dunlin Group mudrocks
 - d) Huldra condensate

Appendices

- 1 Report on stable isotopes, gas samples from well 30/2-1, 30/2-2 and 30/2-3, IFE/KR/F-92/188
- 2 Report on isotopic analysis of condensate from Huldra Field, IFE/KR/F-93/003
- 3 Replicate Iatroscan analyses, Huldra Field condensates

- 4 Whole condensate GC traces (including light hydrocarbons)
- 5 Saturated hydrocarbons GC traces
- 6 Aromatic hydrocarbons GC traces
- 7 Saturated hydrocarbons GCMS traces
- 8 Aromatic hydrocarbons GCMS traces

SUMMARY

1. This study was funded jointly by PL051 and PL052. One of the partners (Conoco) does not, however, have access to information on well 30/3-A1 (Veslefrikk Field). In order to minimise re-writing of the report, references to the black oils in well 30/3-A1 have been retained in the text of Conoco's version, although all data pertaining to this well have been removed from Tables 10-16. Discussion of the special case DST#1, well 30/3-A1, has also been deleted from Conoco's version.
2. Five gases and six condensates from three wells on Huldra Field have been analysed using a wide range of organic geochemical techniques. As a result, an analytically consistent data set comprising bulk, molecular and isotopic compositions has been compiled.
3. Based on this new data set, it is concluded that all fluid samples (gases and condensates) from Huldra Field are identical in geochemical composition. All data and parameters, without exception, confirmed this conclusion.
4. The fluids in Huldra appear to be high thermal maturity products formed within the oil to gas cracking window. However, the source is most likely direct generation and expulsion of a gas/condensate from either the Heather Formation or the Dunlin Group. Cracking of Draupne Formation-sourced oil to gas can not, however, be ruled out from geochemical criteria alone. Phase separation from a black oil is considered to be the least likely origin.
5. The data for Huldra have been compared with geochemical data taken from previous reports for Veslefrikk Field. In stark contrast to Huldra, the black oils in Veslefrikk are sourced from a conventional Draupne Formation within the main oil generation window.
6. The gas/condensate in the Statfjord Formation in well 30/3-A1 in Veslefrikk was most likely produced from either cracking of Draupne Formation-sourced oil to gas, or direct from the Heather or Dunlin. In either case, the thermal maturity over which generation occurred is believed to be lower than for the fluids in Huldra.

1 INTRODUCTION

Three wells (30/2-1, 30/2-2 and 30/2-3) have now been drilled in Huldra Field (Fig. 1) and in each case a gas column was encountered in the Brent Group. Pressure testing suggests that each well is in communication, although the gas-water contact (GWC) is ca. 80m shallower in 30/2-3 than 30/2-2 indicating possible compartmentalisation (Table 1).

The main aim of this study was to analyse geochemically the five available gas samples and six condensates from DSTs in the three wells (Table 2), and to determine whether or not there are variations in fluid composition, thermal maturity and source. Data for source rocks¹⁻³ in the three wells are included for comparison. Hence, these conclusions should contribute to the evaluation of possible compartmentalisation in Huldra Field.

The second purpose of this report was to compare the source and maturity of the gas/condensate in Huldra with the oil in Veslefrikk, using existing geochemical data^{4,5} in the latter case.

2 **SAMPLES AND METHODS**

2.1 **Samples**

The five gas and six condensate samples analysed from Huldra Field are described in Table 2. No gas sample was available for DST#3, well 30/2-1. The data for source rock samples from the Draupne and Brent Formations in Huldra were taken from existing reports¹⁻³. Data for oils from Veslefrikk Field were also extracted from previous reports^{4,5}.

2.2 **Methods**

The samples from Huldra Field were analysed using the following methods:

Condensates

API gravity;
Topping (preparation of >210°C fraction);
Asphaltene precipitation (% asphaltenes);
Iatroscan (% saturates, aromatics and polars);
MPLC (isolation of saturates and aromatics fractions);
GC of saturates fraction;
GC aromatics fraction;
Whole condensate gas chromatography (GC);
Gas chromatography-mass spectrometry (GCMS) of saturates fraction;
GCMS of aromatics fraction;
 $\delta^{13}\text{C}$ of whole condensates.

Gases

Chemical composition (% methane, ethane, propane, butane and CO_2);
Isotopic composition ($\delta^{13}\text{C}$ of C_1 to C_4 ; δD of C_1 ; $\delta^{18}\text{O}$ of CO_2).

All analyses were carried out according to the methods described in the Norwegian Industry Guide to Organic Geochemical Analyses (3rd edition), 1993, except where otherwise stated. Isotopic analyses (gases and condensates) and gas chemical compositions were carried out by IFE (Appendices 1 and 2); all other work was done internally in Statoil.

3 RESULTS

3.1 Gases

Five gas samples from Huldra Field (Table 2) were analysed for their chemical and isotopic compositions. The results are summarised in Appendix 1 ("Report on stable isotopes, gas samples from well 30/2-1, 30/2-2 and 30/2-3", IFE Report No. IFE/KR/F-92/188).

Briefly, the results for all five gases are very similar. Methane contents are around 80% (79.3-82.6) with gas wetnesses ($\sum [C_2-C_5] / \sum [C_1-C_5]$) of ca. 0.15 (0.13-0.17). Carbon dioxide contents are also uniform (4-5%). $\delta^{13}C$ values for methane are around -41‰ in each case (-41.0 to -41.4) and there is a smooth progression towards heavier values from methane to butane. δD values for methane are consistent in all samples, being around -200‰ (-189 to -210), whilst $\delta^{18}O$ for carbon dioxide gives values all within the -1.4 to -4.2‰ range.

3.2 Condensates

Six condensate samples were analysed from Huldra Field (Table 2) with the following results:

3.2.1 Bulk composition

API Gravity:

Values for all six samples are in the mid-40's (42.8-45.4) (Table 3) and are typical for condensates, albeit possibly at the low to average end of the normal range.

Chemical group composition:

All samples have extremely high saturated hydrocarbon contents (ca. 85%) (Table 3) and correspondingly very low polars and asphaltene levels (<4% combined). Such a high saturates content is compatible with a relatively low proportion of C_{15+} material (ca. 60%, Table 3).

Replicate analyses of bulk composition by Iatroscan are given in Appendix 3.

$\delta^{13}C$ of whole condensates:

All six values lie between -27.9 and -28.5‰ (Appendix 2) and hence show only small differences. Individual fractions were not analysed because of the bulk composition (>80% one fraction i.e. saturated

hydrocarbons). Large enough quantities of, especially, the polars and asphaltene fractions (<4% combined) for analysis could not be readily obtained.

3.2.2 Molecular composition

Whole condensate GC data:

Gas chromatograms of whole condensate samples are given in Appendix 4, together with the expanded light hydrocarbon interval. All six samples produced chromatograms with a steep decline in n-alkane abundance with increasing carbon number, characteristic of condensates. The parameters calculated from the C₁₅+ portion of the chromatogram are discussed in the next section (GC of saturates fractions).

The light hydrocarbon chromatograms show signs of suffering from overloading of the column: this was due to the dominance of these components compared to the longer chain alkanes and the consequent difficulties in obtaining good chromatograms for both intervals of interest.

However, analysis of a diluted sample showed that the calculated Thompson's indices were not altered by the overloading (i.e. the peak areas were not affected). The values for each of these parameters (which are taken from reference 7 inter alia) for the six samples (Table 4) are very consistent, with no sample being significantly different from the others. The single anomaly is the apparently different value of the S parameter for well 30/2-2, DST#3 (Table 4). However, this is due to the extremely small peak for the 2,2dmC₄ compound (Appendix 4).

GC of saturates fractions:

The six gas chromatograms of the saturates fractions (Appendix 5) repeat the rapid decline in n-alkane abundance with increasing carbon number, shown by the whole condensate traces (Appendix 4). There is at first sight some variation in the rate of this decline, as evidenced by the nC₁₇/(nC₁₇+nC₂₇) ratio (Table 5a). However, comparison with the same parameter calculated from the whole condensate chromatograms (Table 5b) reveals that these slight differences must be ascribed to analytical variations, as the same trend is not seen in both instances.

The Pr/nC₁₇ ratios (Table 5a) show mostly small variations (0.47-0.53), with one exception (0.66 -

S6533). The latter is the only value which is statistically significantly different. The same applies for the Ph/nC₁₈ ratios, where S6533 has a higher value (0.42) than the other samples (0.29-0.34). However, inspection of the results from the whole condensate gas chromatograms (Table 5b) does not confirm this trend for S6533 and suggests that this sample has in fact lower Pr/nC₁₇ and Ph/nC₁₈ ratios, in line with the other samples.

Pr/Ph ratios lie between ca. 1.8 and 2.5 for the saturates fractions (Table 5a). The values at the low end of the range (1.9 and 1.8 for S6533 and S6534 - both well 30/2-1; 2.0 for S6538 - DST#3, 30/2-3) are statistically different from the two highest ones (2.5 for S6535 - well 30/2-2; 2.5 for S6537 - DST#2, well 30/2-3). However, these differences are again not verifiable from the whole condensate gas chromatograms, where Pr/Ph values for all six samples are between 2.0 and 2.1.

In summary, the whole condensate GC data show absolutely no differences between the six samples for any of the parameters measured. The small differences shown by some samples for some of the parameters from the saturates fractions GC data are presumably the result of analytical variations.

GC of aromatics fractions:

Individual gas chromatograms of the aromatics fractions are given in Appendix 6, whilst the three parameters calculated therefrom (MPI1, F1 and F2) are listed in Table 6. These three ratios are all based on phenanthrenes and show almost no change from one sample to the next. MPI1 values are around 0.85-0.90, those for F1 all lie close to 0.50 whilst F2 values are ca. 0.25.

GCMS of saturates fractions:

The raw GCMS data and tables of peak intensities (Appendix 7) have been used to calculate a number of biomarker parameters, reported in Table 7. The derivation of these ratios is explained in Appendix 7, which also contains a list of the compound codes.

The six samples from Huldra were originally analysed as the complete saturates fractions, which is normal practice. However, the resulting mass chromatograms (e.g. m/z 191 and 217) were extremely weak, due to the low abundances of the triterpane and sterane biomarkers.

Hence these compounds were concentrated up, by removal of the n-alkanes using 5A molecular sieve. The mass chromatograms subsequently acquired were considerably improved, but it can be seen in Appendix 7 that those for the triterpanes (notably m/z 191) are still very weak. Furthermore, the distributions of the hopanes are not typical of oil samples generally. Thus the biomarker parameters based on the triterpanes, presented in Table 7 and described in detail in Appendix 7, have either not been calculated or, where numbers are included, should be regarded with a degree of caution.

In contrast, the mass chromatograms for the steranes (e.g. m/z 217 and 218) are relatively stronger and show a more normal distribution of components. Hence the values for parameters such as 20S, $\beta\beta$, %C₂₇-C₂₉ and DIA/REG (Table 7) are more reliable in this instance. These four parameters show little variation from one sample to another: 20S values are around 0.63 (0.60-0.67), $\beta\beta$ shows even less variation (0.60-0.63), %C₂₇ data are all within 36 to 40% and DIA/REG values fall between 4.42 and 5.38.

GCMS of aromatics fractions:

Mass chromatograms for monoaromatic (m/z 253) and triaromatic (m/z 231) steroids are given in Appendix 8. However, it is evident, from comparison with chromatograms for a standard oil, that both the mono- and triaromatic steroid components are present in only trace amounts amongst a number of other unidentified peaks. Hence, no ratios have been calculated.

4 DISCUSSION

4.1 Inter-DST variations in Huldra Field

Six DSTs covering three wells (Table 2) were analysed in this study and a striking feature is the exceptionally high degree of similarity in the results for all six, both in terms of the gas and condensate fractions. Gas isotopic and chemical compositions are extremely similar (Appendix 1). For the condensates there are, for example, no analytically significant differences in bulk chemical (%C₁₅₊; % saturates, aromatics, polars and asphaltenes; Table 3) and isotopic (Appendix 2) composition between the samples. The values for each sample for each of the so-called Thompson's indices from light hydrocarbon analysis were analytically identical (Table 4). Small apparent differences in some GC parameters (e.g. Pr/nC₁₇; Pr/Ph; nC₁₇/(nC₁₇+nC₂₇); Table 5a) for the saturates fractions were shown to be due to analytical variations, as the same data for the whole condensates (Table 5b) were remarkably uniform.

Similar comments about consistency of the data apply also to the aromatics fractions, both in terms of the appearances of the GC traces and the parameters calculated therefrom (Table 6). Finally, the GCMS data for the saturates fractions (Table 7) conform to the general pattern of no significant differences between samples (especially for the steranes, the triterpanes being too weak to interpret reliably).

The similarity in the data from geochemical analyses from one sample to the next is reflected both in the API gravities (Table 3) and the condensate/gas ratios (CGR) from well testing (Table 2). Both these data sets (with the exception of one CGR resulting from a poor test, Table 2) show minimal variations between samples.

The net result is that, from an analytical viewpoint, the six samples can be considered to be identical, both in terms of gas and condensate composition. Thus, the ensuing discussion of thermal maturity and source correlation for the Huldra fluids applies equally to all samples.

4.2 Thermal maturity of the Huldra fluids

Gas/condensates can in general be considered to have one of three principal origins:

- i) Secondary cracking of oil (i.e. a high temperature product).

ii) Physical separation of a gas phase (bearing dissolved condensate) from an oil phase (i.e. as a result of decrease in pressure and temperature (P,T), for example during secondary migration).

iii) Generation and expulsion of gas/condensate from a source rock (e.g. coals or low quality marine source rocks) (see ¹ below).

Both i) and iii) can be considered to "high thermal maturity" scenarios, albeit from different source rock types, whereas ii) involves a lower thermal maturity in combination with a largely oil prone source rock.

Distinguishing between these possibilities is not always easy, especially as work on phase separation effects is comparatively in its infancy. However, most of the data described above (section 3) are compatible with a high thermal maturity source for the fluids, although there is some uncertainty in the literature as to whether "high" should be taken to mean within the main oil generation window or in the field of gas/condensate formation. The reasons for this conclusion are given in more detail in the ensuing paragraphs:

IFE attributed the gas isotopic and chemical composition to generation "in the condensate field of the oil window" (Appendix 1), corresponding to ca. 1.1-1.2 Ro (vitrinite reflectance). However, the carbon isotope value for methane (ca. -41‰) and the gas wetness (ca. 0.15) are sufficiently light and high respectively to suggest that the samples are at the start of the gas/condensate generation window. The increase in $\delta^{13}\text{C}$ (i.e. to heavier values) with increasing carbon number (i.e. from methane to n-butane) is characteristic of normal thermogenic gases (i.e. those associated with petroleum generation), and one might expect this trend to continue into the condensate (i.e. higher carbon numbers). However, the condensates are all isotopically lighter than the C₃-C₄ gases, as exemplified in Figure 2. One explanation for this is that the bulk gas is on average a somewhat later (i.e. higher temperature) generation product than the condensate, as isotopically lighter material (whether gas, oil or condensate) is generated first^{e.g.6}.

The bulk compositions of the condensates (high API gravities, low %C₁₅₊ and high saturates/low polars+asphaltenes; Table 3) are in accord with

¹"Quality" in this context refers to low hydrogen indices and/or low S₂ values, and may be due to either input of terrestrial, or oxidation of marine, organic matter.

generation of gas/condensate at high thermal maturity, whilst the molecular data from GC and GCMS (Tables 4-7) are somewhat more equivocal. For example, the light hydrocarbon parameters H and I (Table 4) rank the fluids as "mature" and "supermature" respectively⁷. Mature in this context was defined by Thompson⁷ as an oil that "has undergone continued heating with considerable thermal transformation" whereas supermature fluids "result from protracted thermal transformation and substantial gasification". Both these definitions support generation of gas/condensate in Huldra as being a very high temperature process. The rapid drop-off in the n-alkane abundance with increasing carbon number, as exemplified by the high $nC_{17}/(nC_{17}+nC_{27})$ ratios (Table 5), is further evidence for gas/condensate formation at high thermal maturity.

In contrast, the methylphenanthrene ratio, MPI1, (ca. 0.88; Table 6) gives calculated vitrinite reflectance values (R_c)⁸ of around 0.93, which is conventionally believed to be within the oil window (i.e. prior to gas/condensate formation). However, MPI1 and phenanthrene-based ratios in general are source-dependant and work best for coals or other source rocks with a major terrestrial input. The two sterane maturity parameters in Table 7 (20S and $\beta\beta$) lie at or slightly above (ca. 0.63, 0.62) their theoretical equilibrium values (ca. 0.55 and 0.6) respectively. This means generation within the main oil window, at least, as the two parameters reach equilibrium at around this stage⁹.

However, the very low triterpane abundances (relative to the steranes) (Table 7), the highly distorted nature of the hopane distributions (Table 7) and the almost complete absence of mono- and triaromatic steranes (Appendix 8) is strong evidence in favour of thermal "cracking" of oil. Other biomarker parameters (e.g. low hopane and sterane concentrations - "ppm" in Table 7, high T_s/T_m , high 30D/H, high Dia/reg and high 3R/H) all point to very high thermal maturity for generation of these fluids.

Phase separation of oil and gas (origin (ii) above) due to reduction of P,T can also have profound compositional effects (due to partitioning of condensate into the gas phase). The tendency is for the condensate to become enriched in light hydrocarbons. Thus many of the effects are, unfortunately, similar to thermal "cracking" at high temperature. In addition, the severity of these effects depends greatly on unknowns such as the P,T regimes involved and the composition of the original petroleum (i.e. prior to phase separation)¹⁰⁻¹³. However, the dramatic alteration in the

hopane distributions (Appendix 7), coupled with the almost complete disappearance of the mono- and triaromatic steranes (Appendix 8), are observations that are hard to explain from phase separation effects alone and strongly suggest a high level of thermal maturity within the "gas/condensate generation window".

In summary, the data tend to support the high thermal maturity options, i) or iii) above, as the more likely origin(s) of the gas/condensates in Huldra Field. Much of the data is also compatible with a P,T-controlled phase separation, but several key parameters mitigate against this. The next section will discuss the likely source of the gas/condensates - i.e. i) from a conventional oil-prone source followed by oil to gas cracking or iii) from generation and expulsion of gas/condensate direct from a coal or low quality marine source rock.

4.3 Source correlation for Huldra fluids

Petroleum/source rock correlations are normally carried out using data from, primarily, GC and GCMS analyses of the saturated hydrocarbon (and to a lesser degree the aromatic hydrocarbon) fractions. The raw data for the Huldra fluids are given in Appendices 4-8 and the calculated parameters in Tables 4-7. However, it was noted in section 4.2 that the presumed high thermal maturity experienced by these fluids has i) distorted the hopane distributions such that they do not resemble those normally associated with North Sea oils; ii) caused the almost complete disappearance of the mono- and triaromatic steranes; iii) presumably also affected the steranes by shifting distributions in favour of the lower carbon numbers. The net result is that hopane and sterane distributions a) tend towards the same profiles at high maturities, regardless of source rock, and b) eventually become unusable.

Hence, a conventional petroleum/source correlation using biomarker compounds is not straightforward in this case. An alternative approach is to use other parameters and criteria, based more on the source rocks themselves, and the likelihood that they can have generated and expelled the reservoir fluids. Four formations/groups have been considered, the Draupne and Heather Formations and the Brent and Dunlin Groups. Top and base depths for these four in the three wells on Huldra are given in Table 8, and a summary of geochemical screening parameters is given in Table 9, based on data in refs. 1-3. The likelihood of these four functioning as the source (albeit off structure) of Huldra fluids will be discussed for each candidate in turn.

4.3.1 Draupne Formation

This formation has relatively high TOC contents but only moderate residual hydrogen indices (HIs) (Table 9). The residual HIs are best in well 30/2-3. Production indices (PIs; Table 9) are ca. 0.20 to 0.38 which is suggestive that generation has occurred ("immature" values are commonly around 0.05). PI can not be used directly to assess whether expulsion has taken place. Tmax values of around 445 and vitrinite reflectance of ca. 0.8-0.9^{1,2} would place the Draupne Formation within the oil window in these wells. GC traces of the saturates fractions for the Draupne in wells 30/2-1 and 30/2-2^{1,2} (Fig. 3) confirm that the formation is producing a conventional-looking oil, with Pr/Ph ratios of ca. 1.5. The latter is in contrast to the Huldra fluids (Fig. 3; Appendix 5), with Pr/Ph ratios of ca. 2 (Table 5). This is the only biomarker evidence to suggest (very tentatively) that the Draupne did not source the Huldra fluids. However, it must be borne in mind that Pr/Ph ratios can potentially be altered by processes such as thermal cracking and phase separation.

If no expulsion were to have occurred from the Draupne in these wells, then S1+S2 should be approximately constant compared with the same source when immature. Hence an average current HI of ca. 200 (perhaps somewhat on the high side based on data in Table 9) and PI of 0.2-0.4 is equivalent to a calculated initial (i.e. immature) HI of 250-300 (assuming an initial PI of 0.05). In contrast, immature versions of the Draupne in this area have measured HIs of ca. 350 (pers. comm. from Dr. P.J.D. Park, geochemical consultant, "Parkway", 2 Junction Rd., Lightwater, Surrey, UK). Hence (S1+S2)/TOC are lower in mature Draupne than in currently immature versions in the area. This can be explained in two ways: either there has been a facies change and the mature Draupne is poorer quality than the immature source (in fact, the opposite is expected from depositional models); or there has been petroleum expulsion from the mature source. Either way, these data would suggest that expulsion from the Draupne can not be ruled out in this area. However, the expelled phase would most likely have been oil (with dissolved gas) (based on initial HIs of ca. 350 which indicates a mostly oil-prone source). For the Draupne to have sourced the gas/condensate in Huldra, one must invoke either thermal cracking in the source down dip (i.e. the source must have expelled an oil phase, followed by secondary cracking of the residual oil) or in reservoir (i.e. the reservoir must be/have been very deeply buried).

Assumption of lower current HIs and the same initial HI

(i.e. 350) would only lead to the conclusion that even more expulsion has already occurred. Using the same current HI and a higher initial HI would also give the same result.

4.3.2 Heather Formation

This formation has variable TOC contents but only modest residual HIs (Table 9). The latter are best in wells 30/2-2 and 30/2-3. PIs (Table 9) are ca. 0.2 to 0.4, similar to the Draupne, which is again suggestive that generation has occurred. Tmax values of around 450 and vitrinite reflectance of ca. 0.8-0.9 would place the Heather Formation within the oil window in these wells. GC traces of the saturates fractions for the Heather in wells 30/2-1 and 30/2-2^{1,2} confirm that the formation is producing a conventional-looking oil, but with higher Pr/Ph ratios than the Draupne. The chromatograms of the saturates fractions (Fig. 3) bear, in fact, resemblance to those for Huldra fluids (Fig. 3; Appendix 5). This is the only biomarker evidence to suggest (tentatively) that the Heather may be a source of the Huldra fluids. Again, it must be remembered that Pr/Ph ratios can potentially be affected by processes such as thermal cracking and phase separation, and the similarity here may be coincidence.

As for the Draupne, if no expulsion has occurred from the Heather in these wells, then S1+S2 should be approximately constant compared with the same source when immature. Hence an average current HI of ca. 150 and PI of 0.2-0.4 (Table 9) is equivalent to a calculated initial (i.e. immature) HI of 180-240 (assuming an initial PI of 0.05). In contrast, immature versions of the Heather in this area have measured HIs of up to ca. 300 (pers. comm. from Dr. P.J.D. Park, geochemical consultant, "Parkway", 2 Junction Rd., Lightwater, Surrey, UK). Hence (S1+S2)/TOC are lower in mature Heather than in currently immature versions here. This can be explained in the same two ways as for the Draupne: either there has been a facies change and the mature Heather is poorer quality than the immature source (again, the opposite is expected from depositional models); or there has been petroleum expulsion from the mature source. Either way, these data would suggest that expulsion from the Heather is an actual possibility in this area. Furthermore, the expelled phase could well have been gas (with dissolved condensate) (based on initial HIs of ca. 300 which indicates a more gas-prone source).

Assumption of lower current HIs and the same initial HI (i.e. 300) would only lead to the conclusion that even

more expulsion has already occurred. Using the same current HI, but a higher initial HI, would also give the same result, but the expelled phase is more likely to have been oil, rather than gas.

4.3.3 Brent Group

The main interest here is in the Brent Group coals as the source of the gas/condensate. However, there are several reasons for suspecting that this is not the case.

Firstly, solvent extracts from the Brent coals (and other lithologies in the Group) have carbon isotopic values of around -25 to -27‰² (typical of terrestrial sources), whereas the Huldra condensates are around -28 to -28.5 (Appendix 2). This difference is actually quite large in isotopic terms and suggests strongly that the condensates were not sourced from the Brent Group.

Secondly, the coals in, for example, well 30/2-3 are relatively sparse and thin. On volumetric grounds, it might be difficult to argue for a coal source unless they are laterally more extensive than in this well.

Thirdly, production index ($PI = S1/(S1+S2)$) data give no sign that the coals have generated - let alone expelled - even small amounts of petroleum at depths as great as 4000m (Table 9). This is supported by unpublished work on Hild Field (E. Skålnes, University of Oslo, Cant. Scient. thesis in prep.), which shows that the interbedded coals have contributed only very locally to the reservoired fluids at depths as great as 4200m.

4.3.4 Dunlin Group

Over 350m of the Dunlin Group were drilled in well 30/2-3, and 450m in well 30/2-1. In both cases, there are reasonable TOC contents, typically 1-2% in the latter¹ and 2-2.5% in the former well³ (Table 9). Residual HIs are still around 100-150 (Table 9) in 30/2-3 and above ca. 4100m in 30/2-1. In 30/2-3 at least, around half of the interval drilled is shale or claystone. Hence, given the current depths of burial and maturities (ca. 0.9 to 1.1 Ro)^{1,3}, there are good reasons to believe that this group has both generated and expelled petroleum. Generation is confirmed by PIs (Table 9) which are above 0.25. Using a similar line of argument as for the Draupne and Heather Formations to postulate expulsion is more difficult in this case, as HIs for the immature equivalents of the Dunlin are hard to find (pers. comm.

from Dr. P.J.D. Park, geochemical consultant, "Parkway", 2 Junction Rd., Lightwater, Surrey, UK). Nevertheless, it is reasonable to believe that expulsion has occurred, given the similarity in the data between the Heather and the Dunlin, plus the fact that the latter is even deeper, and hence more mature, than the former.

Gas chromatograms of solvent extracts from Dunlin Formation mudrock samples (Fig. 3) also bear a strong resemblance to both the Heather Formation extracts (Fig. 3) (section 4.3.2) and the Huldra fluids (Fig. 3; Appendix 5).

In summary, the Huldra fluids may plausibly have originated through direct generation and expulsion of a gas/condensate from the Heather Formation or Dunlin Group. An alternative explanation, which can not be ruled out on geochemical grounds alone, is a Draupne Formation source combined with cracking of oil or residual kerogen to gas down dip. The Brent coals are not likely to have been the major source.

4.4 Comparison of petroleum in Huldra with Veslefrikk Field

The data on oils from Veslefrikk Field, given in references 4 and 5, are summarised in Tables 10 to 16, in the same format as for Huldra Field for ease of comparison. No gas data were reported.

DST#1 from well 30/3-A1 has an API gravity of 45.6°, yet it is claimed to be an oil⁴. In fact, the Statfjord Formation here contains predominantly gas (with dissolved condensate) and a thin oil rim below, at near critical conditions (H. Agustsson, DDB RVF, pers. comm.). DST#1 perforated both the gas and oil intervals, and the so-called oil analysed by IKU⁴ is in fact a mixture of condensate and oil. Given the high API gravity, it is presumably mostly condensate. Hence, given its uncertain origin and different phase, this sample is treated separately in the ensuing discussion. As a consequence of its previously mistaken identity, any comments made by IKU concerning maturity etc. of this sample should be disregarded.

4.4.1 Veslefrikk oils - source and thermal maturity

This covers all samples except 30/3-A1, DST#1, for reasons given above.

The data for samples DST#2, well 30/3-A1 and DST#2, well 30/3-2 (Tables 10 to 16) suggest that these two are extremely similar, and the source biomarker parameters

(Tables 13 and 15) and isotopic data (Table 16) are indicative of a normal marine siliciclastic source, presumably the Draupne Formation. A similar conclusion also applies to the two DSTs from well 30/3-4 (Tables 10-16), although the %C₂₇:C₂₈:C₂₉ sterane ratio (Table 15) is biased rather more strongly towards the C₂₉ components. This fact, coupled with a somewhat higher Pr/Ph ratio (Table 13) may mean that these oils came from a source rock facies with a relatively higher terrestrial organic matter input.

Thermal maturity data (Tables 14 and 15) are very similar for all four samples, with the possible exception of MPI1, which is lower for the DSTs from well 30/3-4. However, it is doubtful whether this is a significant difference, as values of MPI1 < ca. 0.7 are often assumed to be random. The data suggest, in general, petroleum generated within the main oil window, in all four cases.

The RFT from well 30/3-A1, which comes from the Tarbert Formation, only has biomarker data available but these are very similar to those for the DST#2 from the IDS in the same well.

A cautionary note: unlike the Huldra data reported above, data for 30/3-A1 and 30/3-2⁴ were acquired several years after those for 30/3-4⁵. Hence, apparent differences may be analytical rather than source or maturity related.

In summary, the oils in Veslefrikk bear all the hallmarks of normal, Draupne Formation or similar-sourced black oils generated within the main oil window. In contrast, the gas/condensates in Huldra are most likely higher thermal maturity products, generated from leaner mudrocks of the Heather or Dunlin (although generation from the Draupne can not be entirely ruled out on geochemical grounds alone, see section 4.3).

4.4.2 DST#1, well 30/3-A1

Although the DST#1 from well 30/3-A1 tested a mixture of the gas/condensate and (thin) oil legs in the Statfjord Formation, the data are worth considering for the following reason: the fluid is predominantly gas/condensate, yet it lies under the main oil legs in the Dunlin and Brent Groups. What are the geological / geochemical reasons behind this phenomenon?

From the high API gravity (45.6, Table 11), it can probably be safely assumed that the liquid phase contains mostly the condensate and not the oil. It is

thus of interest to compare these data with those for the overlying black oils (API gravities ca. 37-39, Table 11). Differences in the data will be first be presented by analysis type, and then subsequently discussed as a whole.

Bulk compositions: the Statfjord condensate has a lower amount (ca. 53%) of higher molecular weight ($>C_{15+}$) material than the Veslefrikk black oils (ca. 70%) (Table 11), comparable to or even lower than the Huldra condensates (54-65%) (Table 3). However, the saturated hydrocarbon content of the $>C_{15+}$ fraction is only slightly higher than those for the black oils (Table 11) and is noticeably lower than the Huldra condensates (Table 3).

Thompson's indices: the light hydrocarbon aromaticity parameters A, B, X and W are highest in the Huldra condensates, followed by the Veslefrikk Statfjord condensate (DST#1, well 30/3-A1), and then the black oils in Veslefrikk (Tables 4 and 12). In contrast, the paraffin branching parameter R is similar for all the Veslefrikk samples but much lower in the Huldra condensates. Paraffinicity parameters C, F and H are also somewhat higher in Veslefrikk. Thus all Veslefrikk samples contain more light n-alkanes compared to branched/cyclic alkanes than Huldra, but the Statfjord condensate is intermediate in terms of aromaticity.

GC data: The Statfjord condensate is not distinguished from the other Veslefrikk samples by GC data (e.g. Pr/nC₁₇, Pr/Ph, Table 13), except that the n-alkane distribution is slightly biased towards lower carbon numbers in the Statfjord condensate compared to DST#2 in the same well (as exemplified by nC₁₇/(nC₁₇+nC₂₇), Table 13). (N.B. the very high values for nC₁₇/(nC₁₇+nC₂₇) for the two oils from 30/3-4 are probably due to poor chromatography, as no other data suggest that these oils should be so extremely heavily biased towards light components.)

The MPI1 value for the Statfjord condensate is statistically higher than for the black oils (Table 14) (N.B. values less than ca. 0.7 may be considered to be random) and is on a par with the Huldra fluids (Table 6).

Biomarker data: data for biomarker parameters based on isomer ratios are very similar for the Statfjord condensate and the Veslefrikk black oils (e.g. 20S, $\beta\beta$, 22S, Table 15). Certain other parameters, based on larger differences in chromatographic retention time (due to differences in carbon number or boiling point/volatility) (e.g. Ts/Tm, 30D/H, 3R/H, 4R/H, 30 $\alpha\beta$,

Dia/reg, C28 $\alpha\beta$ /H), are consistently higher in the Statfjord condensate - i.e. the parameters are biased towards the lighter components. However, the extent of the differences is very variable (e.g. large for Ts/Tm, very small for C28 $\alpha\beta$ /H).

The abundances of the triterpanes and steranes are sufficiently large to allow good quality biomarker data for the Statfjord condensate to be acquired. In contrast, the biomarker data for the Huldra condensates were deemed unreliable due to the extremely low abundances and atypical triterpane distributions obtained (section 4.2).

Isotopic data: the carbon isotopic compositions of the Veslefrikk oils and saturates fractions therefrom are very similar from sample to sample (Table 16), at -29 to -29.7%. The Statfjord condensate is heavier at -28.4%, more in line with values for the Huldra condensates (Appendix 2).

N.B. gas isotope and chemical composition data were not reported by IKU^{4,5} and so can not be used to aid interpretation.

The options for the origin of the Statfjord gas/condensate from Veslefrikk are that:

- a) the data for DST#1 have been so affected by the sampling of both condensate and oil that they can not be interpreted;
- b) it is a gas phase which separated from a normal oil;
- c) the gas phase was formed by cracking of oil at high maturity;
- d) the gas phase was generated from a more gas-prone source rock at high thermal maturity.

a) Given the API gravity (45.6) and the fact that the oil leg is thin, it is assumed that the DST#1 is reasonably representative of the gas/condensate zone in well 30/3-A1. Certainly the compositional parameters are in accord with the general trends commonly reported for condensates (i.e. a tendency towards lighter components, both in general and within a compound class such as the biomarkers). Hence the data appear to be interpretable.

b) Whilst much of the data are compatible with phase separation from a normal oil (e.g. bias in biomarker ratios to lower carbon numbers), increased aromaticity values from light hydrocarbon analysis of the condensate plus the isotopic compositions of the whole condensate and its saturates fraction argues strongly against such

a mechanism. This is because i) isotopic compositions are believed to be little altered during phase fractionation^{e.g.13}, yet the condensate is up to 1% heavier than the black oils in Veslefrikk. ii) Values of B and F (light hydrocarbon aromaticity parameters, Table 12) are similar or higher in the condensate compared to the oil, rather than reduced as would be expected if significant phase fractionation had occurred¹¹.

c) Cracking of a Draupne Formation-sourced oil to gas is also a strong possibility from the geochemical data. However, this can not have happened in the reservoir, because of the presence of normal black oil. Furthermore, the presence of a "normal" distribution of triterpanes and steranes suggests that the extent of cracking can not be as high as in Huldra, where the triterpanes, especially, were more-or-less completely cracked away. Thus oil to gas cracking must have occurred down-dip and to a restricted extent, if this option is correct.

d) The fourth possibility is similar to the one proposed for the Huldra fluids, i.e. that the gas/condensate was generated from a more gas prone source rock (e.g. the Heather Formation or Dunlin Group). However, the light hydrocarbon and biomarker data suggest that there are both source and maturity differences between Huldra and the Veslefrikk condensate. In general, the Veslefrikk condensate appears to be a lower maturity product than Huldra (see (iii) above).

In summary, the gas/condensate in well 30/3-A1 appears to have two likely origins - either as a result of (restricted) down-dip thermal cracking of oil from the Draupne Formation, or as a relatively high maturity product (albeit lower than in Huldra) from the Heather or Dunlin. The current data do not allow a more precise conclusion, although inclusion of gas data might help.

5 CONCLUSIONS

1. All fluid samples (gases and condensates) from Huldra Field are identical in composition, from an analytical viewpoint.
2. The Huldra fluids appear to be high maturity products generated within the "oil to gas cracking" window.
3. The source of the Huldra fluids is most likely generation and expulsion of a gas/condensate directly from either the Heather Formation or the Dunlin Group. However, cracking of Draupne Formation-sourced oil to gas can not be ruled out from geochemical criteria. Phase separation from a normal oil is the least likely possibility.
4. Geochemical data from Veslefrikk Field suggest that the black oils are sourced from a conventional Draupne Formation within the main oil generation window.
5. The gas/condensate in well 30/3-A1 in Veslefrikk is most likely from either cracking of Draupne Formation-sourced oil to gas, or direct from the Heather or Dunlin. In both cases, the thermal maturity is believed to have been lower than for the fluids in Huldra.

6 REFERENCES

1. Geochemical source rock evaluation of sediments from NOCS well 30/2-1 (1983). Paleochem Ltd., UK.
2. Geochemical evaluation of the Statoil 30/2-2 well, offshore Norway (1985). Geochem Laboratories Ltd., UK.
3. Geochemical analysis report for well NOCS 30/2-3 (1993). Geolab Nor a.s., Norway.
4. Organic geochemical characterisation and correlation of crude oils from wells 30/3-A1, 30/3-2 and 30/3-4 (1988). Report No. 22.1988.00/01/88, IKU, Norway.
5. L. Leith, L. Schou, L. Husvik and A. Due (1985). Source rock evaluation of well 30/3-4, hydrocarbon characterisation of oils and cores from well 30/3-4. Report No. 22.1793.00/01/85, IKU, Norway.
6. C.J. Clayton (1991). Carbon isotope fractionation during natural gas generation from kerogen. Mar. Pet. Geol. **8**, 232-240.
7. K.F.M. Thompson (1983). Classification and thermal history of petroleum based on light hydrocarbons. Geochim. Cosmochim. Acta **47**, 303-316.
8. M. Radke and D. Welte (1983). The methylphenanthrene index (MPI): a maturity parameter based on aromatic hydrocarbons. In Adv. Org. Geochem. 1981 (eds. M. Bjorøy et al.), pp504-512, John Wiley and Sons Ltd., Chichester.
9. G.W. van Graas (1990). Biomarker maturity parameters for high maturities: calibration of the working range up to the oil/condensate threshold. Org. Geochem. **16**, 1025-1032.
10. L.C. Price, L.M. Wenger, T. Ging and C.W. Blount (1983). Solubility of crude oil in methane as a function of pressure and temperature. Org. Geochem. **4**, 201-221.
11. K.F.M. Thompson (1988). Gas-condensate migration and oil fractionation in deltaic systems. Mar. Pet. Geol. **5**, 237-246.
12. S. Larter and N.Mills (1991). Phase-controlled molecular fractionations in migrating petroleum charges. In Petroleum migration (eds. W. England and A.J. Fleet), Geol. Soc. Lond. Spec. Publ. No. 59, 137-147.
13. W.A. England, S.R. Andrews and J. Ruckheim (1991).

Experimental simulation of gas-phase migration: results and interpretations. In Organic Geochemistry: Advances and Applications in Energy and the Natural Environment (ed. D. Manning), pp146-150, Manchester University press.

Table 1. Geological information for gas columns in Huldra Field

Well	Group	Gas column depth interval (mRKB)	Depth RKB-MSL (m)
30/2-1	Brent	3675-3793 ¹	30
30/2-2	Brent	3935-3975 ²	29
30/2-3	Brent	3794-3897	25

1 No GWC (entire Brent filled)

2 Estimated GWC

Table 2. Test and analytical information for gas and condensate samples from Huldra Field

Well	DST#	Sample No.	Depth interval (mRKB)	CGR (SM ³ /MMSM ³)	Samples analysed here	
					Gas	Condensate
30/2-1	2	S6533	3761-3771	2470	✓	✓
30/2-1	3	S6534	3720-3728	2576		✓
30/2-2	3	S6535	3935-3974	2190	✓	✓
30/2-3	1	S6536	3895-3898	312 ¹	✓	✓
30/2-3	2	S6537	3874-3881	2092	✓	✓
30/2-3	3	S6538	3794-3803	2169	✓	✓

1 Poor DST sample

Table 3. Bulk compositions for condensate samples from Huldra Field

Well	DST#	Sample No.	API Gravity	C ₁₅₊ ¹ (wt. %)	Saturates ² (%)	Aromatics ² (%)	Polars ² (%)	Asphaltenes ³ (%)
30/2-1	2	S6533	42.8	60	86	11	2	2
30/2-1	3	S6534	43.4	57	86	12	1	1
30/2-2	3	S6535	43.2	65	86	12	0.8	0.9
30/2-3	1	S6536	44.0	63	85	14	0.5	1
30/2-3	2	S6537	43.1	60	86	13	0.5	1
30/2-3	3	S6538	45.4	54	84	15	0.4	0.7

1 From topping

2 From Iatroscan; replicate analyses are included in Appendix 3

3 By precipitation

Table 4. Thompson's indices¹ from light hydrocarbons analysis of Huldra Field condensates

Well	DST#	Sample No.	A	B	X	W	C	I	F	H	U	R	S
30/2-1	DST 2	S6533	0.65	1.4	1.1	6.6	0.78	2.1	0.66	22.5	1.8	2.3	37.7
30/2-1	DST 3	S6534	0.59	1.5	1.1	6.6	0.81	2.2	0.65	22.4	1.8	2.2	36.1
30/2-2	DST 3	S6535	0.59	1.5	1.1	5.7	0.75	2.3	0.65	23.2	2.0	2.4	53.5
30/2-3	DST 1	S6536	0.61	1.4	1.1	6.5	0.81	2.2	0.66	22.4	1.8	2.2	34.8
30/2-3	DST 2	S6537	0.65	1.5	1.1	6.7	0.78	2.1	0.65	22.2	1.8	2.2	31.4
30/2-3	DST 3	S6538	0.57	1.3	1.0	6.7	0.87	2.3	0.70	22.7	1.7	2.2	33.5

1 From Thompson, 1983 (ref. 7) inter alia

Aromaticity

A = benzene/nC₆

B = toluene/nC₇

X = m+p-xylenes/nC₈

W = 10*benzene/cC₆

Paraffinicity

C = (nC₆+nC₇) / (cC₆+mC₆)

I = (2mC₆+3mC₆) / (1cis3dmcC₅+1t3dmcC₅+1t2dmcC₅)

F = nC₇/mC₆

H = (100*nC₇) / (cC₆+2mC₆+2,3dmcC₅+3mC₆+1cis3dmcC₅+1t3dmcC₅+1t2dmcC₅+nC₇+mC₆)

Naphthene branching

U = cC₆/mC₅

Paraffin branching

R = nC₇/2mC₆

S = nC₆/2,2dmC₄

Codes: n = normal; c = cyclo; C₆ = hexane (etc); m = methyl; dm = dimethyl; t = trans

Table 5. Data from GC analysis of whole condensates and saturates fractions, Huldra Field samples

a) Saturates fractions

Well	DST#	Sample No.	Pr/nC ₁₇ (A)	Ph/nC ₁₈ (B)	A/B	Pr/Ph	nC ₁₇ /(nC ₁₇ +nC ₂₇)
30/2-1	DST 2	S6533	0.66	0.42	1.6	1.9	0.92
30/2-1	DST 3	S6534	0.47	0.33	1.4	1.8	0.80
30/2-2	DST 3	S6535	0.52	0.30	1.7	2.5	0.94
30/2-3	DST 1	S6536	0.53	0.33	1.6	2.3	0.91
30/2-3	DST 2	S6537	0.50	0.29	1.7	2.5	0.96
30/2-3	DST 3	S6538	0.48	0.31	1.6	2.0	0.81

b) Whole condensates

Well	DST#	Sample No.	Pr/nC ₁₇ (A)	Ph/nC ₁₈ (B)	A/B	Pr/Ph	nC ₁₇ /(nC ₁₇ +nC ₂₇)
30/2-1	DST 2	S6533	0.46	0.27	1.7	2.0	0.86
30/2-1	DST 3	S6534	0.45	0.27	1.7	2.0	0.89
30/2-2	DST 3	S6535	0.46	0.26	1.8	2.0	0.82
30/2-3	DST 1	S6536	0.46	0.26	1.7	2.1	0.81
30/2-3	DST 2	S6537	0.46	0.27	1.7	2.0	0.87
30/2-3	DST 3	S6538	0.45	0.27	1.7	2.1	0.86

Pr pristane Ph phytane nC₁₇ n-heptadecane nC₁₈ n-octadecane
 nC₂₇ n-heptacosane

Table 6. Data from GC analysis of aromatics fractions, Huldra Field samples

Well	DST#	Sample No.	F1	F2	MPI1
30/2-1	DST 2	S6533	0.49	0.24	0.85
30/2-1	DST 3	S6534	0.50	0.25	0.88
30/2-2	DST 3	S6535	0.51	0.25	0.90
30/2-3	DST 1	S6536	0.49	0.25	0.86
30/2-3	DST 2	S6537	0.50	0.25	0.87
30/2-3	DST 3	S6538	0.51	0.21	0.91

$$\text{MPI1} = \frac{3/2 (2\text{-MP} + 3\text{-MP})}{\text{P} + 1\text{-MP} + 9\text{-MP}}$$

$$\text{F1} = \frac{3\text{-MP} + 2\text{-MP}}{3\text{-MP} + 2\text{-MP} + 9\text{-MP} + 1\text{-MP}}$$

$$\text{F2} = \frac{2\text{-MP}}{3\text{-MP} + 2\text{-MP} + 9\text{-MP} + 1\text{-MP}}$$

P = phenanthrene M = methyl

Table 7. Biomarker parameters¹ from GCMS analysis of saturated hydrocarbon fractions, Huldra Field condensates

Sample No.	Well/DST	Biomarker parameter							
		20S	$\beta\beta$	22S	Ts/Tm	TtX	30D/H	ppmH	ppmS
S6533	30/2-1 2	0.60	0.62	0.70	1.96	n.d.	1.18	45	25
S6534	30/2-1 3	0.63	0.62	0.69	2.12	n.d.	1.29	48	25
S6535	30/2-2 3	0.63	0.60	n.d.	1.80	n.d.	2.13	21	19
S6536	30/2-3 1	0.62	0.63	n.d.	2.14	n.d.	1.20	37	32
S6537	30/2-3 2	0.67	0.62	0.71	2.12	n.d.	1.39	49	31
S6538	30/2-3 3	0.63	0.63	0.73	2.00	n.d.	1.15	51	29

Sample No.	Well/DST	Biomarker parameter							
		%C27	%C28	%C29	C30/st	Dia/reg	C28 $\alpha\beta$ /H	H/S	
S6533	30/2-1 2	38	28	34	8	5.37	0.06	1.8	
S6534	30/2-1 3	37	28	36	8	5.03	0.10	1.9	
S6535	30/2-2 3	40	27	33	8	4.86	0.00	1.1	
S6536	30/2-3 1	37	28	35	11	4.42	0.00	1.2	
S6537	30/2-3 2	36	29	35	9	5.07	0.00	1.6	
S6538	30/2-3 3	38	28	34	8	5.38	0.00	1.8	

n.d. no data

Table 7. cont.

Sample No.	Well/DST	3R/H	4R/H	Biomarker 35/34H	parameter Dem/H	O/H	G/H	30αβ
S6533	30/2-1 2	1.30	0.39	0.00	0.00	0.00	n.d.	0.92
S6534	30/2-1 3	1.00	0.29	0.00	0.00	0.00	n.d.	0.91
S6535	30/2-2 3	1.75	0.50	n.d.	0.00	0.00	n.d.	1.0
S6536	30/2-3 1	0.90	0.30	n.d.	0.00	0.00	n.d.	1.0
S6537	30/2-3 2	1.09	0.39	n.d.	0.00	0.00	n.d.	0.92
S6538	30/2-3 3	1.20	0.40	n.d.	0.00	0.00	n.d.	0.91

n.d. no data

1 The derivation of all parameters is described in Appendix 7.

Table 8. Depth intervals for potential source rocks in wells 30/2-1, 30/2-2 and 30/2-3, Huldra Field

Formation/Group	30/2-1		Well 30/2-2		30/2-3	
	Top	Base	Top	Base (mRKB)	Top	Base
Draupne Fm.	3635	3656	3776	3824	3669	3705
Heather Fm.	3656	3675	3824	3935	3705	3792
Brent Gp.	3675	3793	3935	4135	3792	3961
Dunlin Gp.	3793	4243*	4135	4172*	3961	4325*

* TD

Table 9. Summary of geochemical data for potential source rocks in wells 30/2-1, 30/2-2 and 30/2-3, Huldra Field

Group/Formation¹	TOC	Parameter² HI	PI	Tmax
<u>30/2-1 (ref.1)</u>				
Draupne Fm. (3)	1.7-4.8	90-170	n.d.	n.d.
Heather Fm. (2)	1.7-4.6	90-100	n.d.	n.d.
Brent Gp. (5)	0.8-12.7	75-250	n.d.	n.d.
Dunlin Gp. (16)	0.1-4.6	0-140	n.d.	n.d.
<u>30/2-2 (ref.2)</u>				
Draupne Fm. (4)	4.5-5.5	160-175	0.20-0.30	444-450
Heather Fm. (7)	2.1-5.1	90-170	0.23-0.33	449-453
Brent Gp. (34)	0.9-81.8	50-260	<0.1 (>10% TOC)	457-471
			0.10-0.25 (<10% TOC)	449-466
Dunlin Gp. (3)	1.1-3.4	60-179	0.26-0.37	450-452
<u>30/2-3 (ref.3)</u>				
Draupne Fm. (7)	1.7-6.5	120-230	0.27-0.38	438-447
Heather Fm. (5)	1.6-5.8	100-200	0.33-0.42	442-455
Brent Gp. (6)	0.7-63.9	50-180	<0.14 (>8% TOC)	465-470
			0.20-0.24 (<8% TOC)	459-464
Dunlin Gp. (8)	2.0-2.6	120-160	0.25-0.36	450-457

1 Numbers in brackets represent total samples analysed for that formation/group

2 All data expressed as maxima and minima of available analyses

Table 10. Test information for oil samples from Veslefrikk Field¹

Well	DST#	Sample No.	Depth interval (mRKB)	Formation /Group
30/3-A1	RFT	C7428	n.d.	Tarbert
30/3-A1	1	C7259	3234-3250	Statfjord
30/3-A1	2	C7258	3071-3088	IDS ²
30/3-2	2	C7260	2870-2874	Etive
30/3-4	4	C1648	2866-2882	Brent
30/3-4	1	C1647	3079-3096	IDS

1 Data from reference 4

2 Intra-Dunlin sand

Table 11. Bulk compositions for oil samples from Veslefrikk Field¹

Well	DST#	Sample No.	API Gravity	C ₁₅ + ² (wt. %)	Saturates ³ (%)	Aromatics ³ (%)	Polars ³ (%)	Asphaltenes ⁴ (%)
30/3-A1	RFT	C7428	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
30/3-A1	1	C7259	45.6	53	67	19	9	4
30/3-A1	2	C7258	37.2	68	57	21	10	4
30/3-2	2	C7260	n.d.	68	66	22	8	4
30/3-4	4	C1648	38.1	73	46	19	33	2
30/3-4	1	C1647	39.5	76	57	20	21	1

1 Data for wells 30/3-A1 and 30/3-2 from reference 4; data for well 30/3-4 from reference 5

2 From topping

3 From Iatroscan; replicate analyses are included in Appendix 3

4 By precipitation

Table 12. Thompson's indices¹ from light hydrocarbons analysis of Veslefrikk Field oils²

Well	DST#	Sample No.	A	B	X	W	C	I	F	H	U	R	S
30/3-A1	RFT	C7428	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
30/3-A1	1	C7259	0.41	0.76	0.63	6.0	1.1	2.3	0.83	24.7	1.5	10.9	n.d.
30/3-A1	2	C7258	0.27	0.60	0.40	3.5	0.96	1.6	0.76	23.4	1.4	10.1	n.d.
30/3-2	2	C7260	0.22	0.49	0.38	3.4	1.1	1.6	0.80	23.5	1.3	8.9	n.d.
30/3-4	4	C1648	0.21	0.50	0.37	3.5	1.1	1.5	0.88	24.5	1.2	9.8	n.d.
30/3-4	1	C1647	0.27	0.58	0.40	3.7	1.0	1.5	0.83	24.0	1.3	10.6	n.d.

1 From Thompson, 1983 (ref. 7) inter alia reference 4; data for well 30/3-4 from reference 5

2 Data for wells 30/3-A1 and 30/3-2 from

Aromaticity

A = benzene/nC₆

B = toluene/nC₇

X = m+p-xylenes/nC₈

W = 10*benzene/cC₆

Paraffinicity

C = (nC₆+nC₇) / (cC₆+mC₆)

I = (2mC₆+3mC₆) / (1cis3dmcC₅+1t3dmcC₅+1t2dmcC₅)

F = nC₇/mC₆

H = (100*nC₇) / (cC₆+2mC₆+2,3dmcC₅+3mC₆+1cis3dmcC₅+1t3dmcC₅+1t2dmcC₅+nC₇+mC₆)

Naphthene branching

U = cC₆/mC₅

Paraffin branching

R = nC₇/2mC₆

S = nC₆/2,2dmC₄

Codes: n = normal; c = cyclo; C₆ = hexane (etc); m = methyl; dm = dimethyl; t = trans

Table 13. Data from GC analysis of saturates fractions, Veslefrikk Field oils¹

Well	DST#	Sample No.	Pr/nC ₁₇ (A)	Ph/nC ₁₈ (B)	A/B	Pr/Ph	nC ₁₇ / (nC ₁₇ +nC ₂₇)
30/3-A1	RFT	C7428	n.d.	n.d.	n.d.	n.d.	n.d.
30/3-A1	1	C7259	0.7	0.5	1.5	1.6	0.75
30/3-A1	2	C7258	0.7	0.5	1.4	1.5	0.68
30/3-2	2	C7260	0.9	0.7	1.3	1.5	0.69
30/3-4	4	C1648	0.9	0.7	1.2	1.9	0.99
30/3-4	1	C1647	0.7	0.6	1.3	1.9	0.98

Pr pristane Ph phytane nC₁₇ n-heptadecane nC₁₈ n-octadecane
nC₂₇ n-heptacosane

1 Data for wells 30/3-A1 and 30/3-2 from reference 4; data for well 30/3-4 from reference 5

Table 14. Data from GC analysis of aromatics fractions, Veslefrikk Field oils¹

Well	DST#	Sample No.	F1	F2	MPI1
30/3-A1	RFT	C7428	n.d.	n.d.	n.d.
30/3-A1	1	C7259	n.d.	n.d.	0.9
30/3-A1	2	C7258	n.d.	n.d.	0.7
30/3-2	2	C7260	n.d.	n.d.	0.7
30/3-4	4	C1648	n.d.	n.d.	0.4
30/3-4	1	C1647	n.d.	n.d.	0.4

$$\text{MPI1} = \frac{3/2 (2\text{-MP} + 3\text{-MP})}{\text{P} + 1\text{-MP} + 9\text{-MP}}$$

$$\text{F1} = \frac{3\text{-MP} + 2\text{-MP}}{3\text{-MP} + 2\text{-MP} + 9\text{-MP} + 1\text{-MP}}$$

$$\text{F2} = \frac{2\text{-MP}}{3\text{-MP} + 2\text{-MP} + 9\text{-MP} + 1\text{-MP}}$$

P = phenanthrene M = methyl

1 Data for wells 30/3-A1 and 30/3-2 from reference 4; data for well 30/3-4 from reference 5

Table 15. Biomarker parameters¹ from GCMS analysis of saturated hydrocarbon fractions, Veslefrikk Field oils²

Sample No.	Well/DST	Biomarker parameter							
		20S	$\beta\beta$	22S	Ts/Tm	TtX	30D/H	ppmH	ppmS
C7428	30/3-A1 RFT	0.47	0.69	0.62	2.0	1.5	0.07	n.d.	n.d.
C7259	30/3-A1 1	0.49	0.73	0.62	3.8	n.d.	0.18	n.d.	n.d.
C7258	30/3-A1 2	0.49	0.70	0.61	1.8	1.7	0.10	n.d.	n.d.
C7260	30/3-2 2	0.47	0.67	0.63	1.6	1.2	0.06	n.d.	n.d.
C1648	30/3-4 4	0.51	0.78	0.62	1.4	1.4	0.08	n.d.	n.d.
C1647	30/3-4 1	0.54	0.76	0.64	1.5	2.0	0.12	n.d.	n.d.

Sample No.	Well/DST	Biomarker parameter						
		%C27	%C28	%C29	C30/st	Dia/reg ³	C28 $\alpha\beta$ /H	H/S
C7428	30/3-A1 RFT	n.d.	n.d.	n.d.	n.d.	0.92	0.14	n.d.
C7259	30/3-A1 1	n.d. ⁴	n.d. ⁴	n.d. ⁴	n.d.	0.97	0.17	n.d.
C7258	30/3-A1 2	32	34	35	n.d.	0.94	0.16	n.d.
C7260	30/3-2 2	34	30	35	n.d.	0.89	0.16	n.d.
C1648	30/3-4 4	31	27	41	n.d.	0.79	0.14	n.d.
C1647	30/3-4 1	31	27	41	n.d.	0.81	0.16	n.d.

n.d. no data

Table 15. cont.

Sample No.	Well/DST	Biomarker parameter						
		3R/H	4R/H	35/34H	Dem/H	O/H	G/H	30αβ
C7428	30/3-A1 RFT	0.09	0.07	0.54	0	0	n.d.	0.94
C7259	30/3-A1 1	0.31	0.16	0.60	0	0	n.d.	1.00
C7258	30/3-A1 2	0.10	0.07	0.60	0	0	n.d.	0.93
C7260	30/3-2 2	0.07	0.05	0.55	0	0	n.d.	0.94
C1648	30/3-4 4	0.06	0.05	0.74	0	0	n.d.	0.91
C1647	30/3-4 1	0.05	0.04	0.72	0	0	n.d.	0.91

n.d. no data

- 1 The derivation of all parameters is described in Appendix 7
- 2 Data for wells 30/3-A1 and 30/3-2 from reference 4; data for well 30/3-4 from reference 5
- 3 $27\beta S/27\alpha R$
- 4 insufficient data in ref. 4 to calculate this parameter

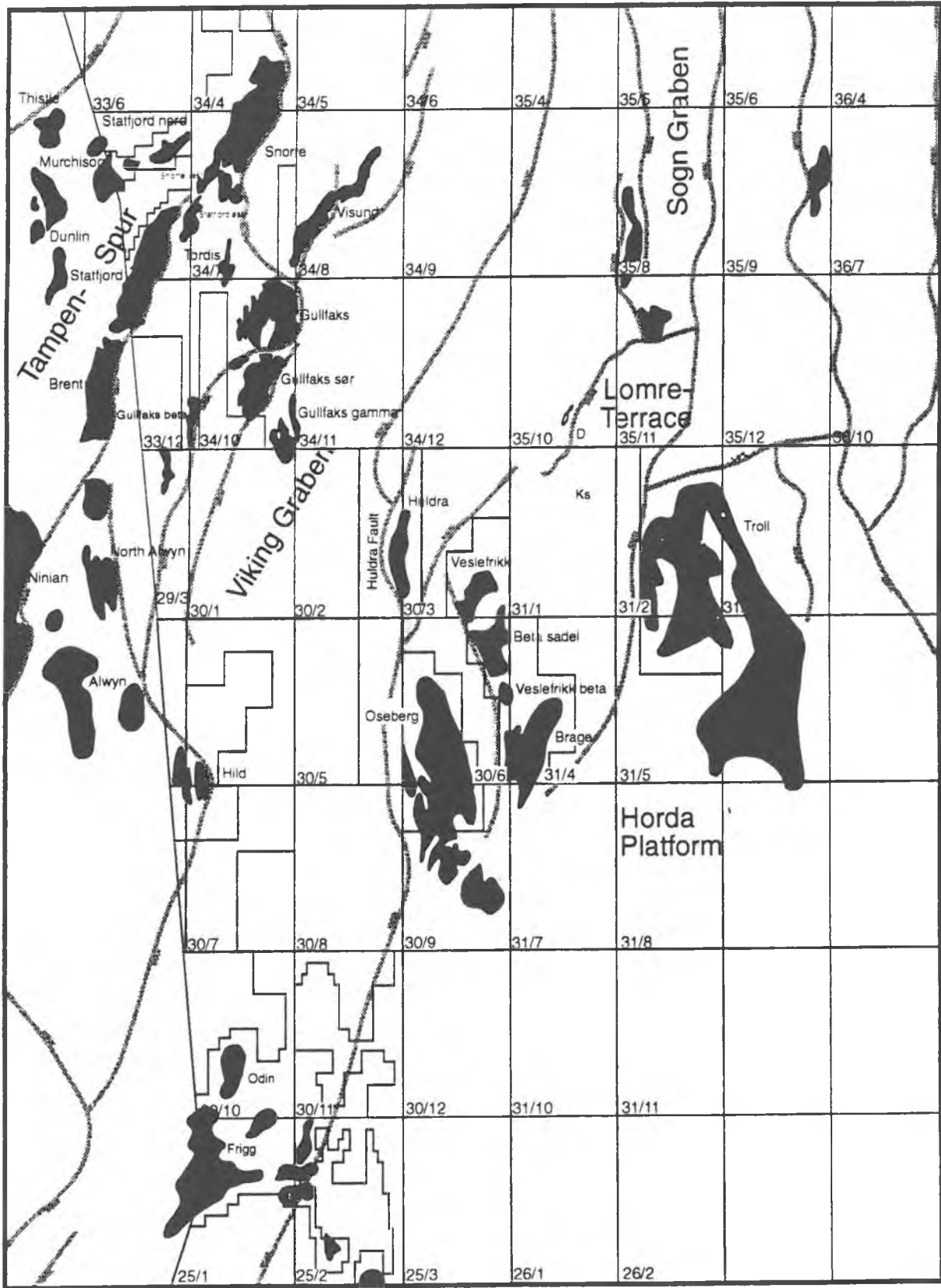
Table 16. Carbon isotopic data for whole oils and separated fractions, Veslefrikk Field¹

Well	DST#	Sample No.	Oil	Saturates	$\delta^{13}\text{C}$ Aromatics (%)	Polars	Asphaltenes
30/3-A1	RFT	C7428	n.d.	n.d.	n.d.	n.d.	n.d.
30/3-A1	1	C7259	-28.4	-28.7	-27.5	-28.0	-27.8
30/3-A1	2	C7258	-29.0	-29.3	-28.1	-27.8	-28.8
30/3-2	2	C7260	-29.3	-29.7	-28.5	-28.3	-29.0
30/3-4	4	C1648	n.d.	-29.6	-28.4	n.d.	n.d.
30/3-4	1	C1647	n.d.	-29.1	-27.8	n.d.	n.d.

1 Data for wells 30/3-A1 and 30/3-2 from reference 4; data for well 30/3-4 from reference 5

Figure 1. Geographical location of the Huldra Field

a) Regional map



GEO-DIB/A91/0623

0 10 km
1:1 mill.

Figure 2. Plot of carbon isotope composition versus fraction for DST#2, well 30/2-1

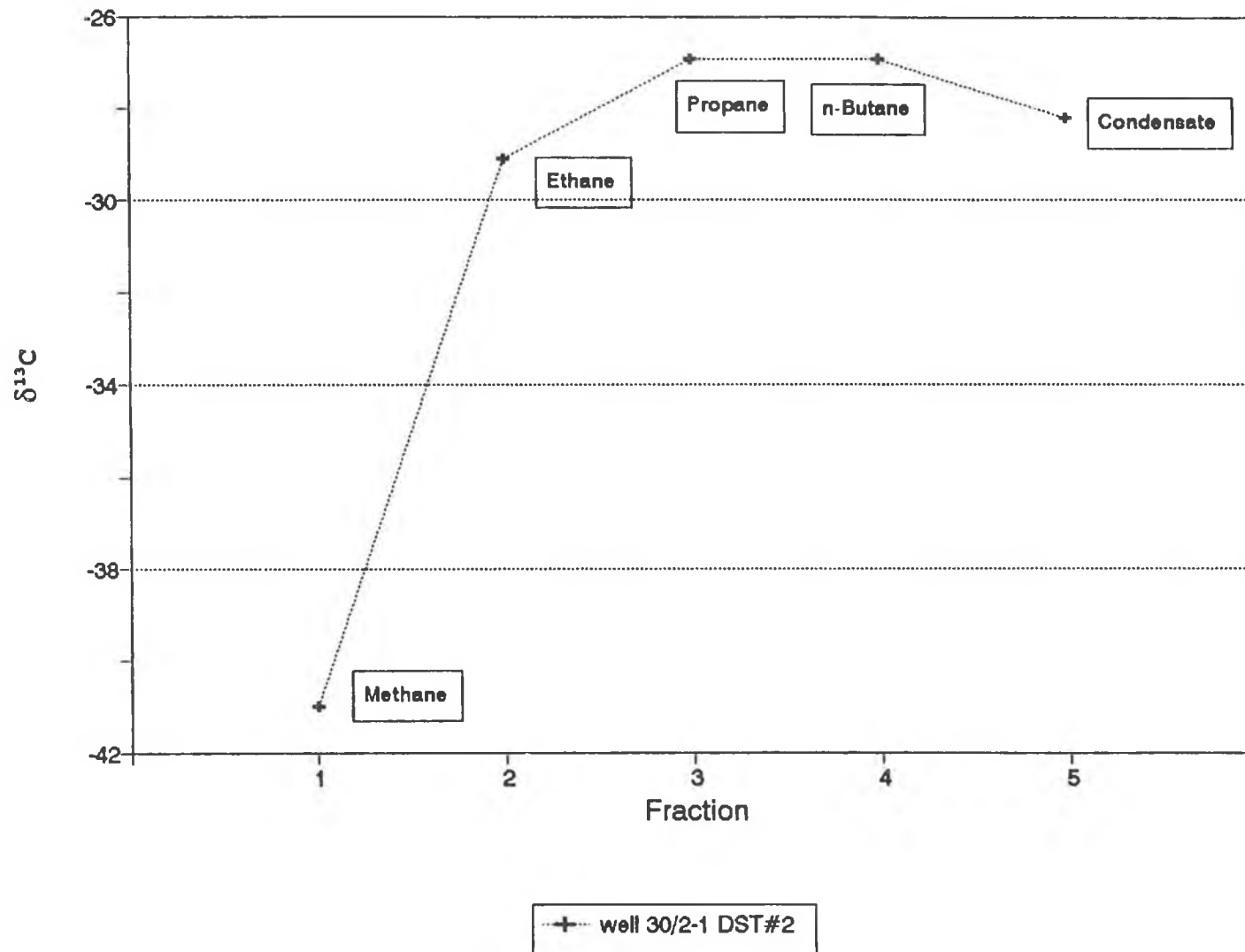


Figure 3. Comparison of GC traces of saturates fractions from source rocks and a DST from Huldra Field

a) Draupne Formation

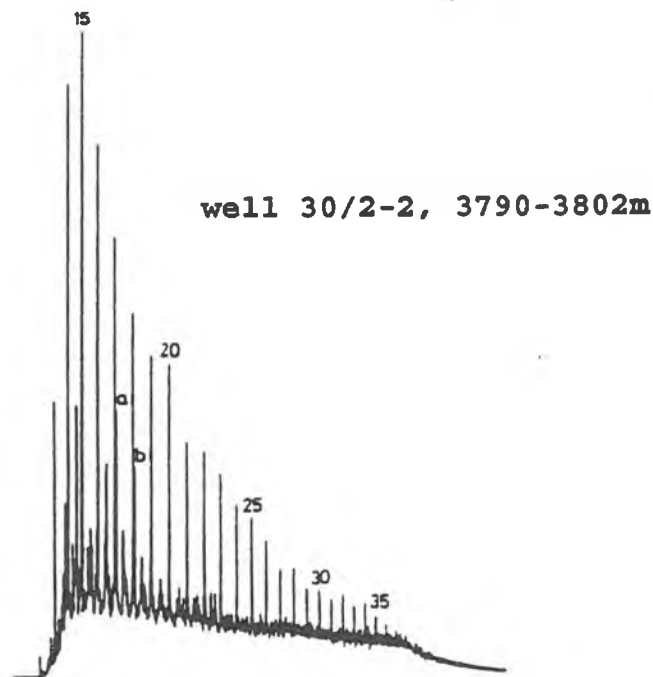
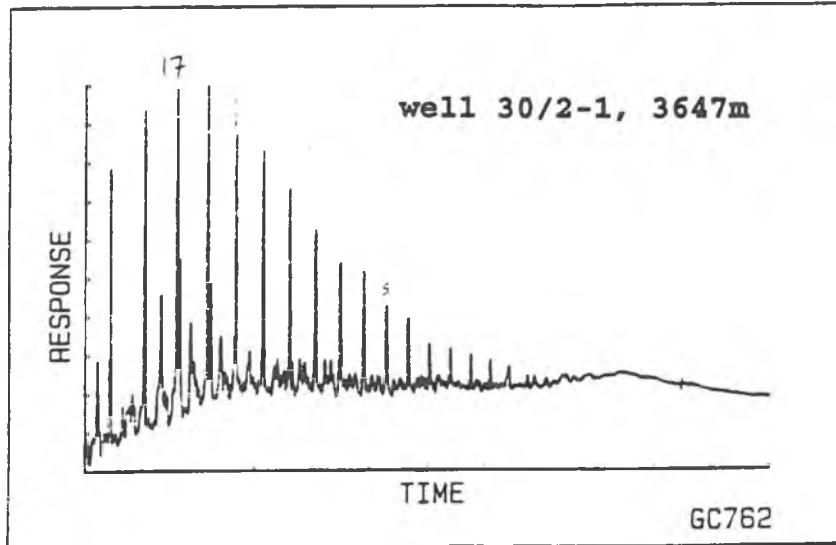


Figure 3. Comparison of GC traces of saturates fractions from source rocks and a DST from Huldra Field

b) Heather Formation

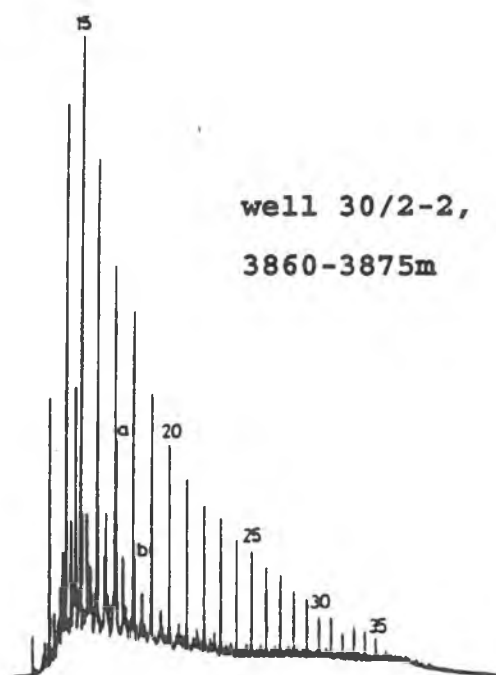
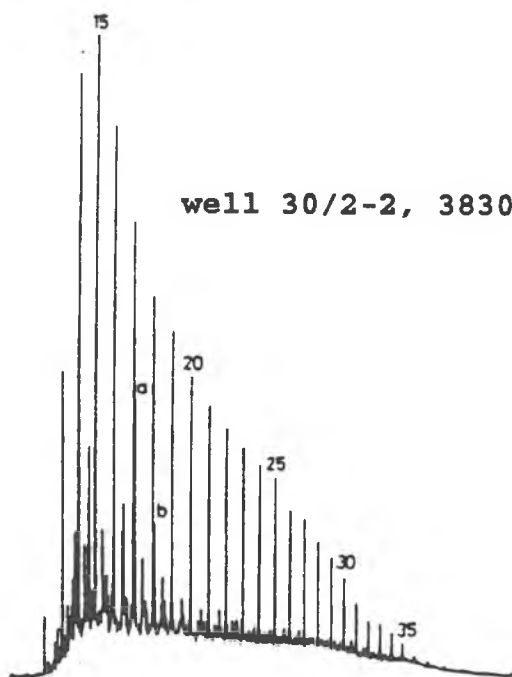
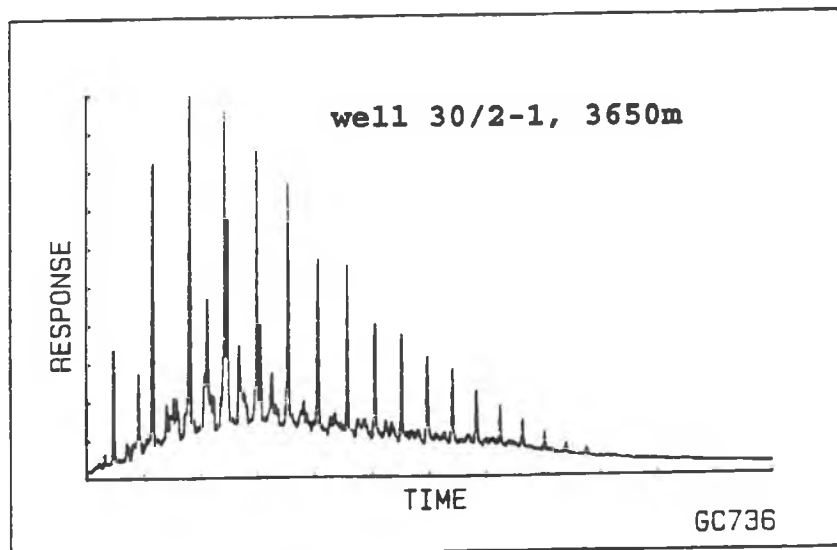
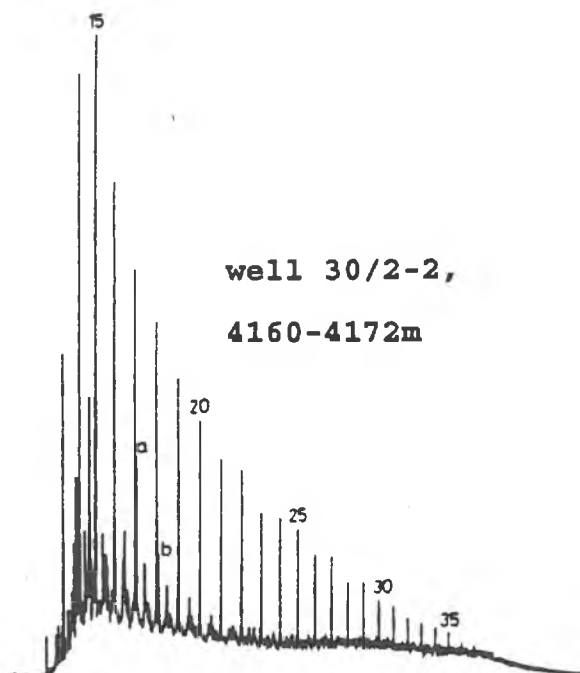
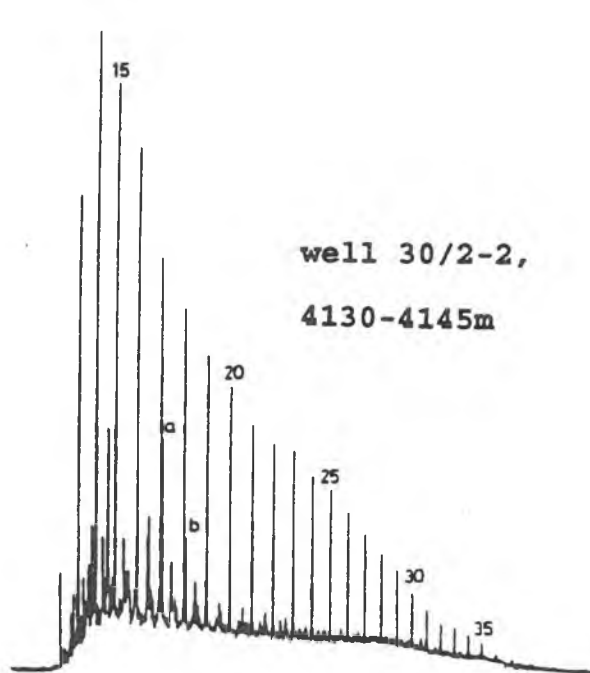
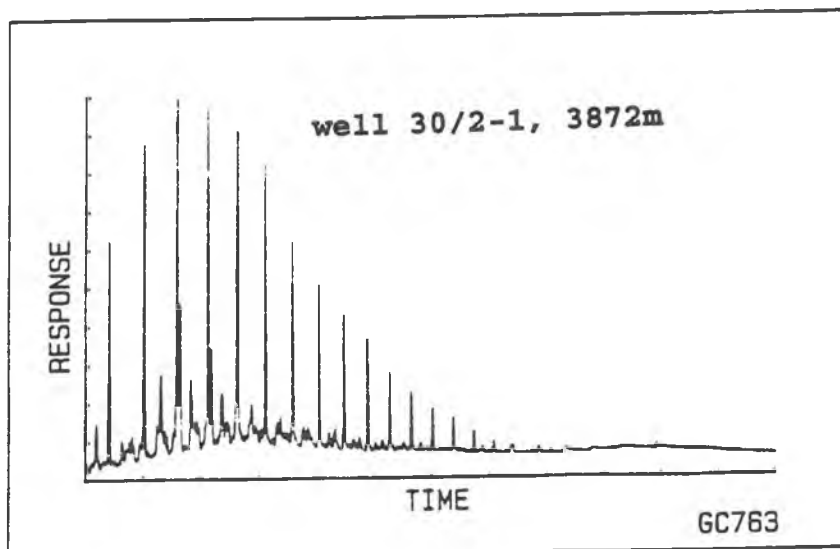


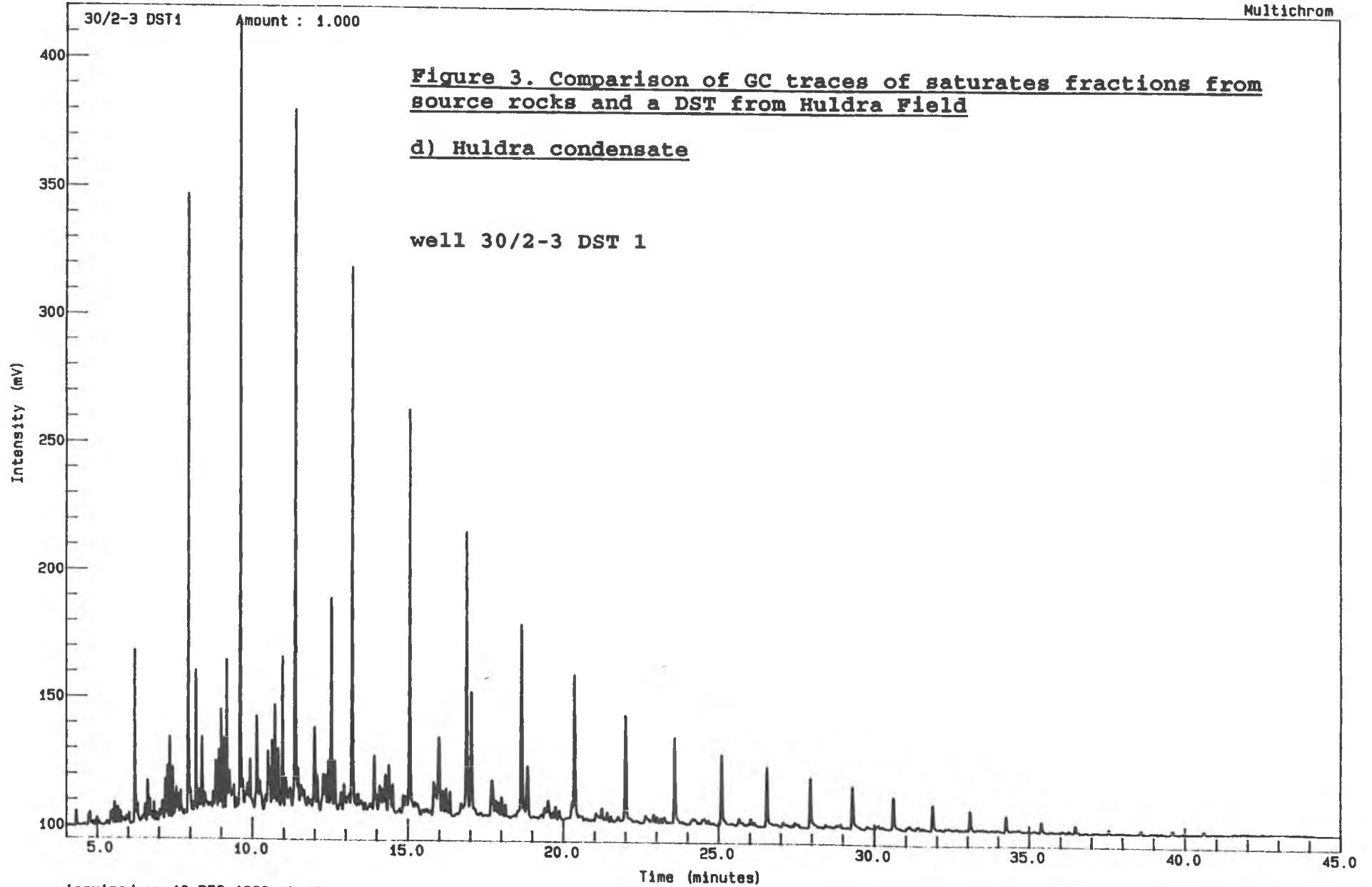
Figure 3. Comparison of GC traces of saturates fractions from source rocks and a DST from Huldra Field

c) Dunlin Group mudrocks



Analysis Name : [GEOKJEMI] 4 S6536I, 1, 1.

Multichrom



Acquired on 10-DEC-1992 at 13:39

Reported on 10-DEC-1992 at 16:44

Appendix 1. Report on "Stable isotopes,
gas samples from well 30/2-1, 30/2-2 and
30/2-3", IFE/KR/F-92/188

ADDRESS KJELLER HALDEN Box 40, N-2007 Kjeller, Norway N-1751 Halden, Norway TELEPHONE +47 6 806000 +47 9 183100 TELEX 74 573 energ n 76 335 energ n TELEFAX +47 6 815553		AVAILABILITY Private Confidential
REPORT TYPE	REPORT NO. IFE/KR/F-92/188	DATE 1992-12-17
	REPORT TITLE REPORT ON STABLE ISOTOPES, GAS SAMPLES FROM WELL 30/2-1, 30/2-2 AND 30/2-3	DATE OF LAST REV.
		REV. NO.
	CLIENT Statoil	NUMBER OF PAGES 7
	CLIENT REF. T 6269/161	NUMBER OF ISSUES 15
SUMMARY <p>The gas components C₁ - C₅ and CO₂ have been separated from one gas sample from well 30/2-1; DST 2, one gas sample from well 30/2-2; DST 3 and three gas samples from well 30/2-3; DST 1, DST 2 and DST 3. The δ¹³C value is measured on methane, ethane, propane, the butanes and CO₂. In addition the δ D value is measured on methane.</p> <p>The maturity situation based on the isotopic composition of the individual hydrocarbon gas components of the gas samples from well 30/2-1, 30/2-2 and 30/2-3 indicate high maturity near the end of the oil window, and with the possibility of a mixed gas situation.</p>		DISTRIBUTION Statoil (10) Andresen, B. Råheim, A. Throndsen, T. File (2)
KEYWORDS		
NAME		DATE
PREPARED BY Bjørg Andresen	1992-12-17	Bjørg Andresen
REVIEWED BY Torbjørn Throndsen	1992-12-17	Torbjørn Throndsen
APPROVED BY Arne Råheim	1992-12-17	Arne Råheim

1 INTRODUCTION

One gas sample from well 30/2-1; DST 2, one gas sample from well 30/2-2; DST 3 and three gas samples from well 30/2-3; DST 1, DST 2 and DST 3 were received and analysed during November and December 1992.

On the samples $C_1 - C_5$ and CO_2 are quantified. The $\delta^{13}C$ value is measured on methane, ethane, propane, the butanes and CO_2 . In addition the δD value is measured on methane.

2 ANALYTICAL PROCEDURE

The natural gas samples have been quantified and separated into the different gas components by a Carlo Erba 4200 gas chromatograph.

The hydrocarbon gas components were oxidised in separate CuO-ovens in order to prevent cross contamination. The combustion products CO_2 and H_2O were frozen into collection vessels and separated.

The combustion water was reduced with zinc metal in a sealed quartz tube to prepare hydrogen for isotopic analysis.

The isotopic measurements were performed on a Finnigan Mat 251 and a Finnigan Delta mass spectrometer. IFEs value on NBS 22 is $29.77 \pm .06\text{‰}$ PDB.

3 RESULTS

The volume composition of the gas samples is given in Table 1. The results have been normalised to 100%. The stable isotope results are given in Table 2.

The uncertainty in the $\delta^{13}C$ value, based on repeated analysis of a standard gas mixture, is estimated to be $\pm 0.3\text{‰}$ PDB and includes all the different analytical steps, if otherwise not stated. The uncertainty in the δD value is likewise estimated to be $\pm 5\text{‰}$.

The $\delta^{13}C$ values of methane, ethane and propane are plotted in James maturity diagram (James, 1983), Figure 1. The molecular composition related to carbon isotope variations in

methane are plotted in Figure 2 (Schoell, 1983), the carbon and hydrogen variations in methane in Figure 3 (Schoell, 1983) and carbon isotope variations in ethane related to carbon isotope variations in methane in Figure 4 (Schoell, 1983).

Table 1: Volume composition of gas samples from well 30/2-1, 30/2-2 and 30/2-3.

Sample	IFE no	C ₁ %	C ₂ %	C ₃ %	iC ₄ %	nC ₄ %	iC ₅ %	nC ₅ %	CO ₂ %	ΣC ₁ -C ₅	Wet- ness	iC ₄ / nC ₄ /
30/2-1, DST 2	11470	81.8	6.6	5.7	0.48	0.89	0.13	0.15	4.3	95.7	0.15	0.53
30/2-2, DST 3	11471	79.3	8.8	4.6	0.68	1.57	0.26	0.30	4.5	95.5	0.17	0.43
30/2-3, DST 1	11472	81.6	7.4	3.8	0.64	1.22	0.20	0.24	4.9	95.1	0.14	0.52
30/2-3, DST 2	11473	82.5	7.4	3.4	0.54	1.04	0.13	0.14	4.8	95.2	0.13	0.52
30/2-3, DST 3	11474	82.6	7.8	3.5	0.54	1.03	0.12	0.13	4.3	95.7	0.14	0.52

Table 2: Isotopic composition of gas samples from well 30/2-1, 30/2-2 and 30/2-3.

Sample	IFE no	C ₁	C ₁	C ₂	C ₃	iC ₄	nC ₄	CO ₂	CO ₂
		δ ¹³ C ‰ PDB	δ D ‰ SMOW	δ ¹³ C ‰ PDB	δ ¹³ C ‰ PDB	δ ¹³ C ‰ PDB	δ ¹³ C ‰ PDB	δ ¹³ C ‰ PDB	δ ¹⁸ O ‰ PDB
30/2-1, DST 2	11470	-41.0	-189	-29.1	-26.9	-27.9	-26.9	-3.6	-12.8
30/2-2, DST 3	11471	-41.3	-210	-29.7	-26.9	-28.5	-26.9	-1.4	-11.3
30/2-3, DST 1	11472	-41.4	-189	-29.2	-26.9	-27.8	-26.7	-4.0*	0.3
30/2-3, DST 2	11473	-41.4	-205	-29.0	-26.9	-27.4	-26.8	-3.2*	-14.0
30/2-3, DST 3	11474	-41.4	-192	-29.7	-27.0	-27.7	-27.1	-4.2*	-1.8

* Repeated determination of the carbon isotope composition of carbon dioxide gives an uncertainty in the reported values of ± 1‰ PDB.

4 INTERPRETATION

A general isotopic trend for normal unaltered gases is found to be a smooth progression from methane to n-butane, excluding i-butane (James, 1983).

In the present samples from well 30/2-1, 30/2-2 and 30/2-3 the $\delta^{13}\text{C}$ butane values are at the same level as the $\delta^{13}\text{C}$ propane values. This may indicate a mixed gas situation with gas at least derived from two different sources with one source dominating from the $\text{C}_1 - \text{C}_3$ range and the other source dominating from C_4 (and higher). Gases derived from the same source but at different maturity levels may also be the case. The present relationship between the $\delta^{13}\text{C}$ values of propane and n-butane may also be due to a high maturity situation.

A source LOM between 11 and 12, corresponding to a vitrinite reflectance of $\% R_0 = 1.0 - 1.3$ (Robert, 1985), is indicated when the $\delta^{13}\text{C}$ values of methane, ethane and propane are plotted in James maturity diagram, Figure 1 (James, 1983), e.g. at a high maturity level in the oil window.

A high maturity situation in the condensate field of the oil window is indicated with the combined use of the carbon and hydrogen isotopes of methane (Schoell, 1983), Figure 3. A high maturity situation is also in accordance with the combined use of the carbon isotopes of methane and ethane as illustrated in Figure 4 (Schoell, 1983).

5 CONCLUSION

The maturity situation based on the isotopic composition of the individual hydrocarbon gas components of the gas samples from well 30/2-1, 30/2-2 and 30/2-3 indicate high maturity near the end of the oil window, and with the possibility of a mixed gas situation.

6 REFERENCES

- James, A.T. (1983). Correlation of natural gas by use of carbon isotopic distribution between hydrocarbon components. *The American Association of Petroleum Geologists Bulletin*, **67**, 1176-1191.
- Robert, P. (1985). Methods and means of paleothermal analysis. *Organic Methamorphism and Geothermal History*, Elf-Aquitaine and D. Reidel Publishing Company.
- Schoell, M. (1983). Genetic characterisation of natural gases. *The American Association of Petroleum Geologists Bulletin*, **67**, 2225-2238.

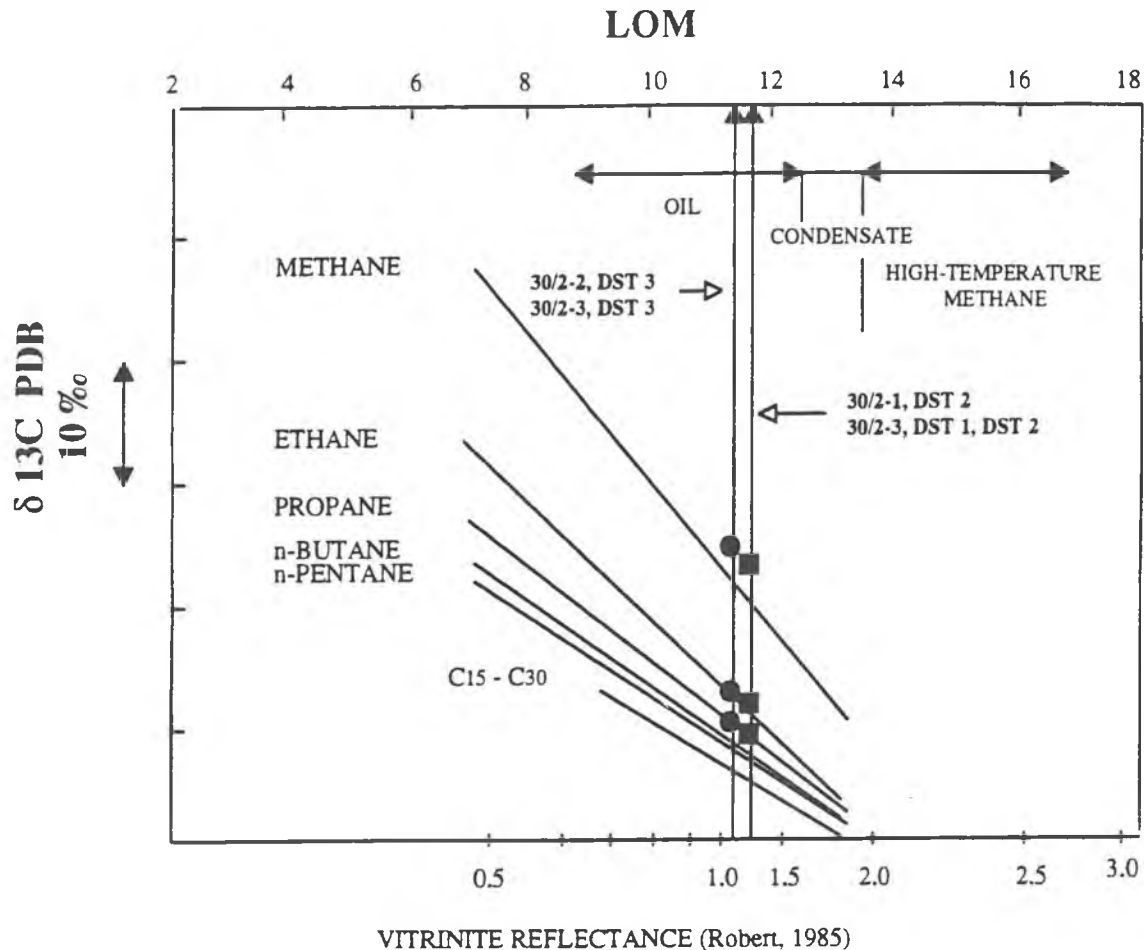


Figure 1

Carbon isotopic separation of gas samples from well 30/2-1, 30/2-2 and 30/2-3 plotted on the maturity diagram (after James, 1983). A source LOM between 11 and 12 is indicated for the gas samples.

The calculated carbon isotopic separations between gas components are plotted on the vertical axes using a sliding scale that is simply the algebraic difference, in parts per mil, between the isotopic composition 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.

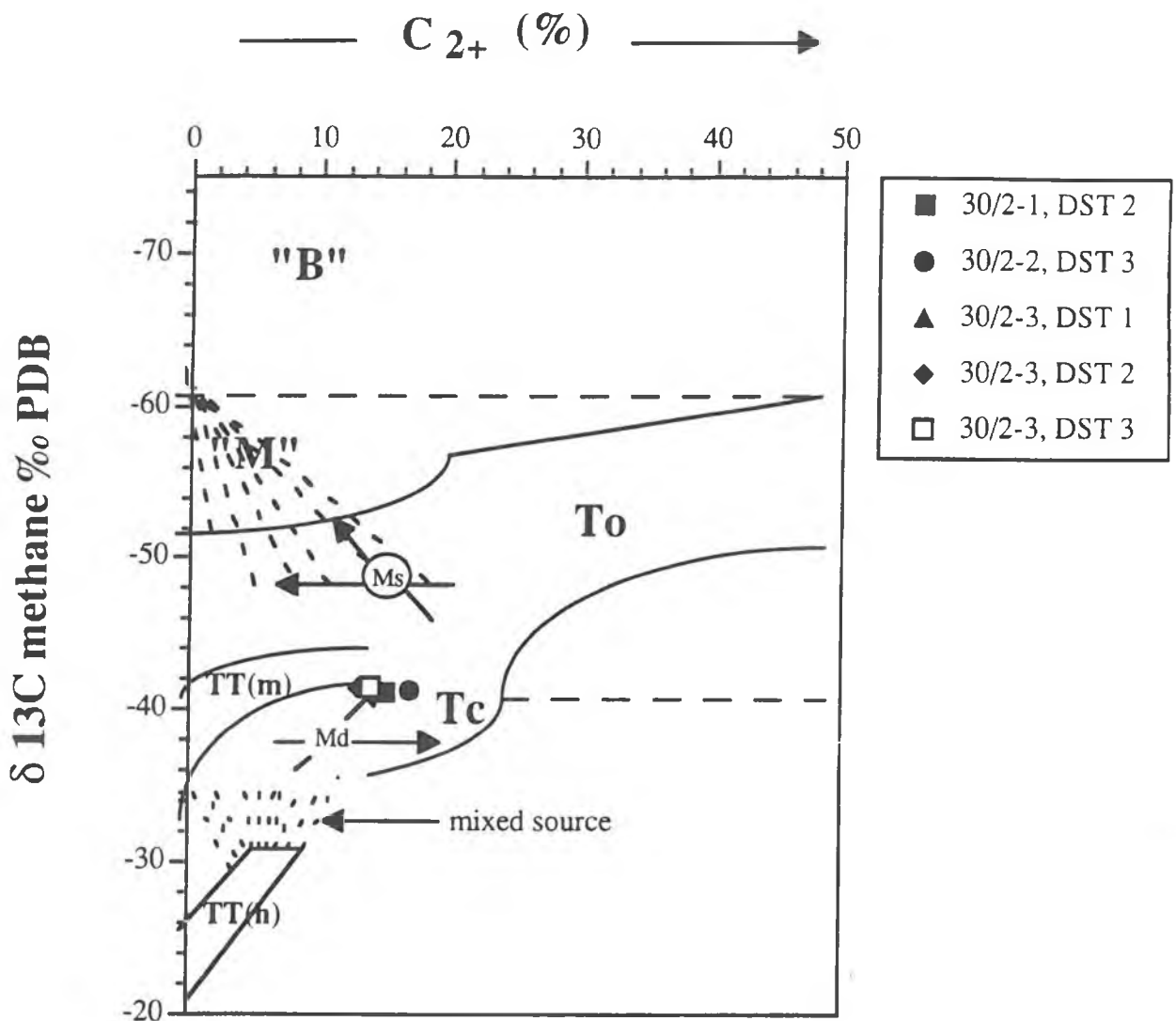


Figure 2

Variations of molecular composition in natural gases related to the isotope variations of methane in gas samples from well 30/2-1, 30/2-2 and 30/2-3.

The principles for the genetic characterisation of natural gases is that 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. "To" are gases associated with petroleum in an initial phase of formation. "Tc" are gases associated with condensates (Schoell, 1983).

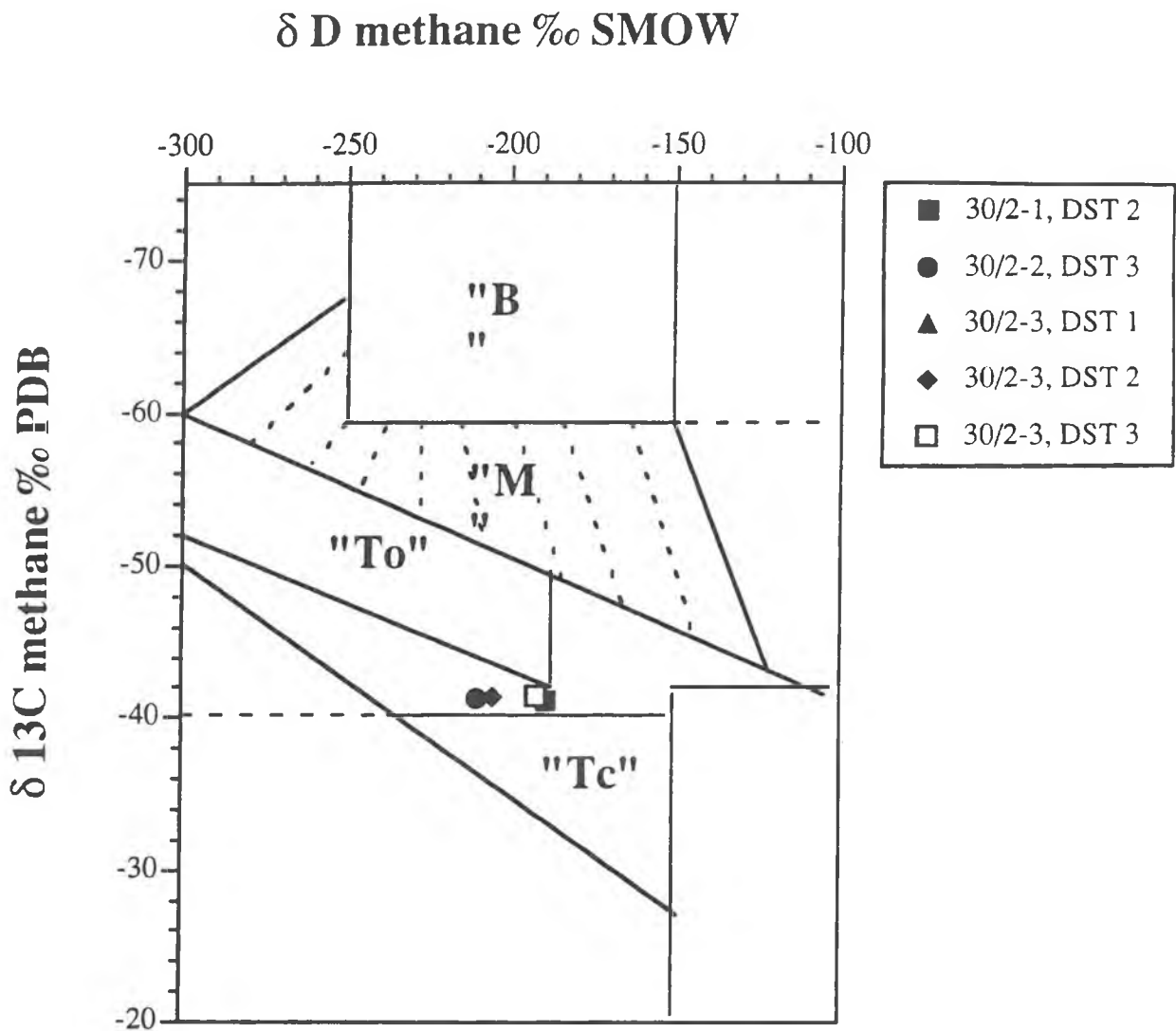


Figure 3

Carbon and hydrogen variations in methane in gas samples from well 30/2-1, 30/2-2 and 30/2-3.

The principles for the genetic characterisation of natural gases is that 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. "T₀" are gases associated with petroleum in an initial phase of formation. "T_c" are gases associated with condensates (Schoell, 1983).

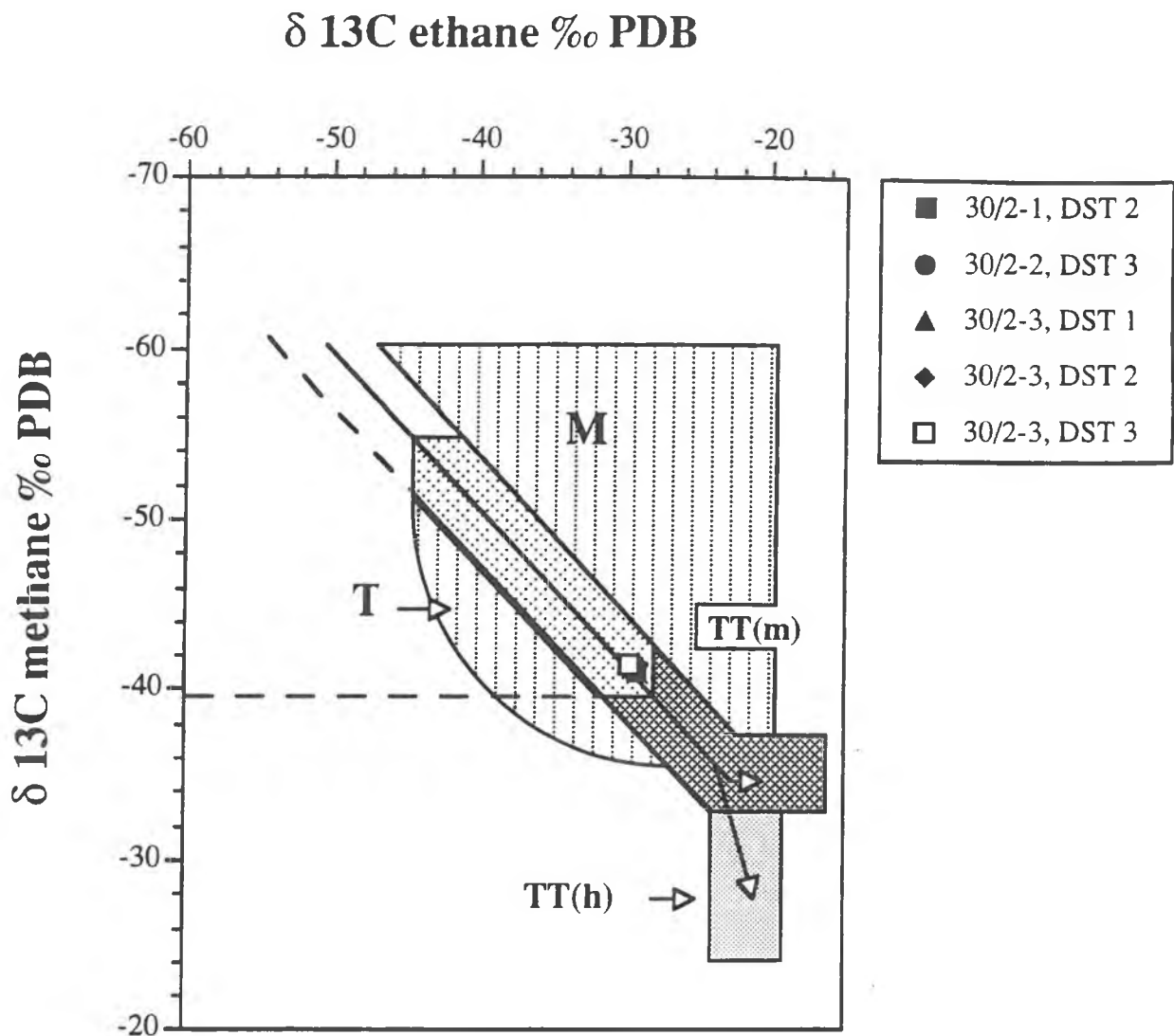


Figure 4

Carbon isotope variations in ethane related to carbon isotope variations in methane in gas samples from well 30/2-1, 30/2-2 and 30/2-3.

The principles for the genetic characterisation of natural gases is that 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. "T₀" are gases associated with petroleum in an initial phase of formation. "T_c" are gases associated with condensates (Schoell, 1983).

Appendix 2. Report on "Isotopic analysis
of condensate from Huldra Field",
IFE/KR/F-93/003

POSTADRESSE TELEFON TELEKS TELEFAKS	KJELLER Boks 40, 2007 Kjeller +47 6 806000 74 573 energ n +47 6 815553	HALDEN Boks 173, 1751 Halden, +47 9 183100 76 335 energ n	TILGJENGELIGHET
RAPPORT TYPE	RAPPORT NR. IFE/KR/F-93/003	DATO 06.01.93	
	RAPPORTTITTEL Isotopanalyse av kondensat fra Huldra-feltet	DATO FOR SISTE REV.	
		REV. NR.	
	OPPDRAGSGIVER Statoil	ANTALL SIDER 1	
	OPPDRAGSGIVERS REF. Kontrakt T 6269/163	ANTALL EKS 8	
SAMMENDRAG Datarapport, karbon isotopsammensetning av kondensat fra Huldra-feltet, kontrakt T 6269/163		DISTRIBUSJON Statoil (5) B. Andresen (1) Arkiv (2)	
STIKKORD			
UTARBEIDET AV		DATO	SIGNATUR
Bjørge Andresen		06.01.93	Bjørge Andresen
KONTROLLERT AV			
GODKJENT AV			

INNLEDNING

6 kondensat er motatt for bestemmelse av $^{13}\text{C}/^{12}\text{C}$ karbonisotop forholdet.

ANALYSEPROSEDYRE

Ca. 2-4 mg av prøvene er overført til Pyrex glassampuller. CuO er tilsatt før ampullene er smeltet igjen under vakuum. Prøvene er forbrent ved 550°C i 1 time (Zofer, 1980). Forbrenningsproduktene CO_2 og H_2O er separert og $^{13}\text{C}/^{12}\text{C}$ forholdet bestemt på et Finnigan MAT 251 massespektrometer. For hver 10. prøve analyseres en intern laboratoriestandard. Spredningen i verdiene av intern laboratoriestandard er $\pm 0.1\text{‰}$ (ca. 40 analyser utført i løpet av 6 måneder).

IFEs verdi på NBS 22 er $-29.77 \pm 0.06 \text{‰ PDB}$.

RESULTATER

Resultatet av analysen er gitt i tabell 1.

Tabell 1. Karbon isotopsammensetningen av kondensatprøver fra Huldra-feltet, T 6269 nr. 163.

Prøve	IFE no.	Kondensat $\delta^{13}\text{C} \text{‰ PDB}$
S 6533	11627	-28.2
S 6534	11628	-28.3
S 6535	11629	-27.9
S 6536	11630	-28.1
S 6537	11631	-28.1
S 6538	11632	-28.5

Sofer, Z. (1980). Preparation of carbon dioxide for stable isotope analysis of petroleum fractions. *Analytical Chemistry*, **52**, 1389-1391.

Appendix 3. Replicate Iatroscan
analyses, Huldra Field condensates

Appendix 3. Replicate Iatroscan data¹ for Huldra condensate samples

Well	DST#	Depth (mRKB)	Sample No.	Saturates (%)	Aromatics (%)	Polars1 (%)	Polars2 (%)
30/2-1	2	3761-71	S6533	86.7	11.0	0.9	1.4
				88.0	11.0	1.0	0.0
				87.6	11.4	1.0	0.0
				Average	87.4	11.1	1.0
30/2-1	3	3720-28	S6534	86.4	13.0	0.6	0.0
				86.4	12.1	0.9	0.6
				87.1	12.1	0.8	0.0
				Average	86.6	12.4	0.8
30/2-2	3	3935-74	S6535	88.4	11.0	0.6	0.0
				87.7	11.4	0.6	0.4
				85.2	14.0	0.8	0.0
				Average	87.1	12.1	0.7
30/2-3	1	3895-98	S6536	85.5	13.8	0.4	0.3
				85.7	14.0	0.3	0.0
				85.3	14.1	0.3	0.2
				Average	85.5	14.0	0.3
30/2-3	2	3874-81	S6537	86.9	12.5	0.4	0.2
				86.5	13.2	0.3	0.0
				85.7	13.8	0.4	0.0
				Average	86.4	13.2	0.4
30/2-3	3	3794-03	S6538	85.1	14.7	0.2	0.0
				84.9	14.4	0.4	0.2
				84.8	14.9	0.3	0.0
				Average	84.9	14.7	0.3

Appendix 3. cont.

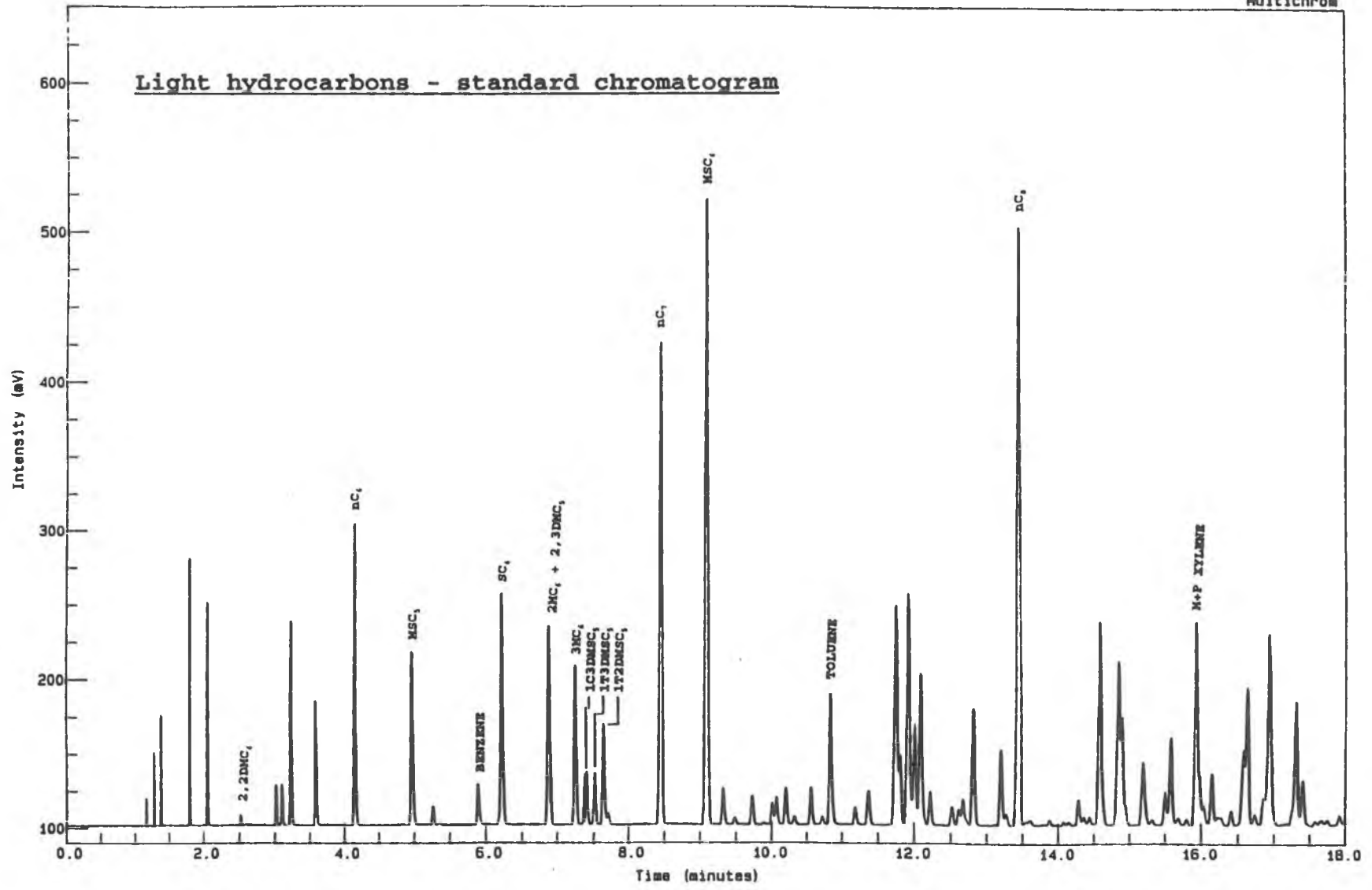
Well	DST#	Depth (mRKB)	Sample No.	Saturates (%)	Aromatics (%)	Polars1 (%)	Polars2 (%)
			STD 11	67.7	27.0	5.3	0.0
				68.3	26.8	4.8	0.0
				71.5	22.9	5.6	0.0
			Average	69.2	25.6	5.2	0.0

1 % Asphaltenes not taken into account in normalisation here

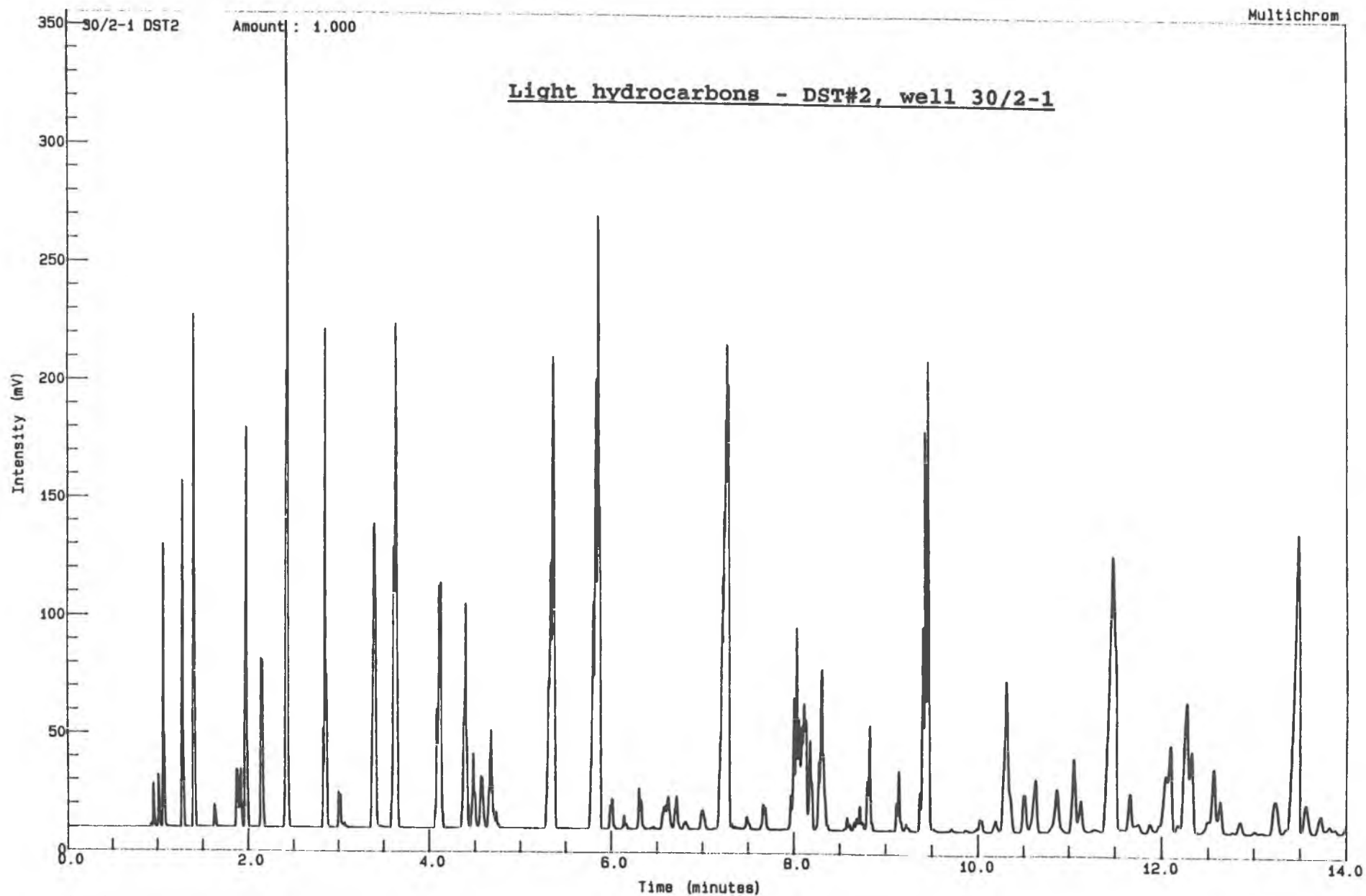
Appendix 4. Whole condensate GC traces
(including light hydrocarbons) for Huldra
samples

Analysis Name : [GEOKJEMI] 6 S1336, 1, 1.

Multichrom



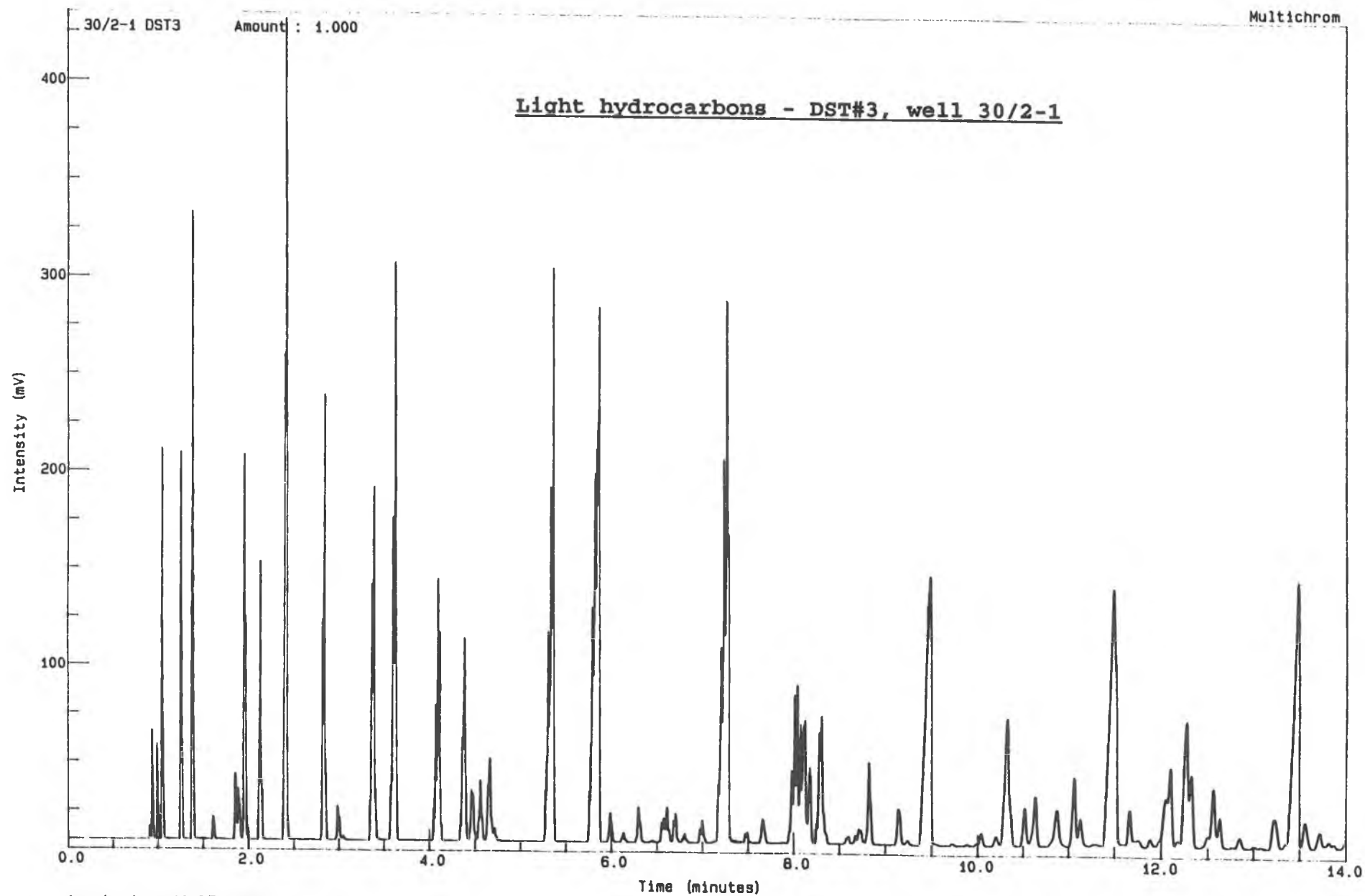
Analysis Name : [GEOKJEMI] 6 S6533A, 1, 1.



Acquired on 10-DEC-1992 at 09: 39

Reported on 10-DEC-1992 at 16: 47

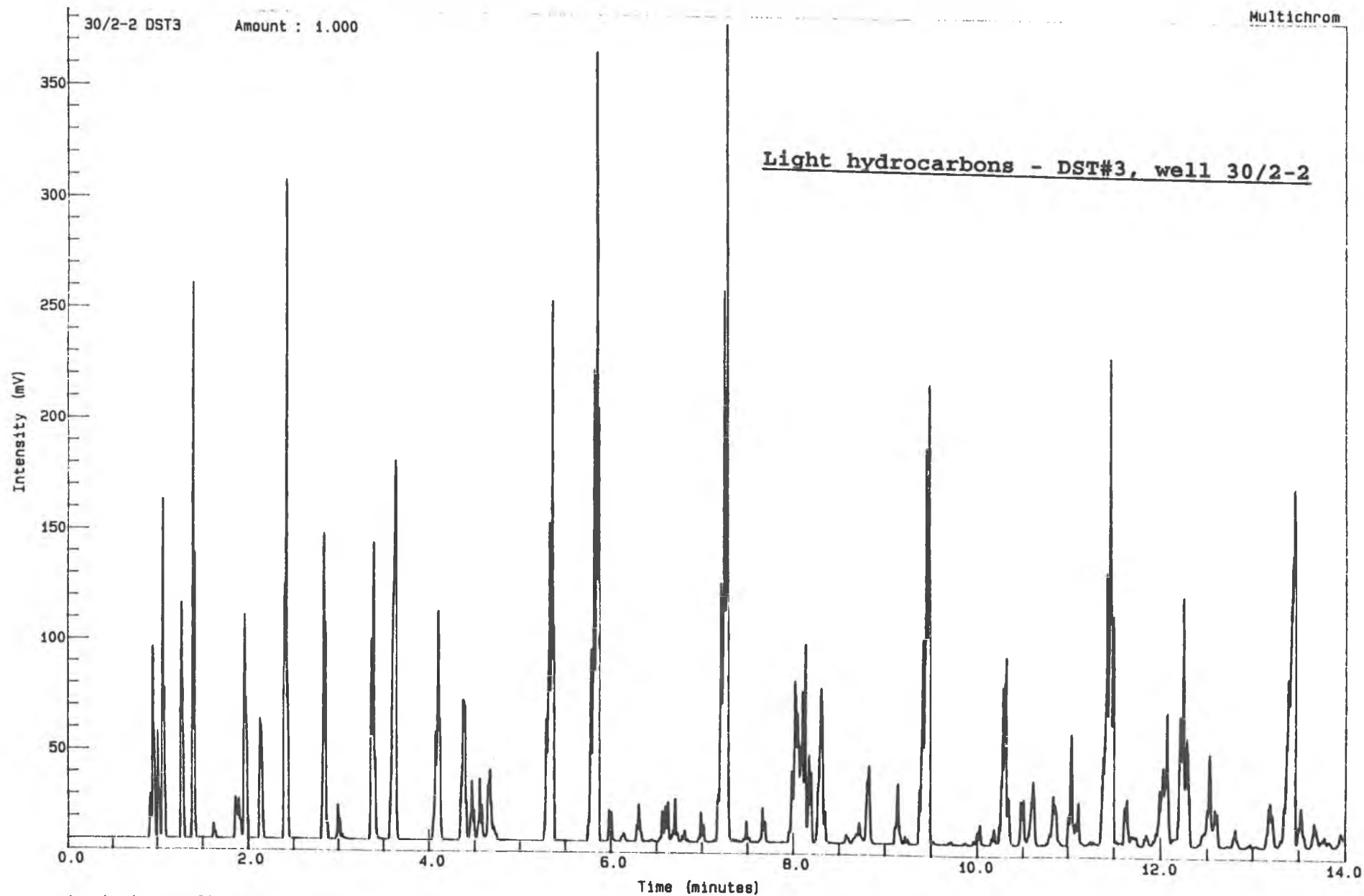
Analysis Name : [GEOKJEMI] 6 S6534A, 1, 1.



Acquired on 10-DEC-1992 at 11:10

Reported on 10-DEC-1992 at 16:49

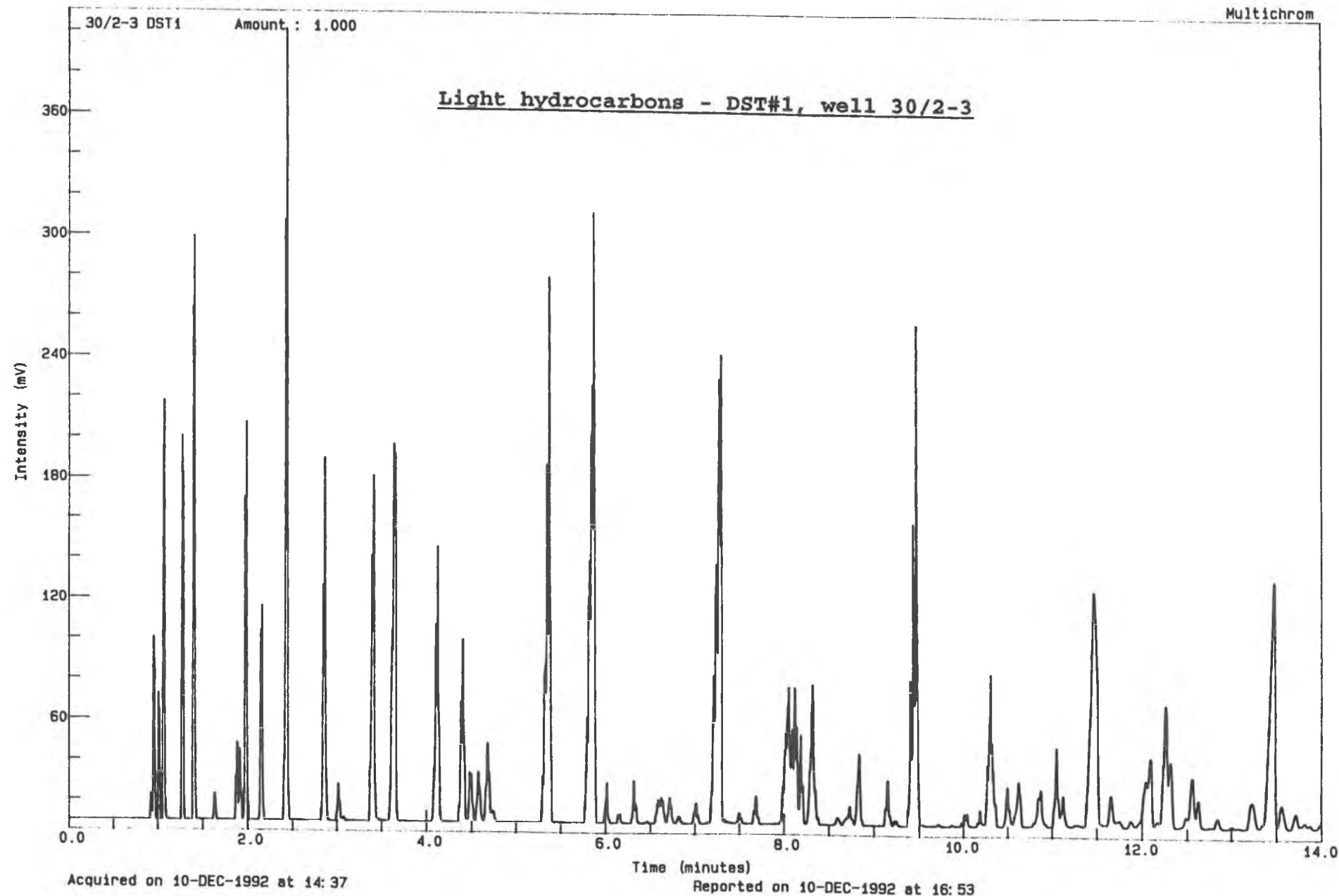
Analysis Name : [GEOKJEMI] 6 S6535A, 1, 1.



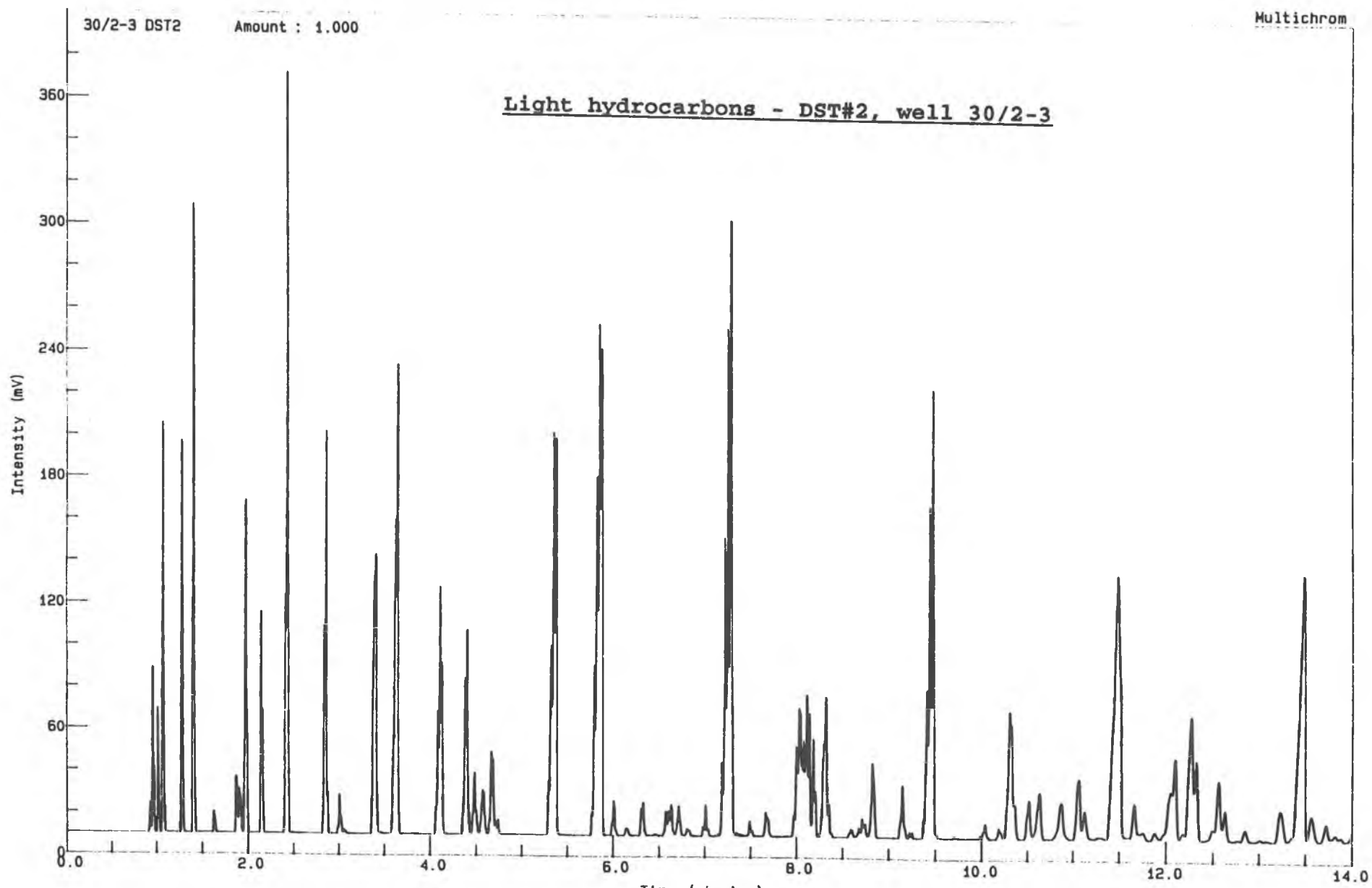
Acquired on 10-DEC-1992 at 13:09

Reported on 10-DEC-1992 at 16:51

Analysis Name : [GEOKJEMI] 6 S6536A, 1, 1.



Analysis Name : [GEOKJEMI] 6 S6537A, 1, 1.

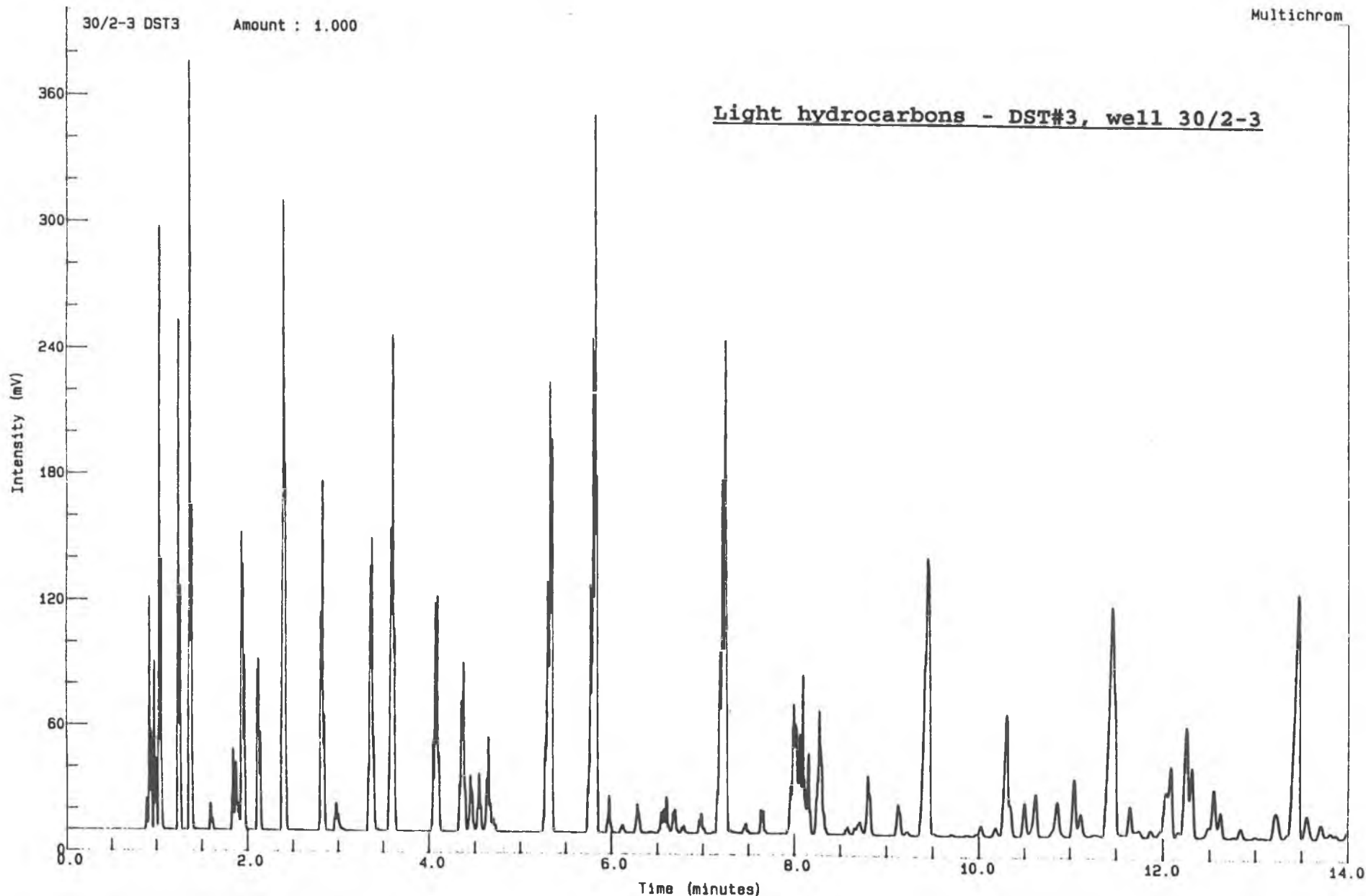


Acquired on 10-DEC-1992 at 16:12

Time (minutes)

Reported on 10-DEC-1992 at 16:55

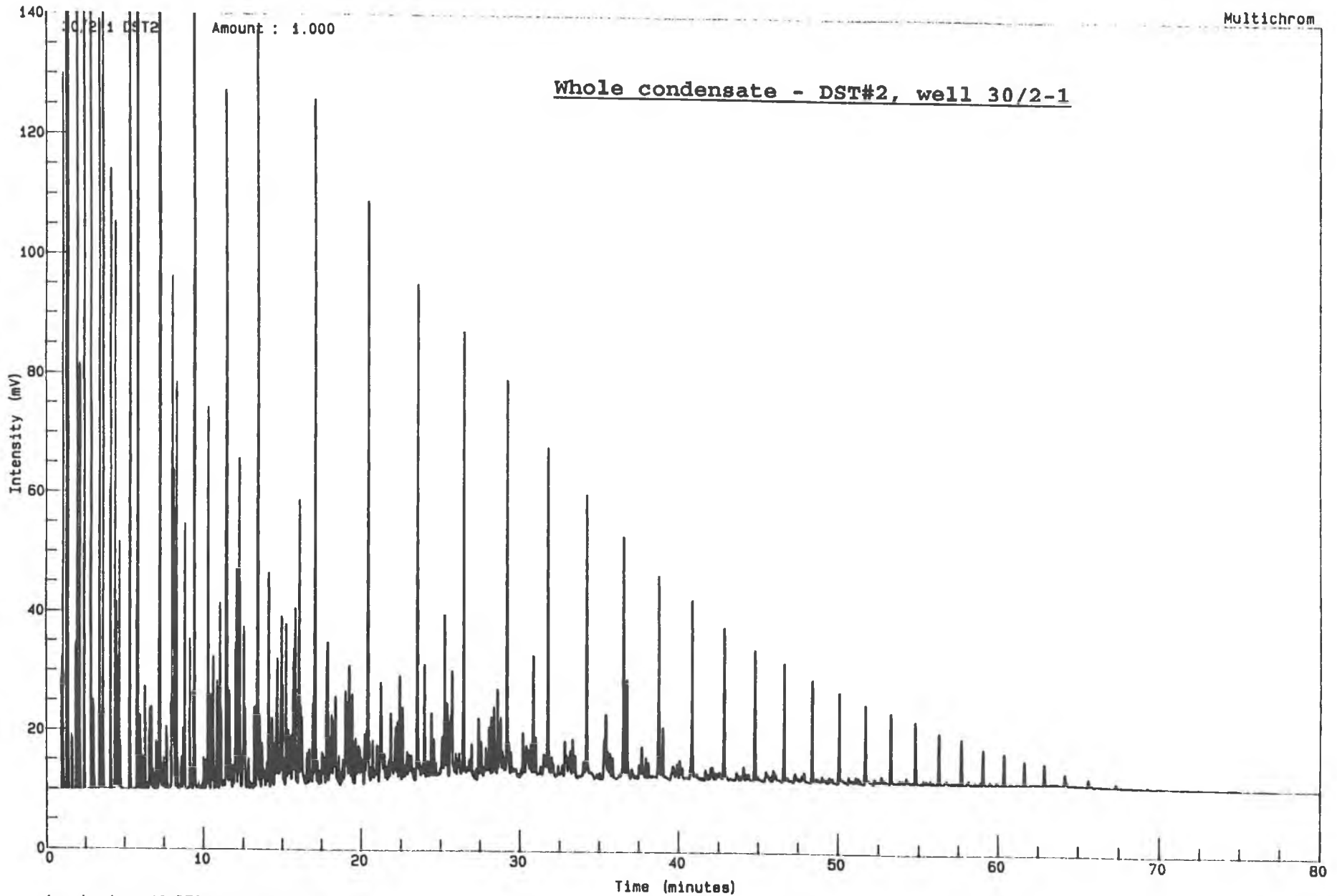
Analysis Name : [GEOKJEMI] 6 S6538A, 1, 1.



Acquired on 11-DEC-1992 at 12:03

Time (minutes)
Reported on 11-DEC-1992 at 13:03

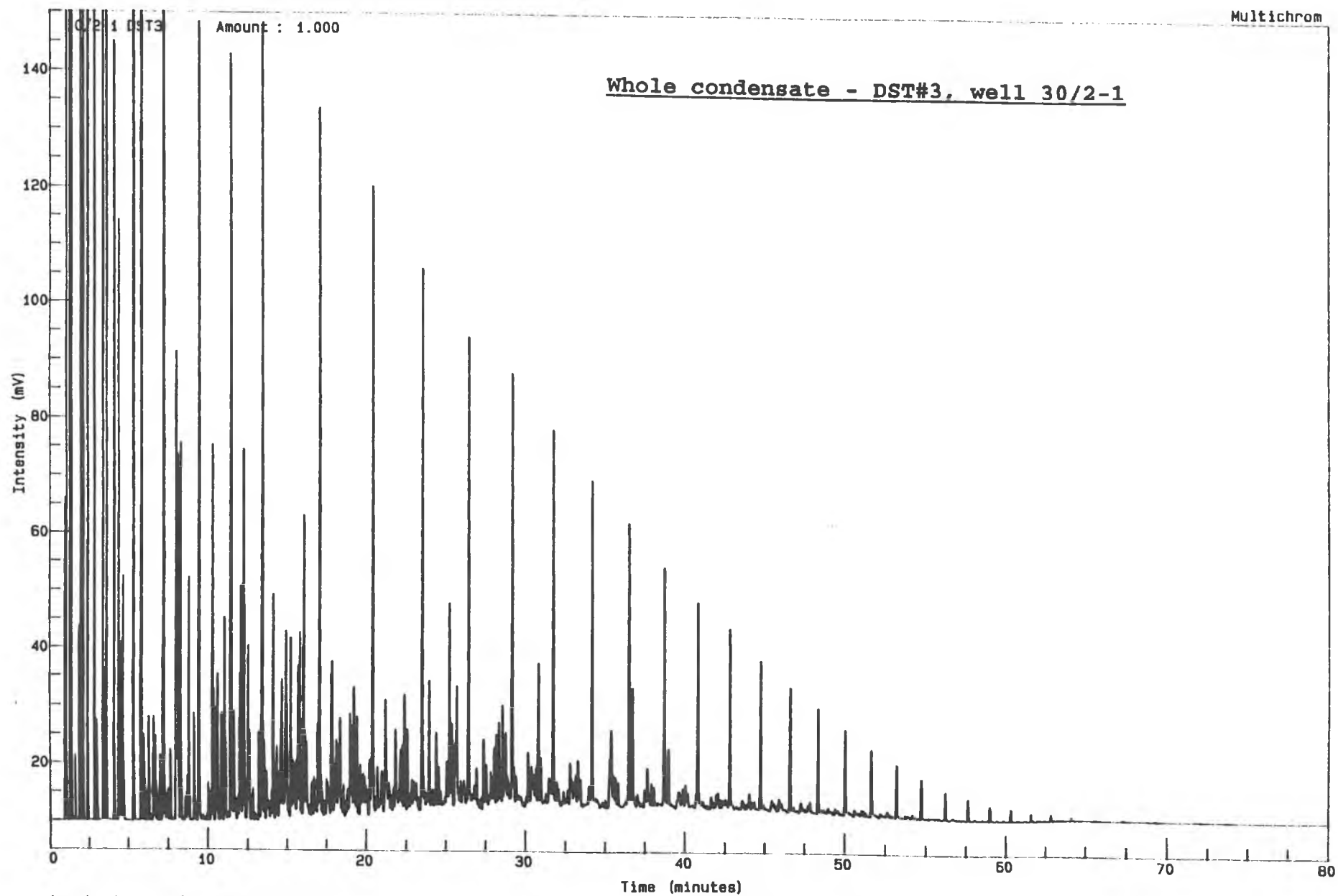
Analysis Name : [GEOKJEMI] 6 S6533A, 1, 1.



Acquired on 10-DEC-1992 at 09:39

Reported on 10-DEC-1992 at 16:49

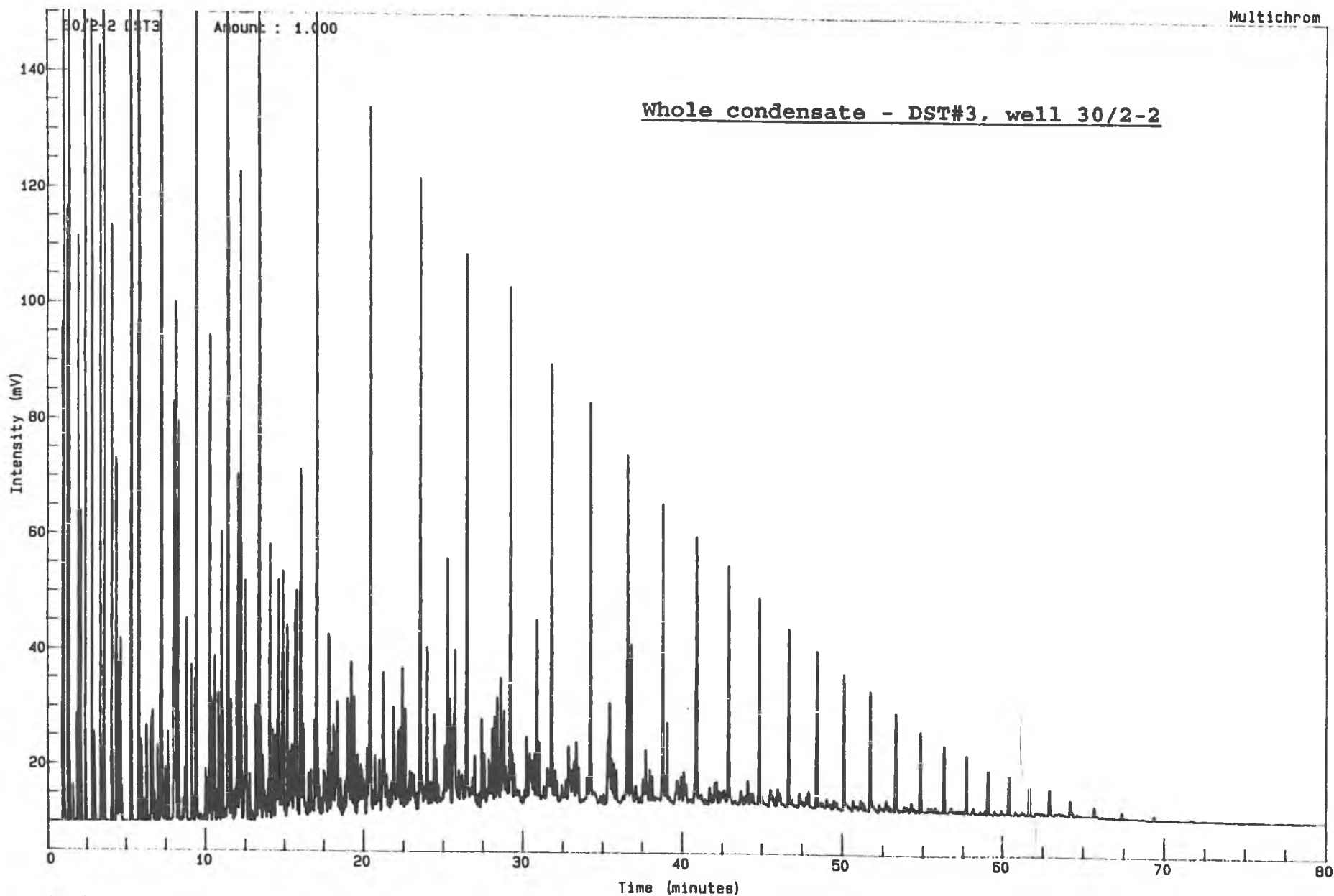
Analysis Name : [GEOKJEMI] 6 S6534A.1.1.



Acquired on 10-DEC-1992 at 11:10

Reported on 10-DEC-1992 at 16:51

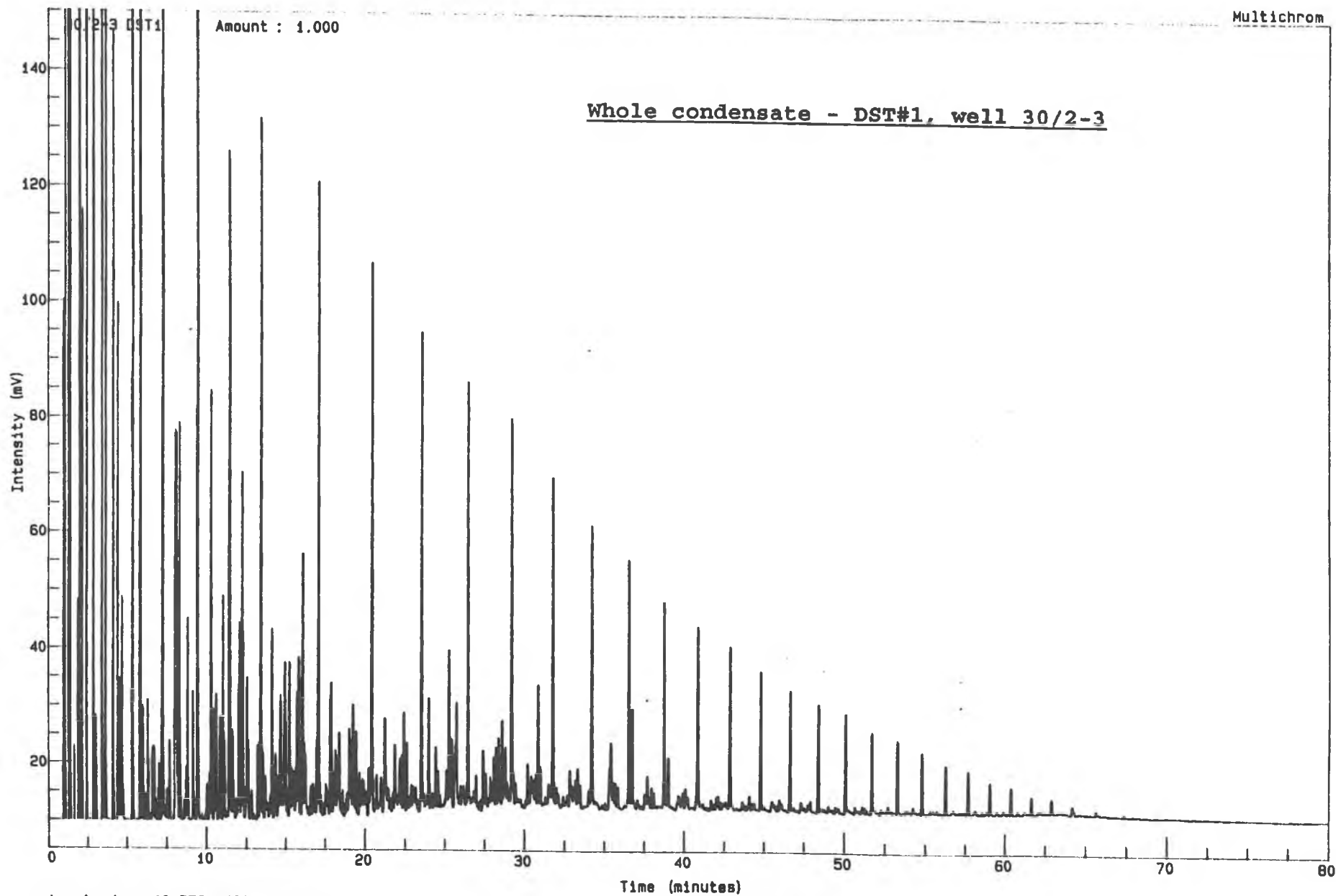
Analysis Name : [GEOKJEMI] 6 S6535A, 1, 1.



Acquired on 10-DEC-1992 at 13:09

Reported on 10-DEC-1992 at 16:53

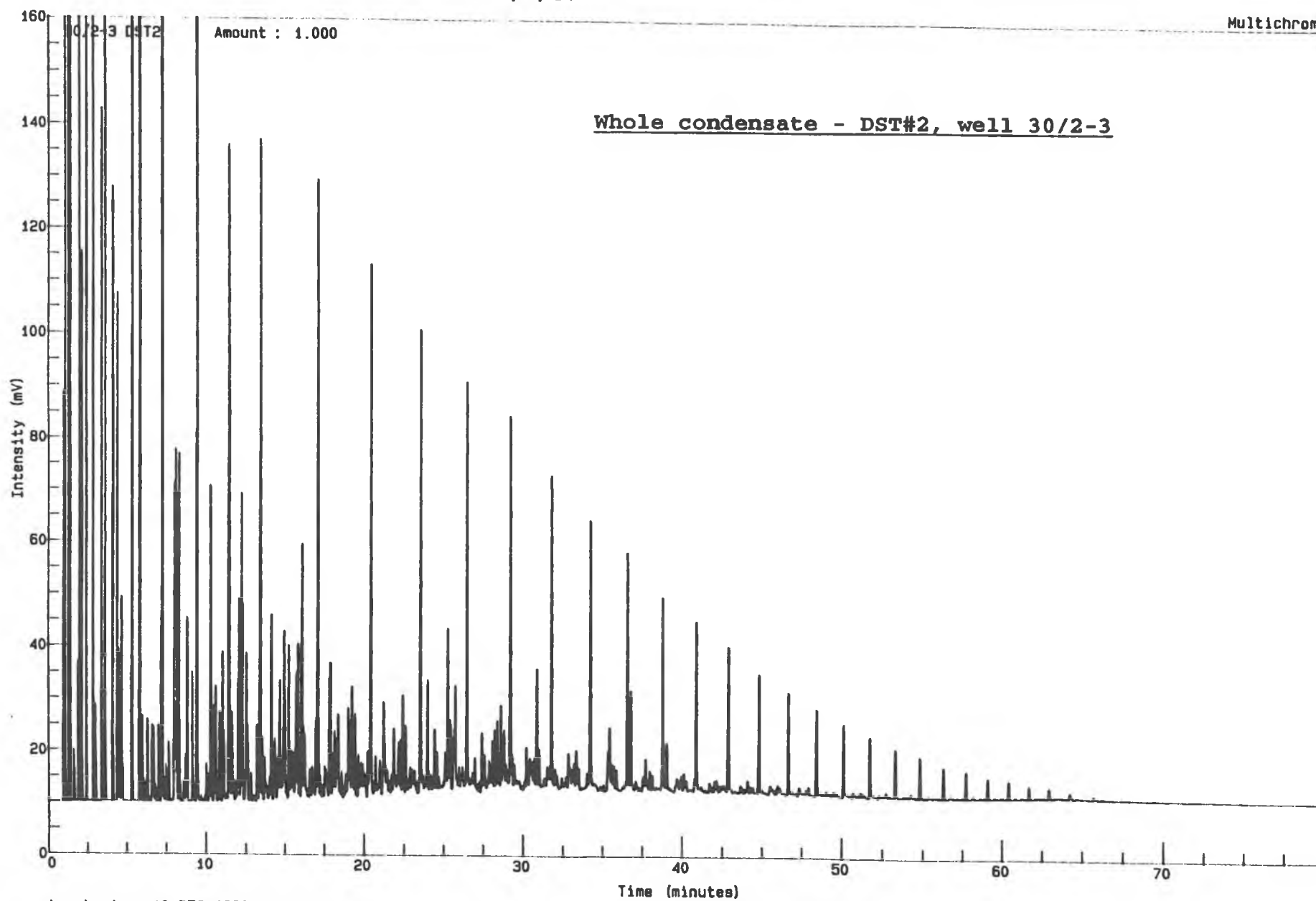
Analysis Name : [GEOKJEMI] 6 S6536A, 1, 1.



Acquired on 10-DEC-1992 at 14:37

Reported on 10-DEC-1992 at 16:54

Analysis Name : [GEOKJEMI] 6 S6537A, 1, 1.

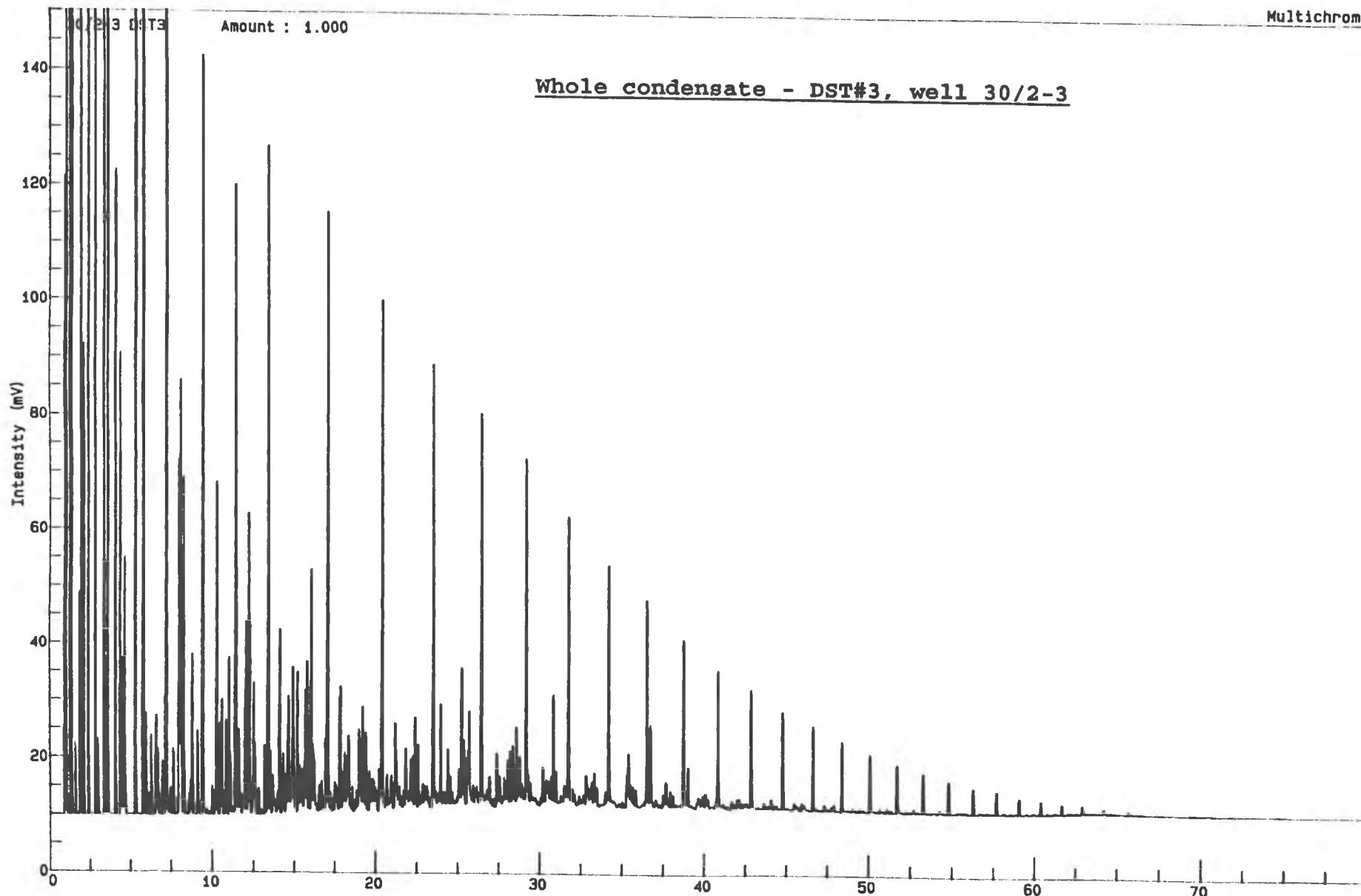


Acquired on 10-DEC-1992 at 16:14

Reported on 11-DEC-1992 at 14:10

Analysis Name : [GEOKJEMI] 6 S6538A, 1, 1.

Multichrom



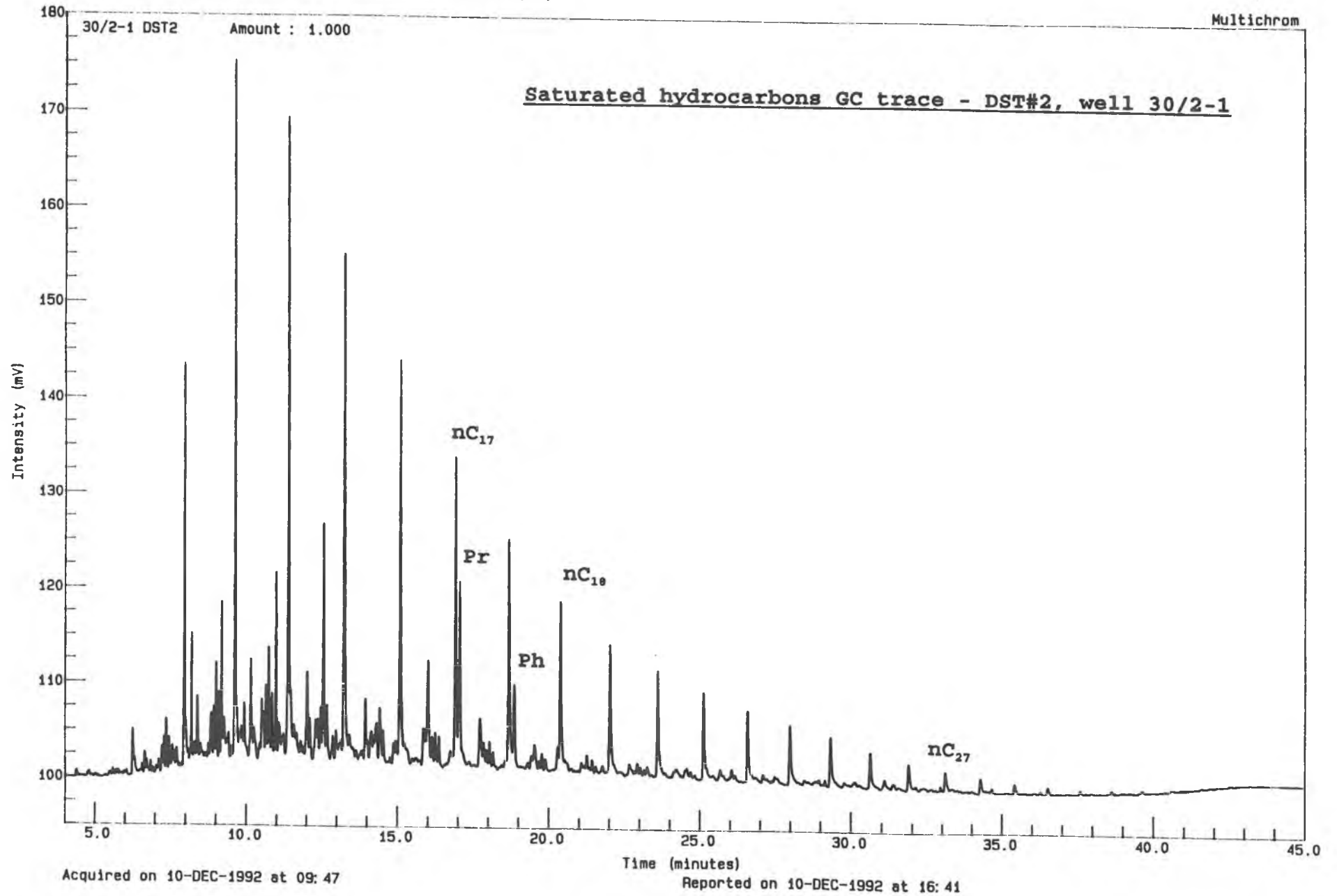
Acquired on 11-DEC-1992 at 12:09

Reported on 11-DEC-1992 at 14:11

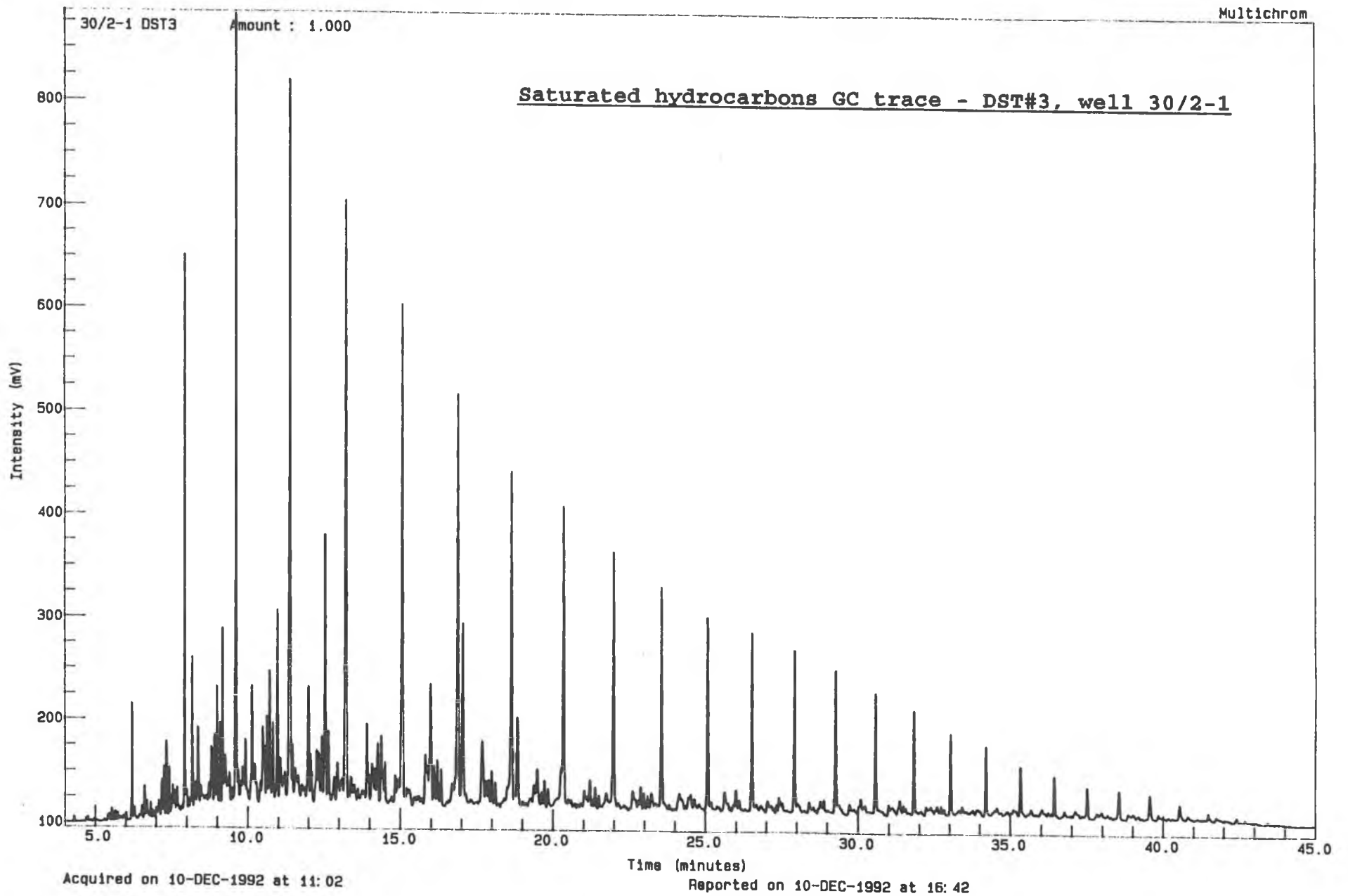
Appendix 5. Saturated hydrocarbon GC
traces for Huldra condensates

Analysis Name : [GEOKJEMI] 4 S6533I, 1, 1.

Multichrom

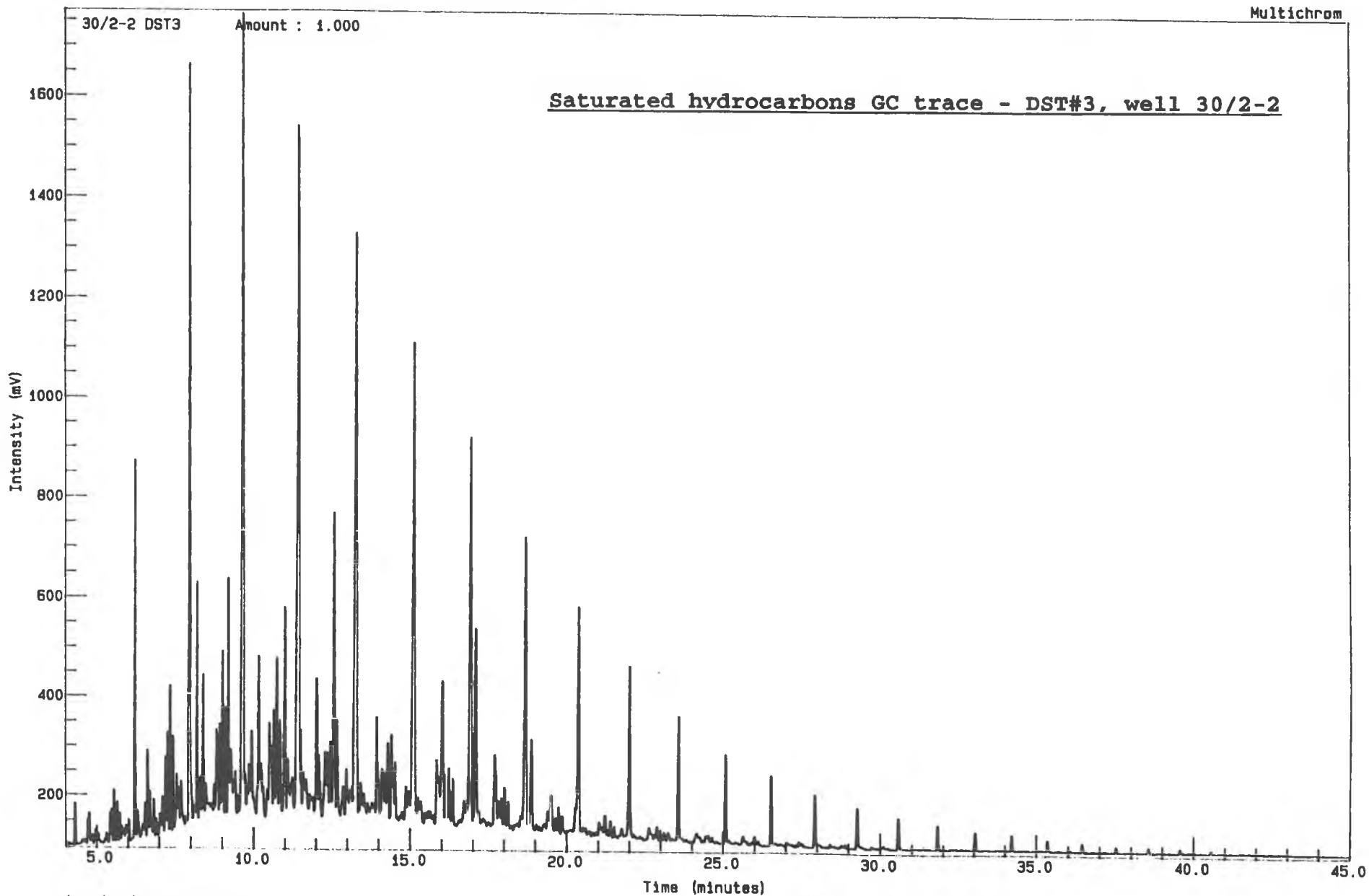


Analysis Name : [GEOKJEMI] 4 S6534I, 1, 1.



Analysis Name : [GEOKJEMI] 4 S6535I, 1, 1.

Multichrom

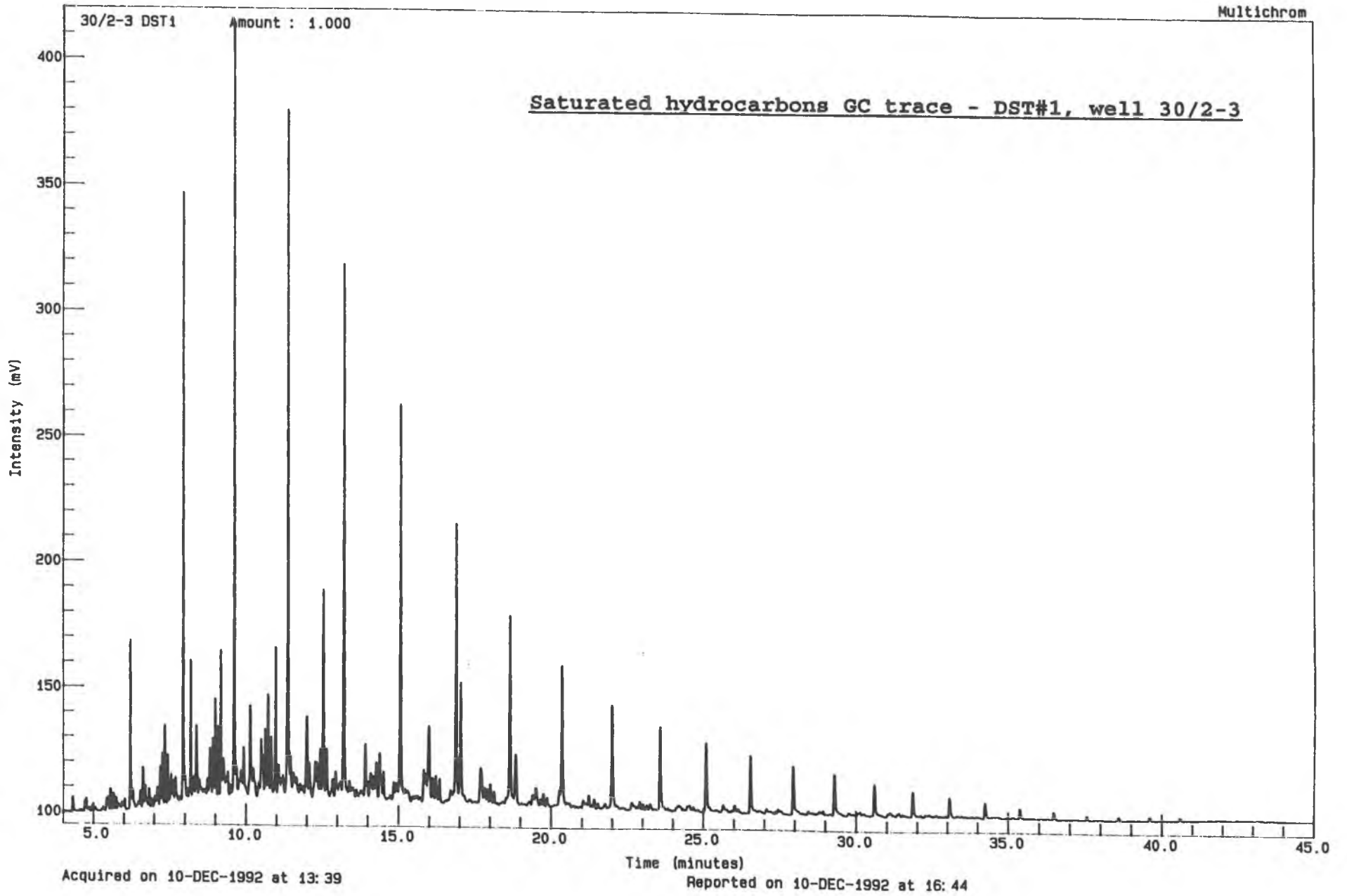


Acquired on 10-DEC-1992 at 12:18

Reported on 10-DEC-1992 at 16:43

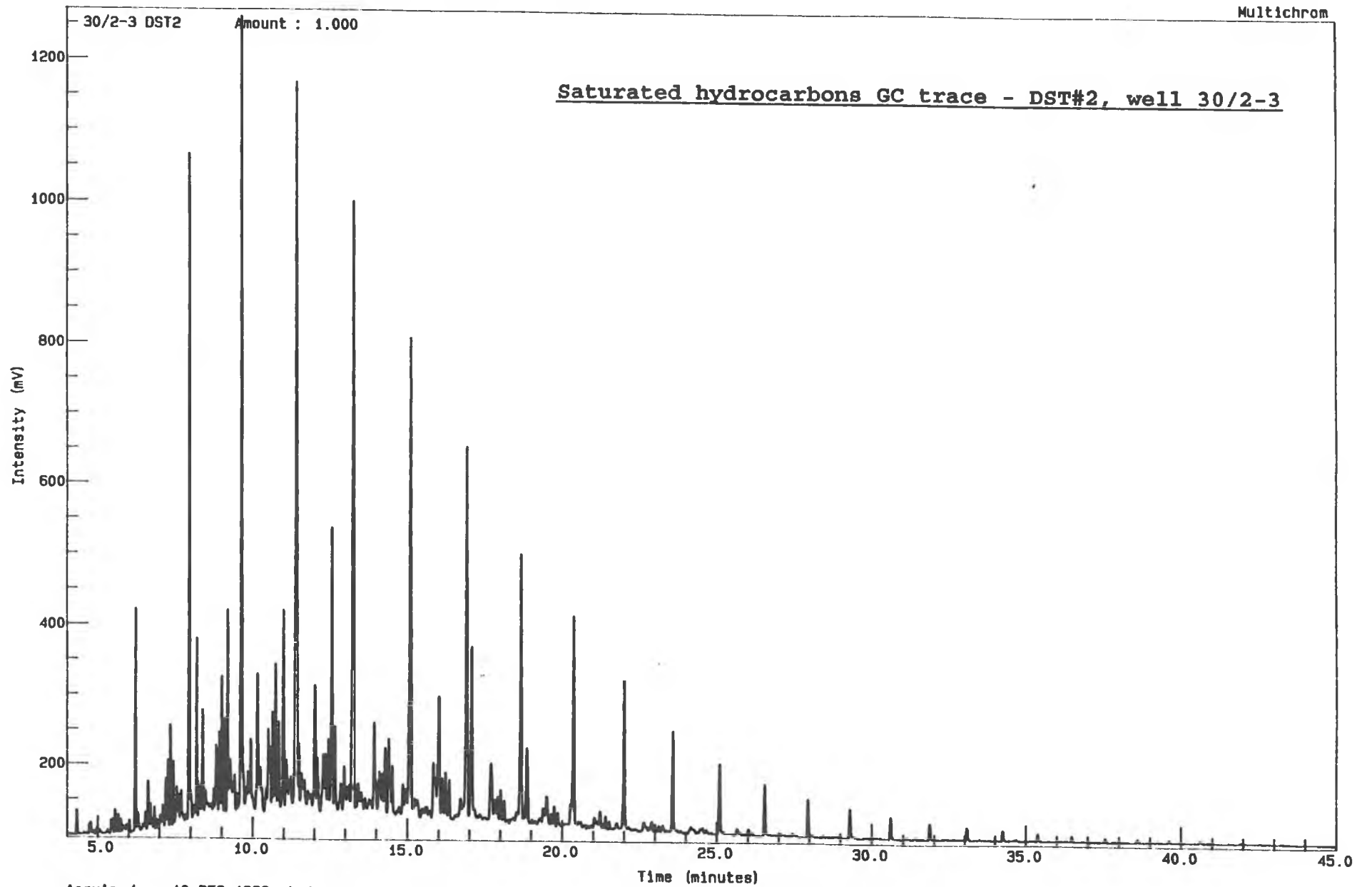
Analysis Name : [GEOKJEMI] 4 S6536I, 1, 1.

Multichrom



Analysis Name : [GEOKJEMI] 4 S6537I, 1, 1.

Multichrom

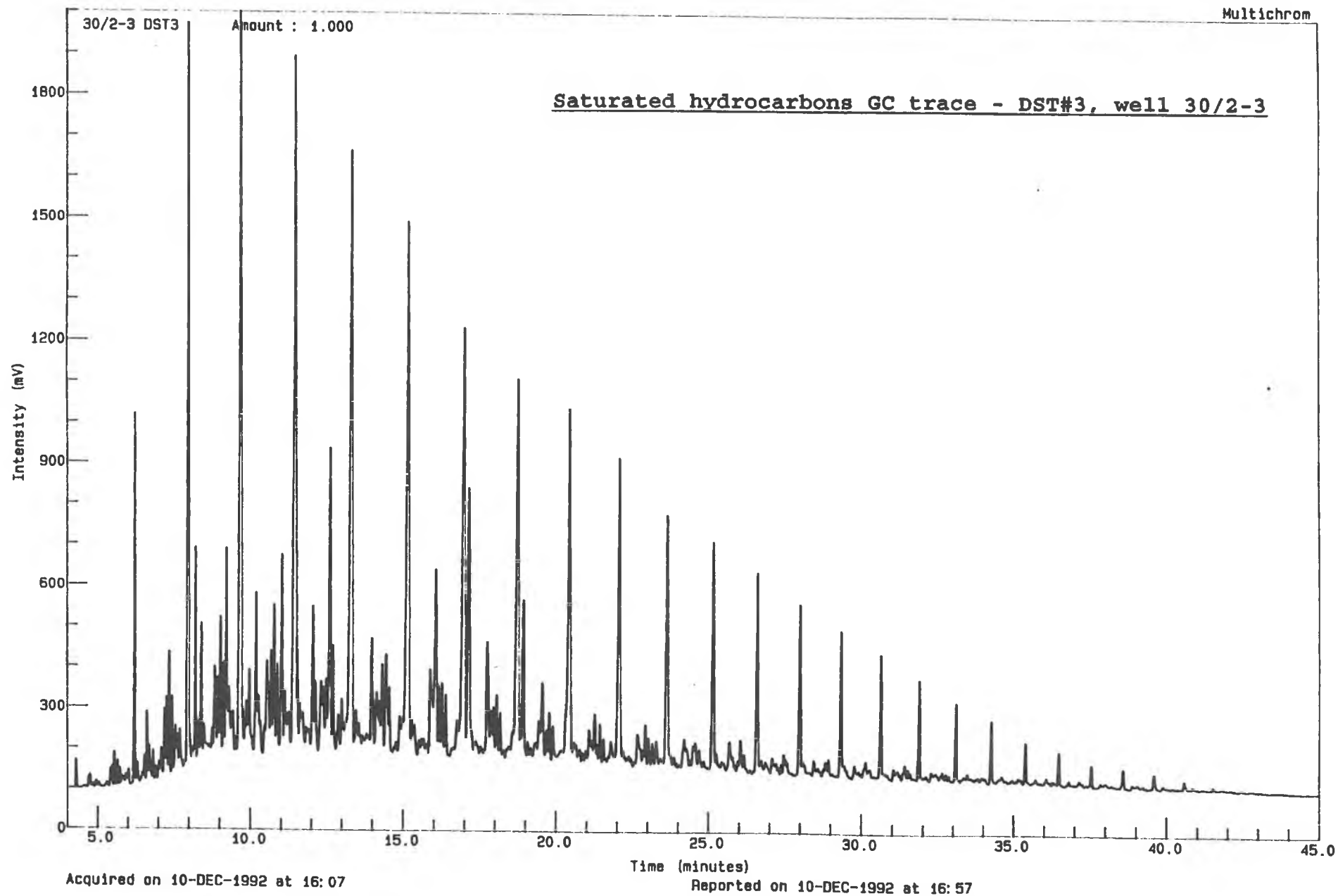


Acquired on 10-DEC-1992 at 14:54

Reported on 10-DEC-1992 at 16:45

Analysis Name : [GEOKJEMI] 4 S6538I, 1, 1.

Multichrom



Appendix 6. Aromatic hydrocarbon GC
traces for Huldra condensates