SOURCE ROCK KINETICS ANALYSIS

GIPPSLAND BASIN WELLS

Prepared for:

Energy and Minerals Victoria

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SOURCE ROCK KINETICS STUDY

GIPPSLAND BASIN WELLS

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1. INTRODUCTION

Two source rock samples from the **Burong-1** and **North Seaspray-1** wells in the Gippsland Basin were submitted for oil generation kinetics analysis. This work was carried out as part of a broader hydrocarbon characterisation study undertaken by Geotechnical Services Pty Ltd for Energy and Minerals Victoria in March 1997.

Two copies of this report have been sent to Mr. Kourosh Mehin at Energy and Minerals Victoria. Any queries pertaining to the data or interpretive content presented herein should be directed to either Dr. Paul Kralert or Dr. Birgitta Hartung-Kagi at Geotechnical Services Pty Ltd.

All data and information are proprietary to Energy and Minerals Victoria and are considered as highly confidential by all Geotechnical Services Pty Ltd personnel.

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2. ANALYTICAL PROCEDURE

Kinetic measurements were carried out using a modified Rock-Eval II micro-scale pyrolysis instrument (Delsi Instruments). Flame ionisation detector and oven thermistor outputs were captured and processed on an IBM-compatible 486DX/33 personal computer linked to the pyrolyzer via a Humble Instruments interface module and a PE Nelson 9000 Series A/D converter (sampling rate 1 Hz).

All samples selected for analysis were ground to a particle size of less than 125 μm and solvent-extracted by ultrasonication with dichloromethane for 2 hr to remove free hydrocarbons (i.e. soluble organic matter).

Pyrolysis experiments were performed in duplicate at four different heating rates, *viz.* 5, 15, 25 and 50°C min^{-1}. Sample weights used ranged from 30 to 60 mg according to the organic carbon content of the rock. Initial and final isotherms were 300°C (5 min) and 550°C (1 min), respectively. In cases where T_{max} values recorded for duplicate experiments differed by more than 1°C, additional runs were made until the required level of reproducibility was attained.

Oil generation kinetics were calculated from the pyrolysis data obtained for each sample using the KINETICS© program (v. 2.4.3) developed by the Lawrence Livermore National Laboratory (USA). Computations were based on the discrete distributed activation energy (E_a) model, and involved an iterative non-linear regression analysis of reaction rate data derived from S_2 peak profiles. Calibration of the Rock-Eval oven temperature was achieved using solvent-extracted Green River Anvil Points shale (AP22) as a reference standard (principal E_a = 54 kcal mol^{-1}).

3. RESULTS

Calculated activation energy distributions for the **Burong-1 3777 ft** and **North Seaspray-1 3213 ft** samples are presented in tabular form in Tables 1 and 2, respectively. These data are also shown graphically in Figures 1 and 2.

Measured and calculated reaction rate profiles generated for the two source rocks at the four different heating rates used are given in Appendix A to show the level of goodness of the curve fits obtained. The contents of the original computational output files generated by the KINETICS© program are included for reference purposes in Appendix B.

Table 1

BURONG-1 3777 ft SWC

(TOC = 4.05%, %R_v = 0.38)

Frequency factor A = 1.06 x 10^{13} s^{-1}

Percent of reaction	Activation energy E_a (kcal mol^{-1})
0.00	43
0.00	44
0.00	45
0.00	46
0.00	47
0.00	48
0.00	49
73.05	50
4.16	51
19.58	52
0.00	53
1.12	54
0.04	55
0.00	56
0.00	57
2.05	58

Figure 1

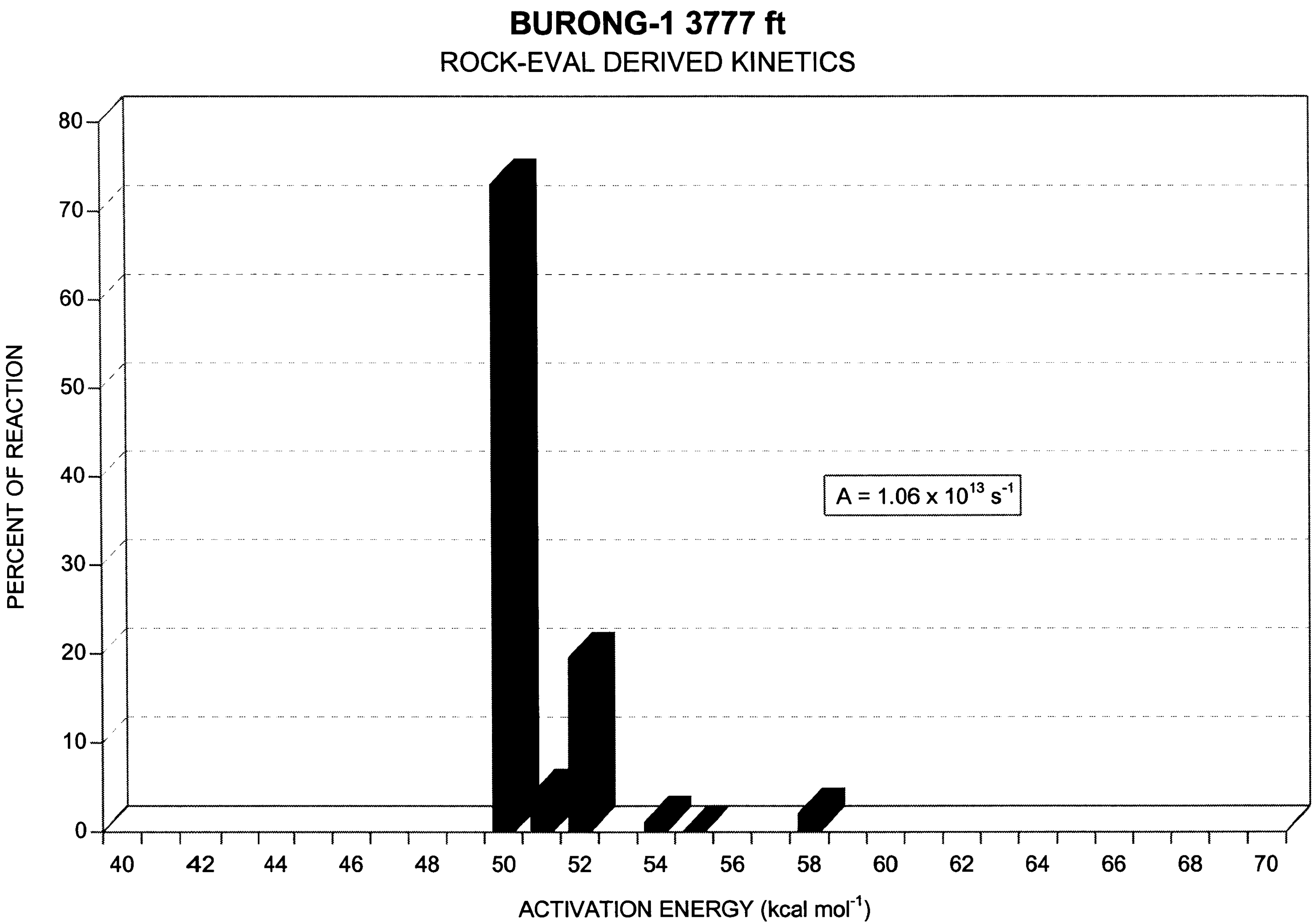

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Table 2

NORTH SEASPRAY-1 3213 ft CORE

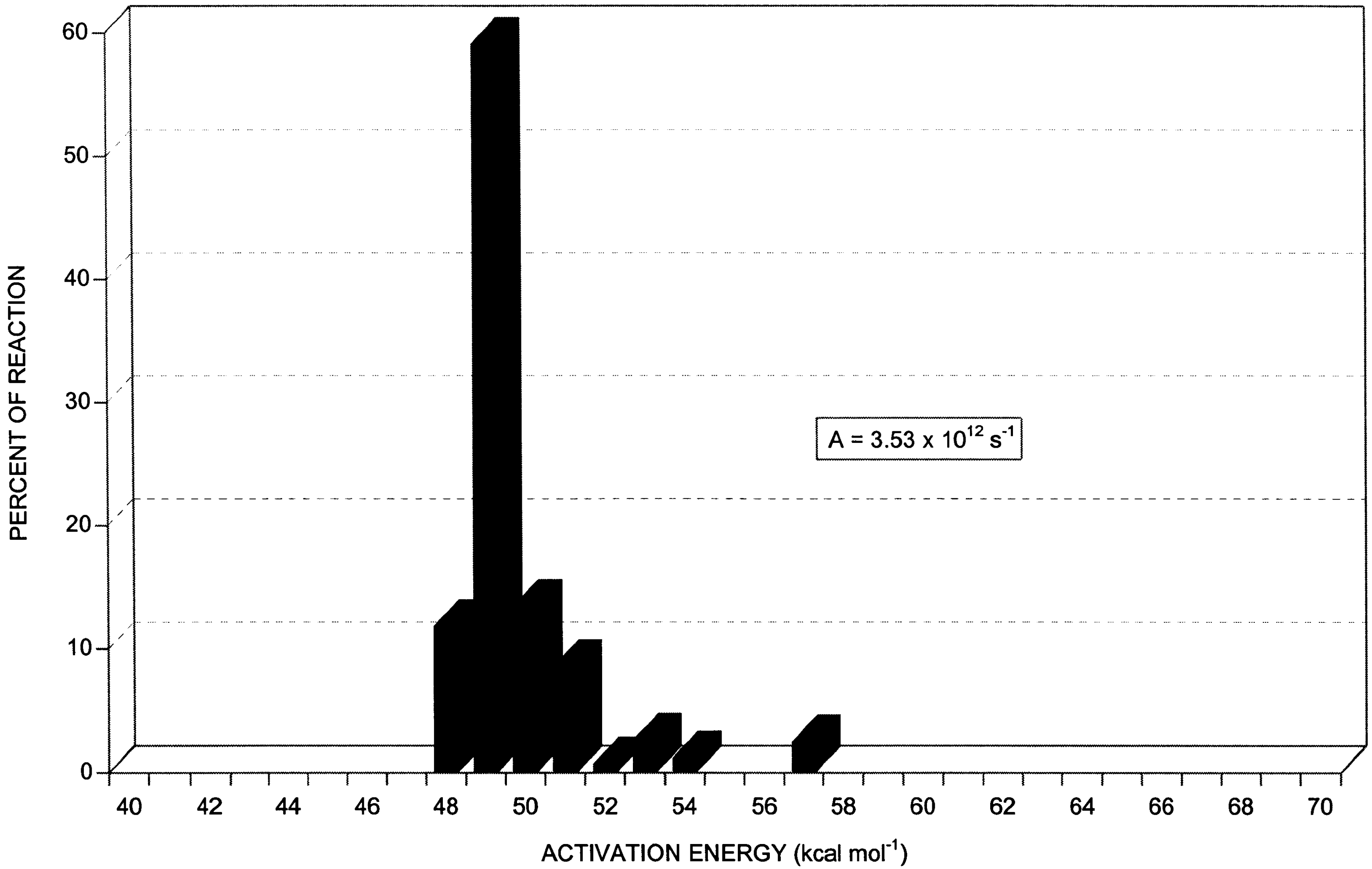
(TOC = 5.94%, %R_v = 0.39)

Frequency factor A = 3.53 x 10^{12} s^{-1}

Percent of reaction	Activation energy E_a (kcal mol^{-1})
0.00	42
0.00	43
0.00	44
0.00	45
0.00	46
0.00	47
11.83	48
59.10	49
13.44	50
8.59	51
0.71	52
2.63	53
1.19	54
0.00	55
0.00	56
2.51	57

Figure 2

NORTH SEASPRAY-1 3213 ft
ROCK-EVAL DERIVED KINETICS



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4. INTERPRETATION

Burong-1 3777 ft SWC

The activation energy distribution is dominated by contributions at E_a = 50 kcal mol^{-1} (73.0%) and, to a lesser extent, at E_a = 52 kcal mol^{-1} (19.6%). The geochemical study prepared by Geotechnical Services Pty Ltd for Energy and Minerals Victoria in March 1997 indicated that this sample was a shaly coal or related lithotype. The relatively low E_a values obtained, coupled with the narrow spread of the distribution, suggest that the kinetic behaviour of the source rock is primarily influenced by the liptinite component of the sample. Oil generation for this source rock will commence at relatively low levels of thermal maturity.

North Seaspray-1 3213 ft core

This sample was taken from an interval comprised of argillaceous siltstone with sandy lenses, interbedded with thin coal laminae. The low principal activation energy value of 49 kcal mol^{-1} (59.1%) is atypical of data reported for most coals and indicates that the kinetic character of the sample is largely governed by the more thermally labile organic component of the rock. Oil generation is expected to occur at relatively low sediment maturities.

5. BIBLIOGRAPHY

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Tissot B. P., Pelet R. and Ungerer P. (1987) Thermal history of sedimentary basins, maturation indices, and kinetics of oil and gas generation. *Am. Assoc. Petrol. Geol. Bull.* **12**, 1445-1466.

APPENDIX A

REACTION RATE PLOTS

Figure A1

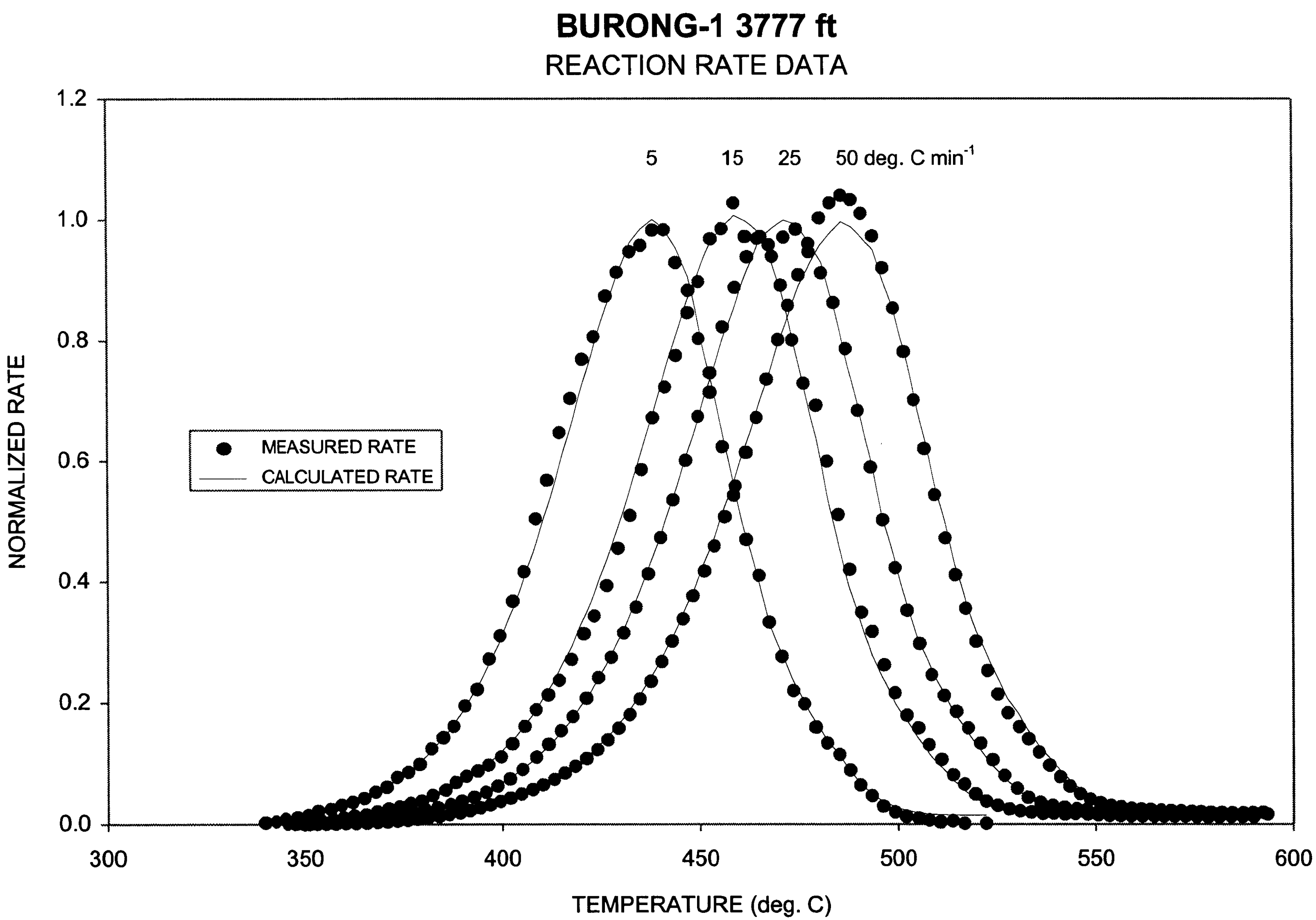

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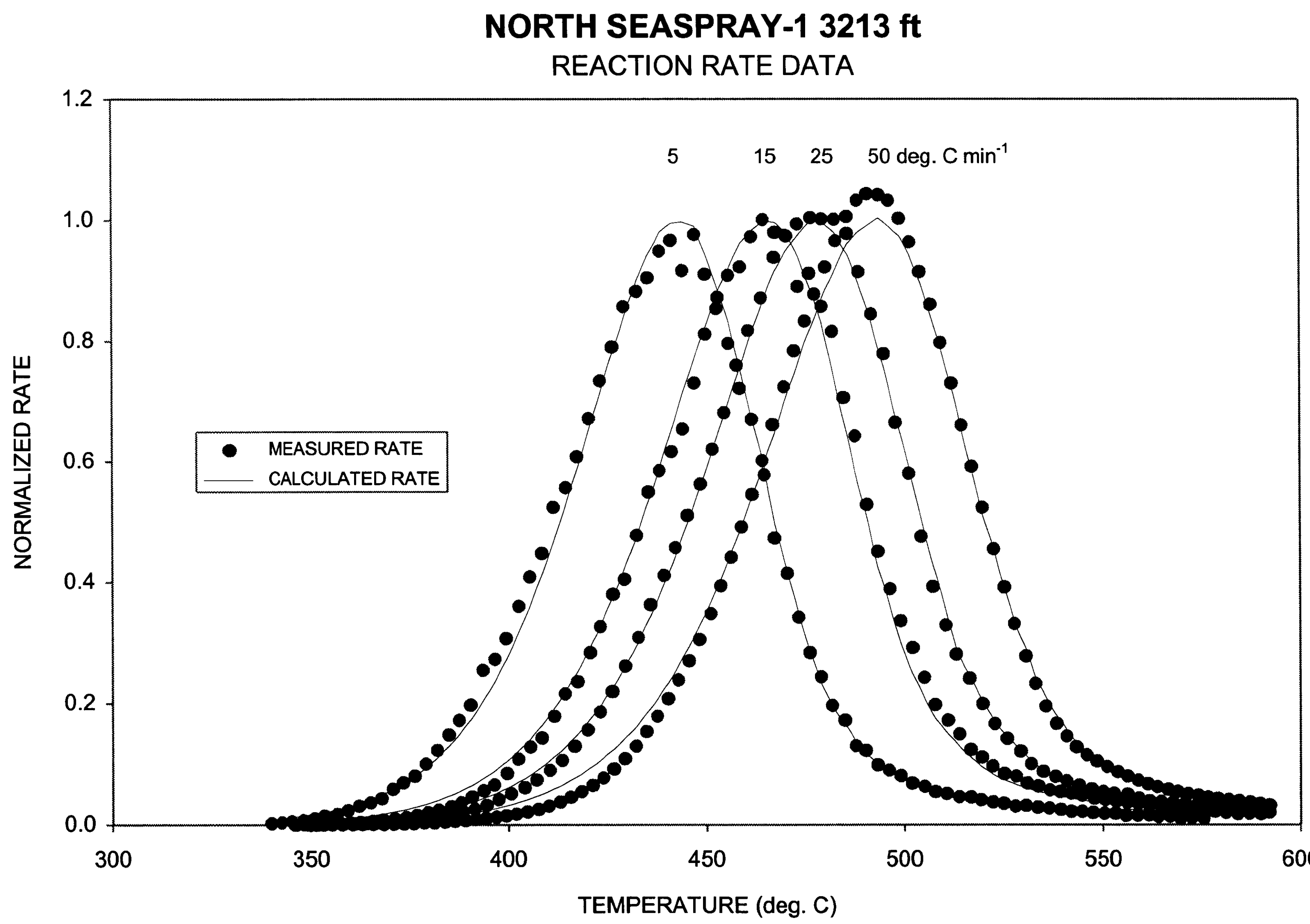
Figure A2



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APPENDIX B

OUTPUT FILES

BURONG-1 3777ft SWC

Code Version: 2.43   Output File: BURONGA.OUT

Data file	Number of data (total)	(used)	Group weight
A05BURD1.LLL	63	63	1.0000E+00
A15BURH1.LLL	86	86	1.0000E+00
A25BURF1.LLL	81	81	1.0000E+00
A50BURI1.LLL	94	94	1.0000E+00

Title line of data files:

A05BURD1

A15BURH1

A25BURF1

A50BURI1

Friedman-type analysis at fraction reacted = x
(Valid only if data extend to nearly complete reaction)

x	ln[A(1-x)^n]	A(for n=1) (s^-1)	E (cal/mol)	E std.err. (cal/mol)
.1	2.8953E+01	4.167E+12	49067.	1741.
.2	2.7655E+01	1.280E+12	47382.	2002.
.3	2.8567E+01	3.644E+12	48871.	2051.
.4	2.9084E+01	7.130E+12	49869.	1655.
.5	2.9352E+01	1.118E+13	50615.	1923.
.6	2.8973E+01	9.569E+12	50490.	2766.
.7	2.8789E+01	1.061E+13	50814.	3017.
.8	2.8047E+01	7.583E+12	50614.	3204.
.9	2.5131E+01	8.212E+11	47912.	6239.

Mean approximate A and E over fraction-reacted interval from 0 to x
(Valid only if data extend to nearly complete reaction)

x	A (s^-1)	E (cal/mol)	E std.err. (cal/mol)
.1	1.0962E+14	49340.	782.
.2	2.3938E+13	48769.	1489.
.3	8.6780E+12	48398.	1538.
.4	5.7822E+12	48710.	1583.
.5	5.0044E+12	49345.	1545.
.6	3.4400E+12	49680.	1721.
.7	2.1883E+12	50003.	2009.
.8	9.5732E+11	50010.	2662.
.9	3.1486E+11	50277.	3156.

Interpolation from parabolic fit of Tmax vs. log(Heating rate):
Tmax = 470.02 C at Heating rate = 25 C/min

Interpolation from linear fit of FWHH vs. log(Heating rate):
FWHH = 54.02 C at Heating rate = 25 C/min

Interpolation from linear fit of Asymmetry vs. log(Heating rate):
Asymmetry = .814 at Heating rate = 25 C/min

Approximate fit of disk data to a single first-order reaction:

Data	Heating rate (C/min)	Tmax (C)	Exp.FWHH (C)	Cal.FWHH (C)	Exp./Calc.	Asymmetry
1	4.9150E+00	437.45	52.83	47.47	1.11285	.8449
2	1.4643E+01	459.90	53.36	50.32	1.06036	.8267
3	2.6728E+01	470.91	55.85	52.00	1.07408	.8354
4	5.3182E+01	486.11	53.31	54.03	.98680	.7797

A(s^-1) = 9.0060E+12
E(cal/mol) = 4.9971E+04 (std. err. = 1.046E+03)
S(%E) = 8.8532E-01
n(order) = 1.0000e+00

Fitting method: Discrete (option 1)
Least squares of: Relative Rates
Error tolerance for initial search: 1.0000E-01
Error tolerance for final convergence: 1.0000E-02
Thermal history: Constant heating rate (max. rel. std. dev. = 1.212E-03)

Initial minimum frequency factor(s^-1): 9.0060E+11
Initial maximum frequency factor(s^-1): 9.0060E+13

Results

Frequency factor = 1.0615E+13 s^-1

Percent	Activation energy (cal/mol)
.00	43000.
.00	44000.
.00	45000.
.00	46000.
.00	47000.
.00	48000.
.00	49000.
73.04	50000.
4.16	51000.
19.58	52000.
.00	53000.
1.12	54000.
.04	55000.
.00	56000.
.00	57000.
2.05	58000.

Least squares exit: successful completion
Sum of squares of weighted normalized rate residuals: 7.1905E-02
Sum of squares of weighted integrated rate residuals: 8.5992E-03

NORTH SEASPRAY-1 3213ft CORE

Code Version: 2.43 Output File: NSEASPRA.OUT

Data file	Number of data (total)	(used)	Group weight
A05NSSA1.LLL	86	86	1.0000E+00
A15NSSD1.LLL	86	86	1.0000E+00
A25NSSB1.LLL	81	81	1.0000E+00
A50NSSB1.LLL	94	94	1.0000E+00

Title line of data files:

A05NSSA1

A15NSSD1

A25NSSB1

A50NSSB1

Friedman-type analysis at fraction reacted = x
(Valid only if data extend to nearly complete reaction)

x	ln[A(1-x)^n]	A(for n=1) (s^-1)	E (cal/mol)	E std.err. (cal/mol)
.1	2.6324E+01	3.006E+11	45677.	1228.
.2	2.7838E+01	1.538E+12	48027.	1655.
.3	2.8233E+01	2.607E+12	48828.	1524.
.4	2.8818E+01	5.459E+12	49997.	1792.
.5	2.8879E+01	6.964E+12	50456.	1593.
.6	2.8814E+01	8.159E+12	50847.	2465.
.7	2.9082E+01	1.422E+13	51895.	2396.
.8	2.8898E+01	1.776E+13	52597.	2528.
.9	3.0835E+01	2.463E+14	57701.	4118.

Mean approximate A and E over fraction-reacted interval from 0 to x
(Valid only if data extend to nearly complete reaction)

x	A (s^-1)	E (cal/mol)	E std.err. (cal/mol)
.1	1.0400E+12	43428.	1488.
.2	1.2093E+12	45001.	1393.
.3	1.3784E+12	46202.	1540.
.4	1.5005E+12	47215.	1505.
.5	1.5415E+12	48111.	1647.
.6	1.5147E+12	48982.	1735.
.7	1.0610E+12	49460.	2231.
.8	1.0426E+12	50693.	2102.
.9	1.1773E+12	52946.	2830.

Interpolation from parabolic fit of Tmax vs. log(Heating rate):
Tmax = 475.89 C at Heating rate = 25 C/min

Interpolation from linear fit of FWHH vs. log(Heating rate):
FWHH = 58.74 C at Heating rate = 25 C/min

Interpolation from linear fit of Asymmetry vs. log(Heating rate):
Asymmetry = .867 at Heating rate = 25 C/min

Approximate fit of disk data to a single first-order reaction:

Data	Heating rate (C/min)	Tmax (C)	Exp.FWHH (C)	Cal.FWHH (C)	Exp./Calc.	Asymmetry
1	4.9026E+00	441.89	57.61	49.50	1.16369	.8250
2	1.4606E+01	464.65	59.03	52.59	1.12244	.9035
3	2.6665E+01	477.65	58.35	54.41	1.07249	.8333
4	5.2976E+01	492.29	59.19	56.60	1.04578	.8836

A(s^-1) = 2.3691E+12
E(cal/mol) = 4.8499E+04 (std. err. = 5.143E+02)
S(%E) = 1.3361E+00
n(order) = 1.0000e+00

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Fitting method: Discrete (option 1)
Least squares of: Relative Rates
Error tolerance for initial search: 1.0000E-01
Error tolerance for final convergence: 1.0000E-02
Thermal history: Constant heating rate (max. rel. std. dev. = 1.202E-03)

Initial minimum frequency factor(s^-1): 2.3691E+11
Initial maximum frequency factor(s^-1): 2.3691E+13

Results

Frequency factor = 3.5275E+12 s^-1

Percent	Activation energy (cal/mol)
.00	42000.
.00	43000.
.00	44000.
.00	45000.
.00	46000.
.00	47000.
11.83	48000.
59.10	49000.
13.44	50000.
8.59	51000.
.71	52000.
2.63	53000.
1.19	54000.
.00	55000.
.00	56000.
2.51	57000.

Least squares exit: successful completion
Sum of squares of weighted normalized rate residuals: 1.2533E-01
Sum of squares of weighted integrated rate residuals: 3.0579E-02