



BCURA Contract B56

Advanced Characterisation of Industrially-Important Coal-Based Carbons

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Coal Characterisation: Why?

- **Problems in coal – firing industries**
- **Comparing coals and coal blends**
- **Furnaces design**
- **Fuel utilisation efficiency**
- **Operating conditions setting**
- **Combustion modelling**



Aims & Objectives

- Adequate coal characterisation is essential, and current techniques are either not reliable or too time-consuming. Thermogravimetric analysis (TGA) is the simplest tool for measuring intrinsic char reactivity, yet there are inherent problems associated with this technique.
- Main aim is to develop a **new thermogravimetric analysis** method to determine the **oxidation reactivity of carbons** in or derived from coal. The new method is expected to be **quicker** and **more reliable** than existing methods for characterising reactivity.
- This may be **useful** for **characterising, comparing, predicting,** and **understanding** the **performance** of existing and new coals and coal blends in important industrial processes such as pulverised-fuel combustion and steel-making.

Presentation Outline

- • **Coal samples**
- **Thermogravimetric analysis**
- **Novel TGA method 1**
- **Novel TGA method 2**
- **Analyses comparison**
- **Conclusions & Future work**

Coal samples: *Proximate analysis*

Coal sample	Volatile matter (wt %) [dry basis]	Fixed carbon (wt %) [dry basis]	Ash content (wt %) [dry basis]
<i>BPL granules</i>	0.0	91.8	8.2
<i>BPL crushed</i>	0.0	91.8	8.2
<i>Pha Lai</i>	6.1	62.5	31.5
<i>Heze coal</i>	10.1	58.2	31.7
<i>Chang Cun</i>	12.2	70.8	17.0
<i>Kellingley</i>	31.4	51.1	17.5
<i>Columbian raw coal</i>	34.8	54.0	11.2
<i>Power River Basin (PRB)</i>	43.6	49.2	7.2
<i>EC 2106</i>	17.2	76.9	5.9
<i>EC 2038</i>	27	62.6	10.4

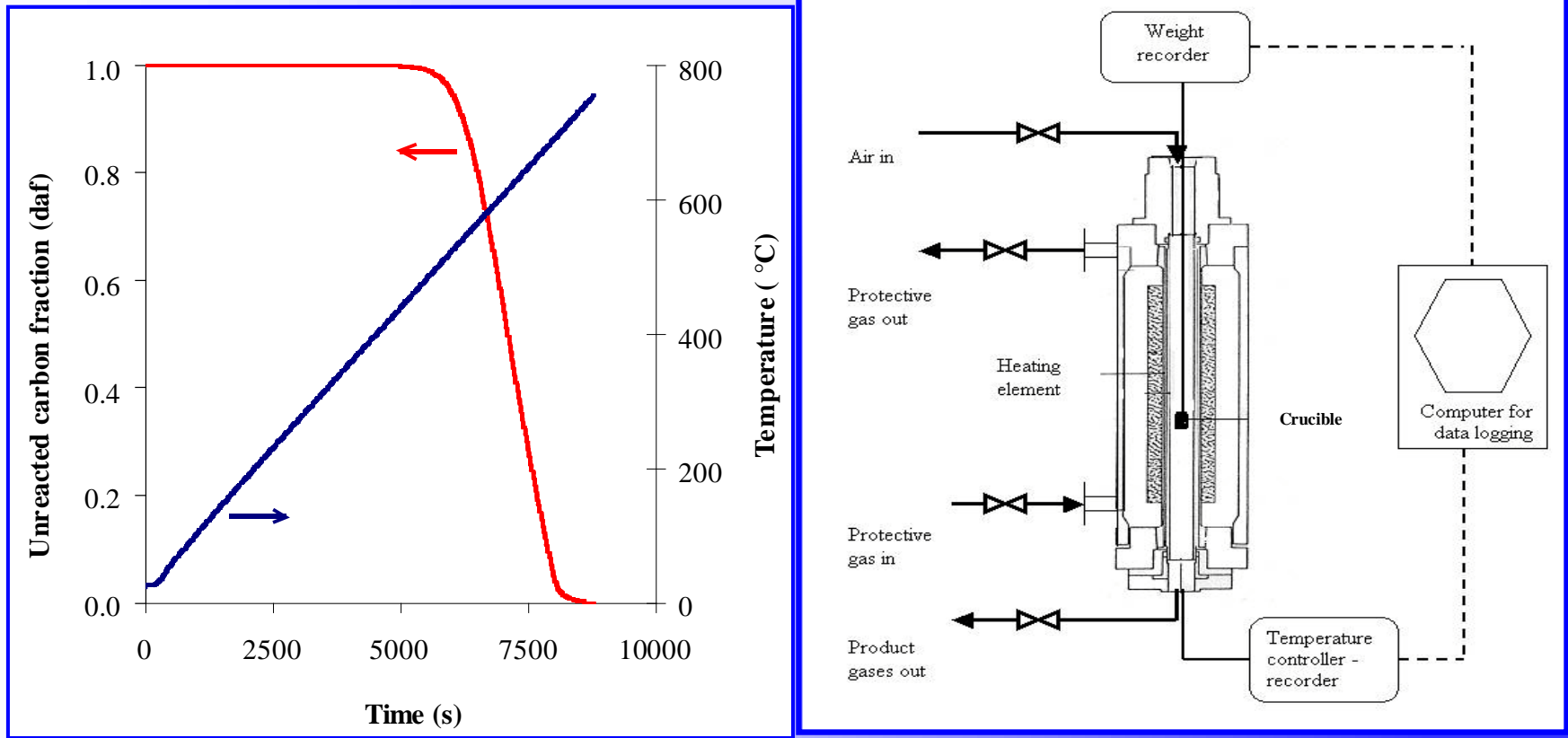
Coal samples: *Char properties*

Coal sample	Origin	Surface area (m ² / g)	Particle size (μm)
<i>BPL granules</i>	USA	1074	1, 000 - 4, 000
<i>BPL crushed</i>	USA	1071	1 - 50
<i>Pha Lai</i>	Vietnam	35	1 - 50
<i>Heze coal</i>	China	94	1 - 50
<i>Chang Cun</i>	China	105	1 - 50
<i>Kellingley</i>	UK	148	1 - 50
<i>Columbian raw coal</i>	Columbia	252	1 - 50
<i>Power River Basin (PRB)</i>	USA	265	1 - 50
<i>EC 2106</i>	Australia	7	500 - 1, 000
<i>EC 2038</i>	USA	29	500 - 1, 000

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Thermogravimetric Analysis



Thermogravimetric Analysis

- **Kinetic model:**

$$\frac{d\alpha}{dt} = k(1 - \alpha)$$

- **Intrinsic rate constant k:**

$$k = A \exp\left(-\frac{E}{RT}\right)$$

- **Constant rate of heating:**

$$\beta = \frac{dT}{dt}$$

- **Kinetic model equation:**

$$-\ln(1 - \alpha) = \frac{A}{\beta} f\left(\frac{E}{RT}\right)$$

a = fractional carbon conversion (daf)

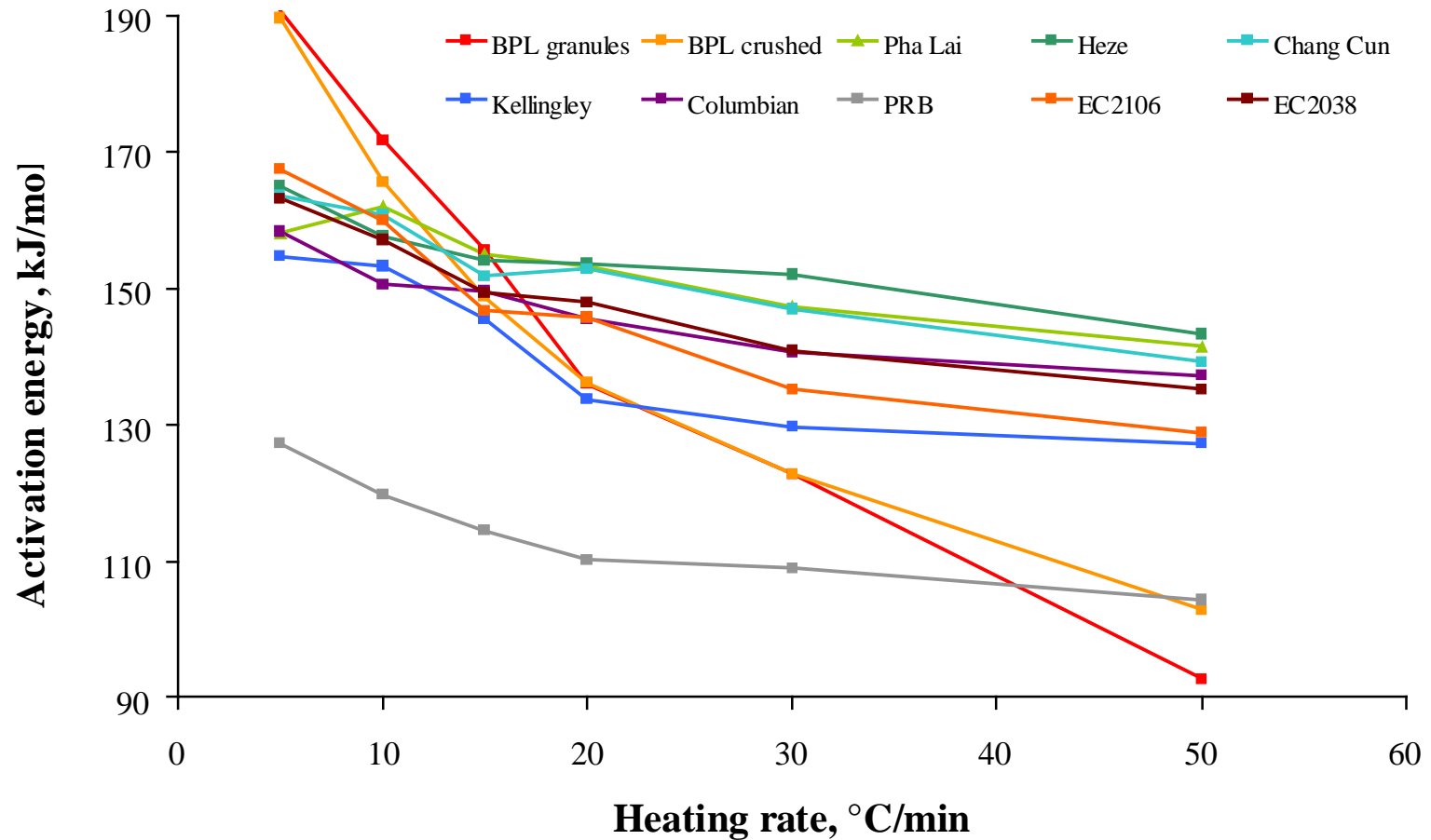
E = activation energy, kJ/mol

T = absolute temperature, K

R = universal gas constant, kJ/mol/K

**Dependent on
the heating rate**

Thermogravimetric Analysis



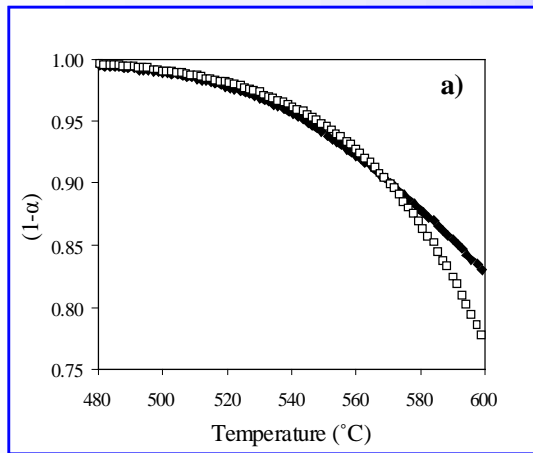
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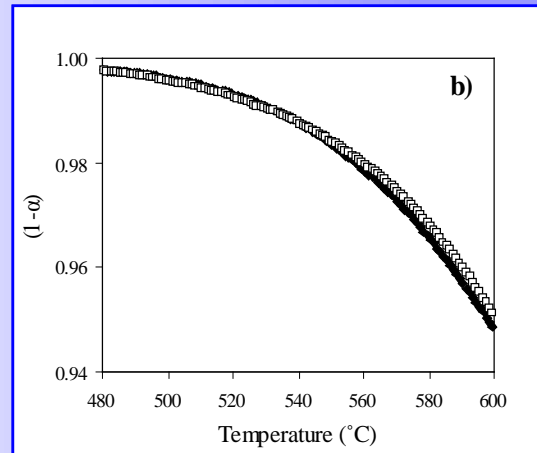
Novel TGA method 1:

Optimum-heating rate

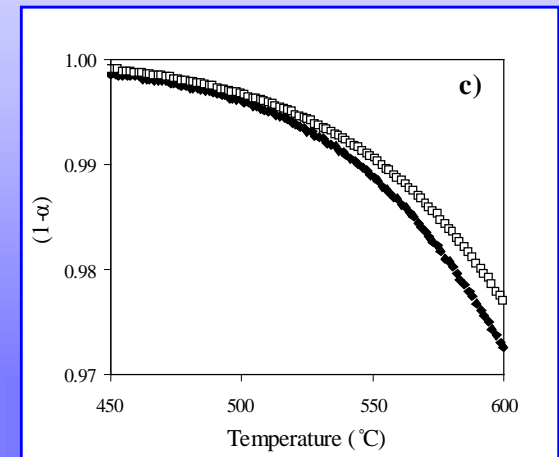
Comparison of experimental (?) and simulated (|) weight loss profile for the air oxidation of BPL granules at various heating rates.



10 °C/min



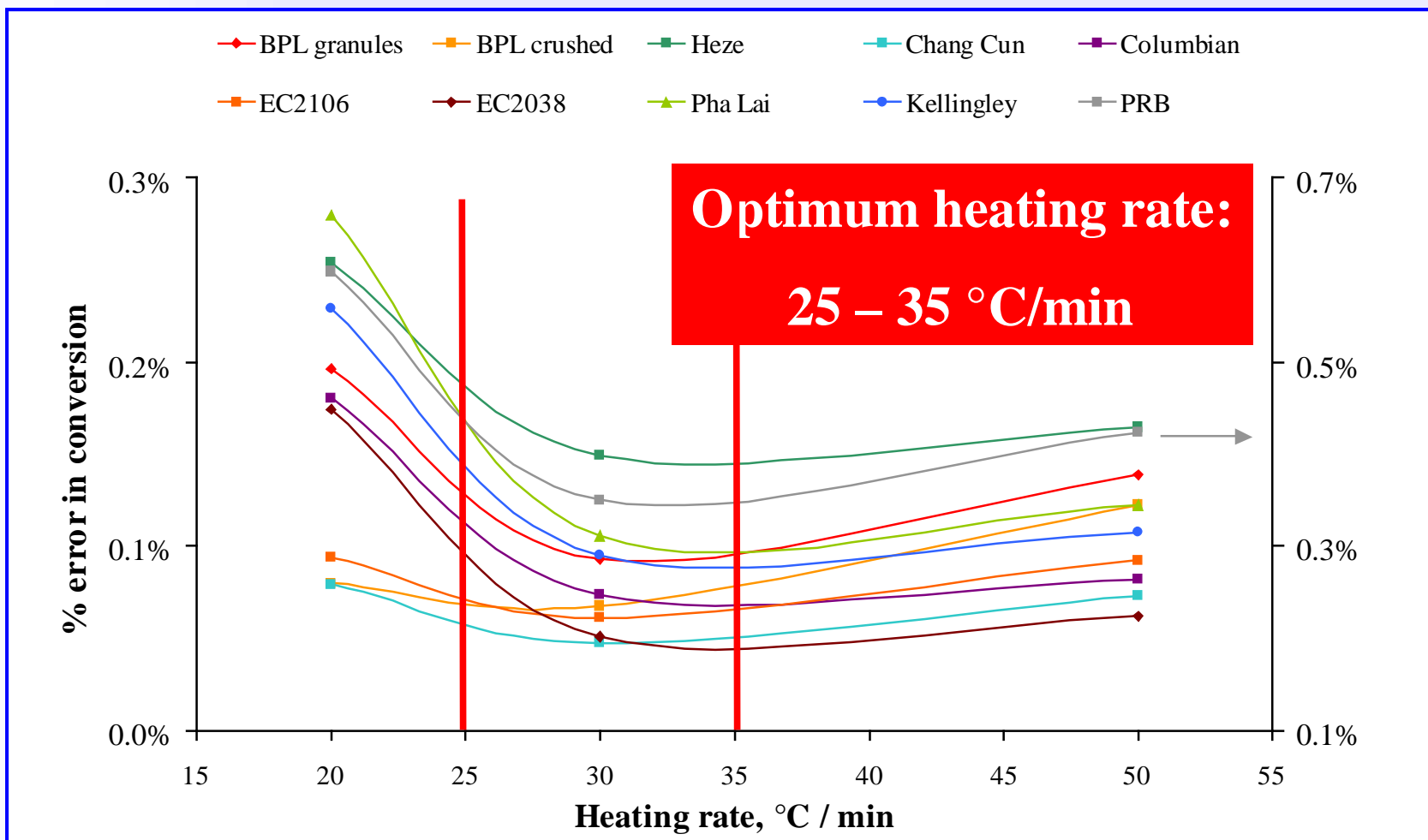
30 °C/min



50 °C/min

Novel TGA method 1:

Optimum-heating rate



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Novel TGA method 2:

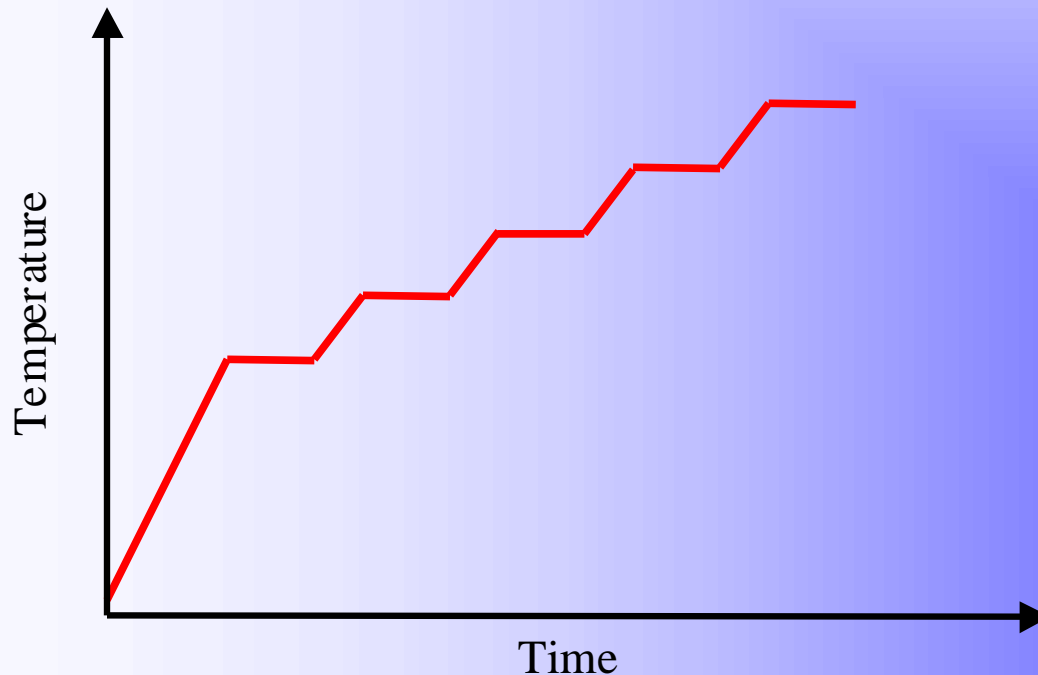
Step-ramp oxidation

- **Kinetic model:**

$$\frac{d\alpha}{dt} = k(1 - \alpha)$$

- **Linear model equation:**

$$-\ln(1 - \alpha) = kt$$

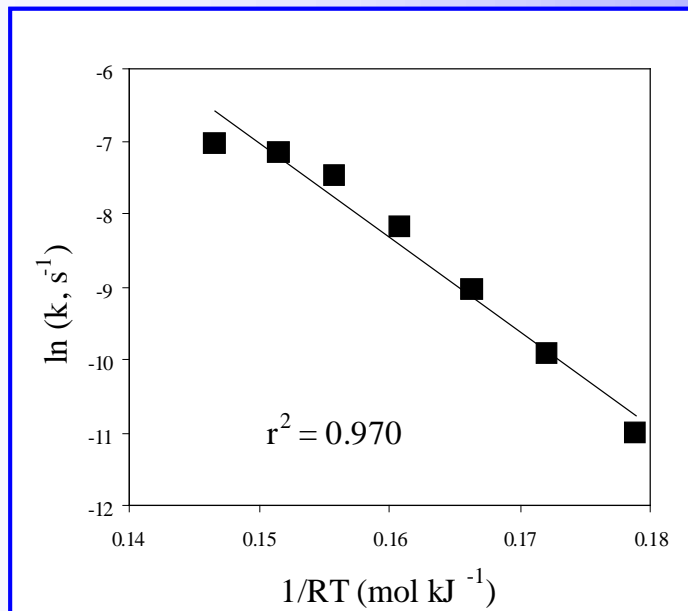


Novel TGA method 2:

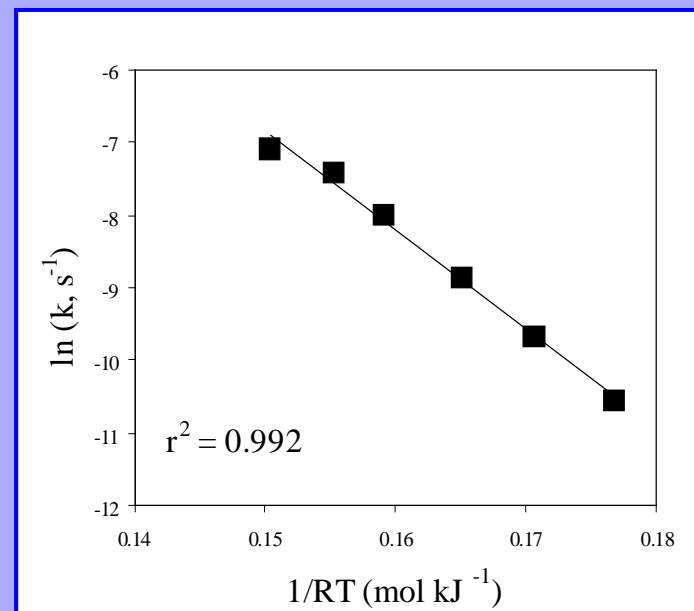
Step-ramp oxidation

Arrhenius Plots: step ramp oxidation processes in air of Kellingley char


Overall weight loss ~25 wt %



Overall weight loss ~10 wt %



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Analysis Comparison

<i>Coal sample</i>	<i>Activation energy values, kJ / mol</i>		
	Isothermal analysis	Optimum heating-rate analysis	Step-ramp analysis
<i>BPL granules</i>	123 ± 11	122 ± 7	127 ± 4
<i>BPL crushed</i>	123 ± 24	124 ± 6	125 ± 7
<i>Pha Lai</i>	162 ± 4	157 ± 2	161 ± 4
<i>Heze coal</i>	145 ± 6	152 ± 2	152 ± 3
<i>Chang Cun</i>	153 ± 6	147 ± 2	148 ± 2
<i>Kellingley</i>	140 ± 3	142 ± 2	143 ± 4
<i>Columbian raw coal</i>	138 ± 11	138 ± 3	140 ± 1
<i>Power River Basin (PRB)</i>	105 ± 12	109 ± 1	111 ± 4
<i>EC 2038</i>	158 ± 14	161 ± 5	160 ± 3
<i>EC 2106</i>	152 ± 11	151 ± 1	150 ± 6

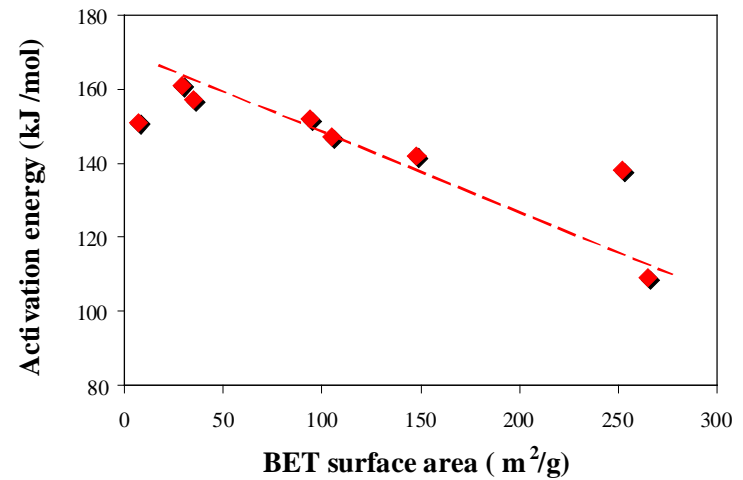
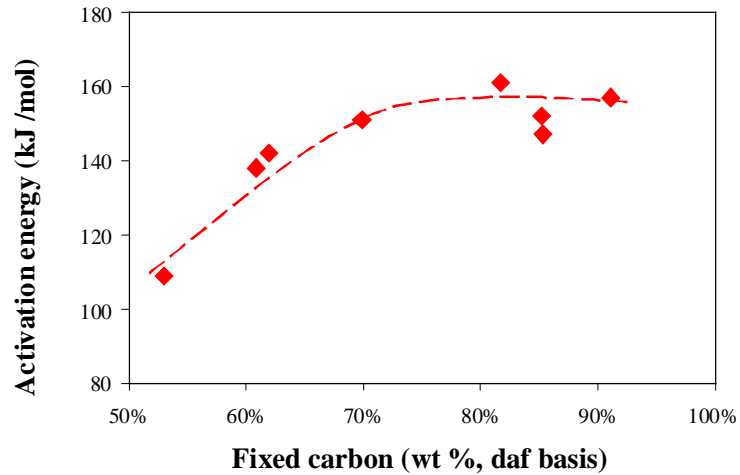
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Conclusions & Future work:

Reactivity and material structure



Conclusions & Future work

- **The novel TGA techniques have successfully been implemented.**
- **Methods are new and original**
- **High degree of accuracy**
- **No heating rate effect**
- **Single experimental run**
- **Need to correlate reactivity data with char properties**
- **Need to correlate with industrial process performance**

References

- **Sima-Ella, E., Mays, T. (2005). J. Therm. Anal. Cal, 80: 109**
- **Sima-Ella, E., Yuan, G. and Mays, T. (2005). Fuel, 84: 1920**
- **Smith, I.W. (1978). Fuel, 57: 409**
- **Sorensen, T.O. (1999). J. Therm. Anal. Cal., 56: 17**