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## APPENDICES

### APPENDIX A

Highveld coal samples before and after chemical fractionation method

**Table A1:** Ultimate analyses (dry ash-free basis, %) of Highveld coal samples before and after sequential leaching with water, ammonium acetate and hydrochloric acid

Lixiviants	Samples	Carbon	Hydrogen	Nitrogen	Sulphur	Oxygen
H <sub>2</sub> O	HUC1	56.35	2.93	1.42	1.03	9.78
	HUC2	52.29	2.60	1.34	1.41	8.56
	HLC1	56.76	2.80	1.42	0.94	9.98
	HLC2	53.59	2.53	1.39	1.17	8.62
NH <sub>4</sub> OAc	HLC1	58.52	2.91	1.87	0.96	9.44
	HLC2	54.63	2.64	1.73	1.15	9.25
HCl	HLC1	58.16	2.93	1.69	0.96	11.66
	HLC2	55.28	2.60	1.57	1.02	10.42

**Table A2:** Inorganic oxide percentages from ICP-OES analysis of LTA samples of Highveld feed coal sample 1 (wt %)

	WL		AAL	HCIL
	HUC1	HLC1	HLC1	HLC1
	%	%	%	%
SiO <sub>2</sub>	51.09	50.88	58.35	57.21
Al <sub>2</sub> O <sub>3</sub>	22.98	23.16	26.63	28.87
Fe <sub>2</sub> O <sub>3</sub>	5.23	4.86	5.21	3.60
TiO <sub>2</sub>	1.37	1.37	1.57	1.72
P <sub>2</sub> O <sub>5</sub>	0.24	0.28	0.30	0.22
SrO	0.19	0.20	0.12	0.16
BaO	0.14	0.15	0.16	0.28
CaO	5.24	5.60	0.50	0.30
MgO	1.81	1.99	0.33	0.27
Na <sub>2</sub> O	0.38	0.21	0.07	0.09
K <sub>2</sub> O	0.51	0.51	0.55	0.27
SO <sub>3</sub>	4.20	3.78	0.30	0.21

**Table A3:** Inorganic oxide percentages from ICP-OES analysis of LTA samples of Highveld coal sample 2 (wt %)

	<b>HUC2</b>	<b>WL</b>	<b>AAL</b>	<b>HCIL</b>
	<b>%</b>	<b>HLC2</b>	<b>HLC2</b>	<b>HLC2</b>
SiO <sub>2</sub>	43.30	43.26	52.77	60.92
Al <sub>2</sub> O <sub>3</sub>	24.24	23.80	28.81	25.73
Fe <sub>2</sub> O <sub>3</sub>	3.99	3.92	4.55	4.31
TiO <sub>2</sub>	1.28	1.28	1.55	1.66
P <sub>2</sub> O <sub>5</sub>	0.80	0.77	0.96	0.05
SrO	0.43	0.42	0.36	0.06
BaO	0.28	0.28	0.33	0.09
CaO	9.10	9.10	1.98	0.15
MgO	2.59	2.57	0.82	0.23
Na <sub>2</sub> O	0.47	0.34	0.12	0.07
K <sub>2</sub> O	0.65	0.66	0.75	0.52
SO <sub>3</sub>	5.25	3.56	1.01	0.10

## APPENDIX B

### Ash samples from gasifier

**Table B1:** Mass percentages of phases in ash and clinker (determined by CCSEM)

Phase	Description	Ash	Clinker
Interstitial and matrix glass	Ca- and Fe-bearing aluminosilicate glass with trace concentrations of Mg, K, P and Ti	40.6	34.5
K-bearing Al-silicate	K-bearing Al-silicate glass with Al/Si ratio similar to microcline and muscovite	4.3	5.1
Anorthite	Anorthite ( $\text{CaAl}_2\text{Si}_2\text{O}_8$ )	10.1	19.0
Mullite	$\text{Al}_6\text{Si}_2\text{O}_{13}$	1.5	0.7
Quartz	Unaltered quartz grains	9.2	9.6
Al-silicate	“Honeycomb” Al-silicate with trace K and Fe. (Transformation product of kaolinite)	21.9	19.2
Qtz60Kao40	Fine mixture of quartz and Al-silicate	4.5	4.6
Qtz80Kao20	Fine mixture of quartz and Al-silicate	2.0	2.2
Pyrrhotite/Fe-S-O/ Fe-oxide	Transformation product of extraneous pyrite	2.2	1.4
Carbonate/CaMgOxide	Transformation product of extraneous carbonates and associated with char	2.1	2.6
Char	Uncombusted carbon	1.5	1.0
Other		0.1	0.1
Total		100.0	100.0

## APPENDIX C

Homogenised turn-out samples of coal and ash particles taken from the gasifier

**Table C1:** Proportions of high temperature transformation products of coal minerals formed at elevated temperatures and pressures during coal gasification (wt %) (determined by XRD)

Minerals identified	Sample 1T	Sample 8T	Sample 16T	Sample 24T	Sample 32T
Anorthite (Ca,Na)(Si,Al) <sub>2</sub> O <sub>6</sub>	18.1	7.7	1.8	0.4	n/d
α-Quartz α-SiO <sub>2</sub>	14.4	14.3	11.7	6.2	6.0
Mullite Al <sub>6</sub> Si <sub>2</sub> O <sub>13</sub>	11.8	5.3	2.4	3.9	n/d
Cristobalite SiO <sub>2</sub>	0.5	0.1	<0.1	n/d	n/d
Hematite α-Fe <sub>2</sub> O <sub>3</sub>	0.3	0.2	<0.1	n/d	n/d
Pyrrhotite Fe <sub>7</sub> S <sub>8</sub>	n/d	<0.1	0.4	n/d	n/d
Magnetite FeFe <sub>2</sub> O <sub>4</sub>	0.2	0.3	n/d	n/d	n/d
Diopside Ca(Mg,Al)(Si,Al) <sub>2</sub> O <sub>6</sub>	<0.1	0.7	1.0	0.2	n/d
Anhydrite CaSO <sub>4</sub>	0.2	0.1	0.4	n/d	n/d

**Note:**

Sample 1T = homogenised gasification ash exiting the gasifier.

Sample 8T = homogenised turn-out sample towards the bottom of the gasifier.

Sample 16T = homogenised sample taken from the centre of the gasifier

Sample 24T = homogenised sample taken from the top of the gasifier.

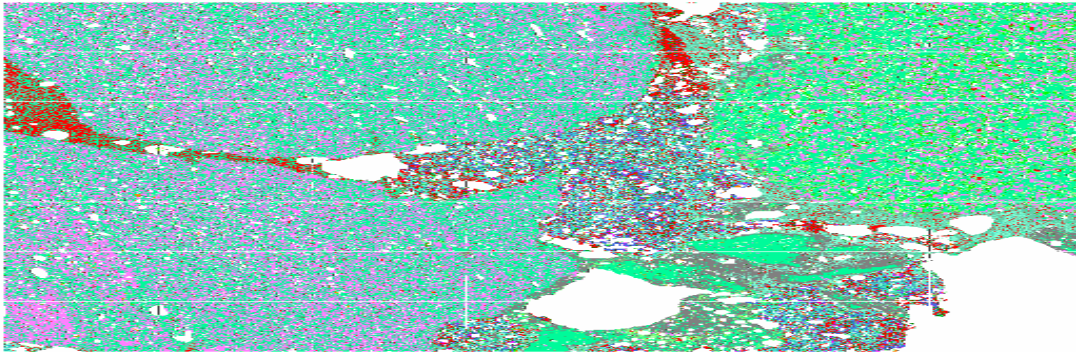
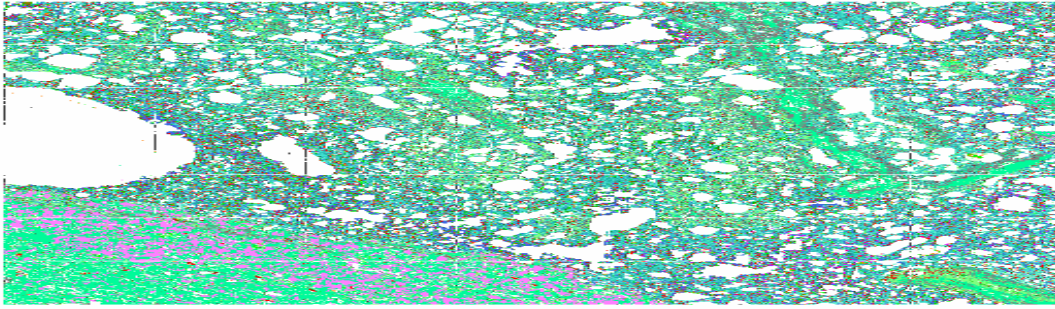
Sample 32T = Homogenised feed coal

**Table C2:** Proportions of coal minerals in the turn-out samples and feed coal determined by XRD (wt %)

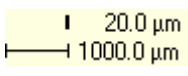
Minerals identified	Sample 1T	Sample 8T	Sample 16T	Sample 24T	Sample 32T
$\alpha$ -Quartz	14.4	14.3	11.7	6.2	6.0
$\alpha$ -SiO <sub>2</sub>					
Muscovite KAl <sub>2</sub> (Si <sub>3</sub> Al)O <sub>10</sub> (OH,F) <sub>2</sub>	0.8	0.8	<0.1	1.2	1.1
Kaolinite Al <sub>2</sub> Si <sub>5</sub> (OH) <sub>4</sub>	n/d	n/d	1.4	6.7	6.7
Calcite CaCO <sub>3</sub>	n/d	2.6	3.4	1.5	1.2
Aragonite CaCO <sub>3</sub>	n/d	n/d	n/d	1.0	1.2
Dolomite CaMg(CO <sub>3</sub> ) <sub>2</sub>	n/d	n/d	n/d	2.4	2.0
Pyrite FeS <sub>2</sub>	n/d	n/d	<0.1	0.2	0.4
Greigite Fe <sub>3</sub> S <sub>4</sub>	n/d	n/d	n/d	0.2	0.2
Rutile TiO <sub>2</sub>	n/d	0.3	0.1	0.2	0.3
Anatase TiO <sub>2</sub>	n/d	n/d	<0.1	n/d	n/d
Gorceixite BaAl <sub>3</sub> (PO <sub>4</sub> )PO <sub>3</sub> (OH)(OH) <sub>6</sub>	n/d	n/d	n/d	0.2	0.2
Non-crystalline content (mainly, glass and/or carbon)	53.3	67.5	76.9	75.7	80.7

**Table C3:** Mass-% phase proportions determined by CCSEM

Minerals and glasses	Sample 1T	Sample 8T	Sample 16T	Sample 24T	Sample 32T
Interstitial and matrix					
glass	30.3	25.4	14.9	6.7	4.2
Kaolinite(pyrite)	1.5	0.7	0.6	0.5	0.3
Kaolinite(carbonate, pyrite)	4.9	5.3	2.7	1.4	1.3
Kaolinite(carbonate)	21.8	18.0	10.6	4.3	2.3
Quartz(carbonate, pyrite)	1.1	0.4	0.4	0.1	0.1
Quartz(carbonate)	1.1	1.0	0.7	0.3	0.3
Glass-rock fragments	2.0	1.9	2.1	1.9	1.3
Orthoclase glass	1.2	1.0	0.9	0.9	0.8
Muscovite glass	0.8	0.9	1.2	1.0	0.5
Crystallites	6.1	9.4	5.2	2.6	0.5
Anorthite	5.4	8.3	4.2	1.3	0.3
Mullite	0.7	1.1	1.0	1.2	0.2
Rock fragments	58.6	60.9	72.5	82.0	80.9
Quartz	9.9	9.7	11.4	13.5	12.3
Metakaolinite	39.7	43.4	52.7	60.4	63.4
Qtz60Kao40	6.9	6.2	6.3	6.0	4.0
Qtz80Kao20	2.0	1.6	2.1	2.1	1.2
Extraneous	2.5	2.3	5.1	6.6	12.0
Pyrrhotite/ Fe-S-O/Fe-oxide	1.2	0.8	0.9	1.6	1.4
Carbonate/ CaMgOxide	1.4	1.6	4.2	5.0	10.6
Other	0.4	0.1	0.1	0.2	1.0
Total	100.0	100.0	100.0	100.0	100.0



**Figure C1:** Top image of clinker sample 4, showing siltstone fragment lower left with pink quartz and green clay (kaolinite) in a glassy matrix determined by QEMSCAN  
Bottom image of clinker sample 8T.

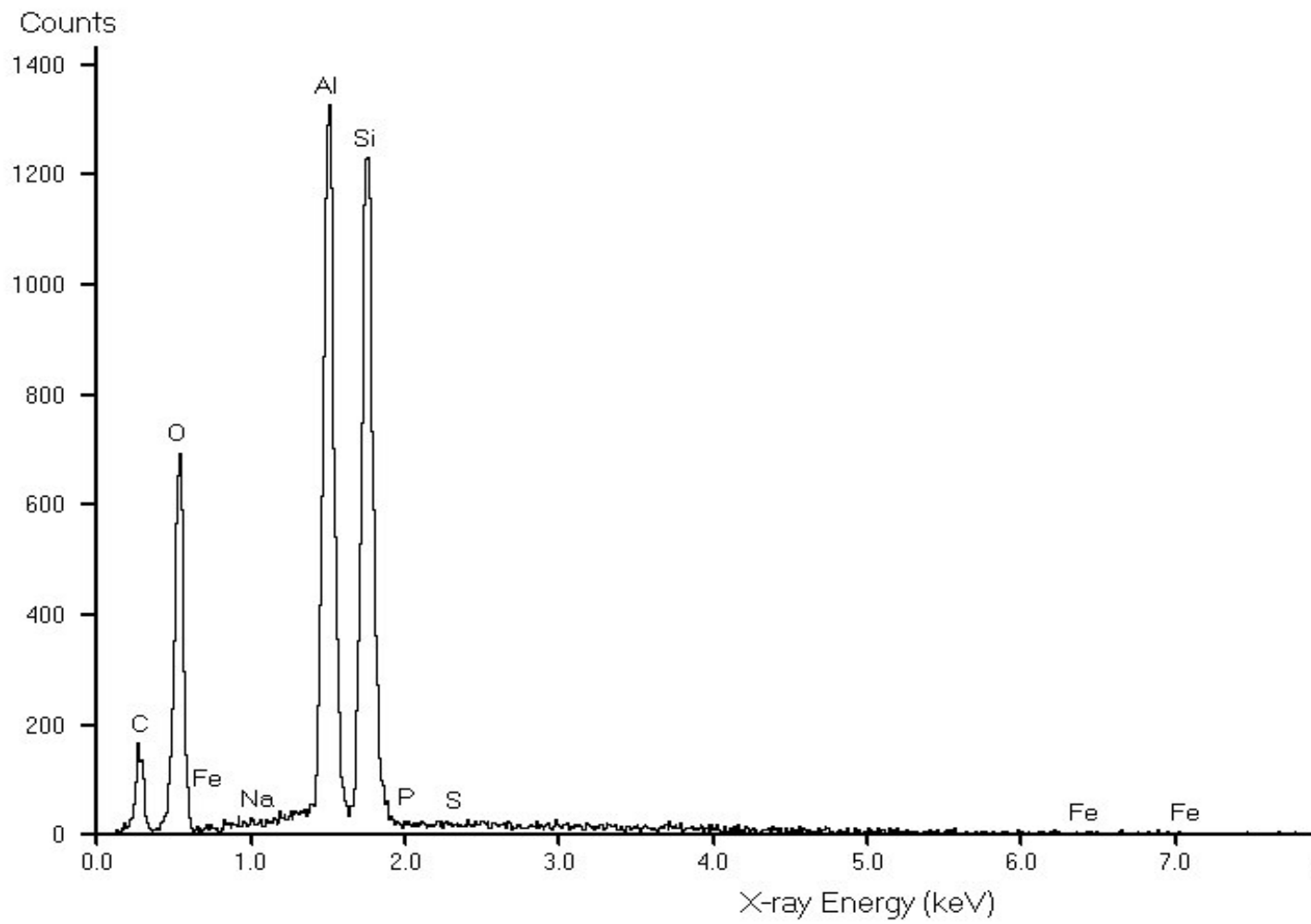
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## APPENDIX D

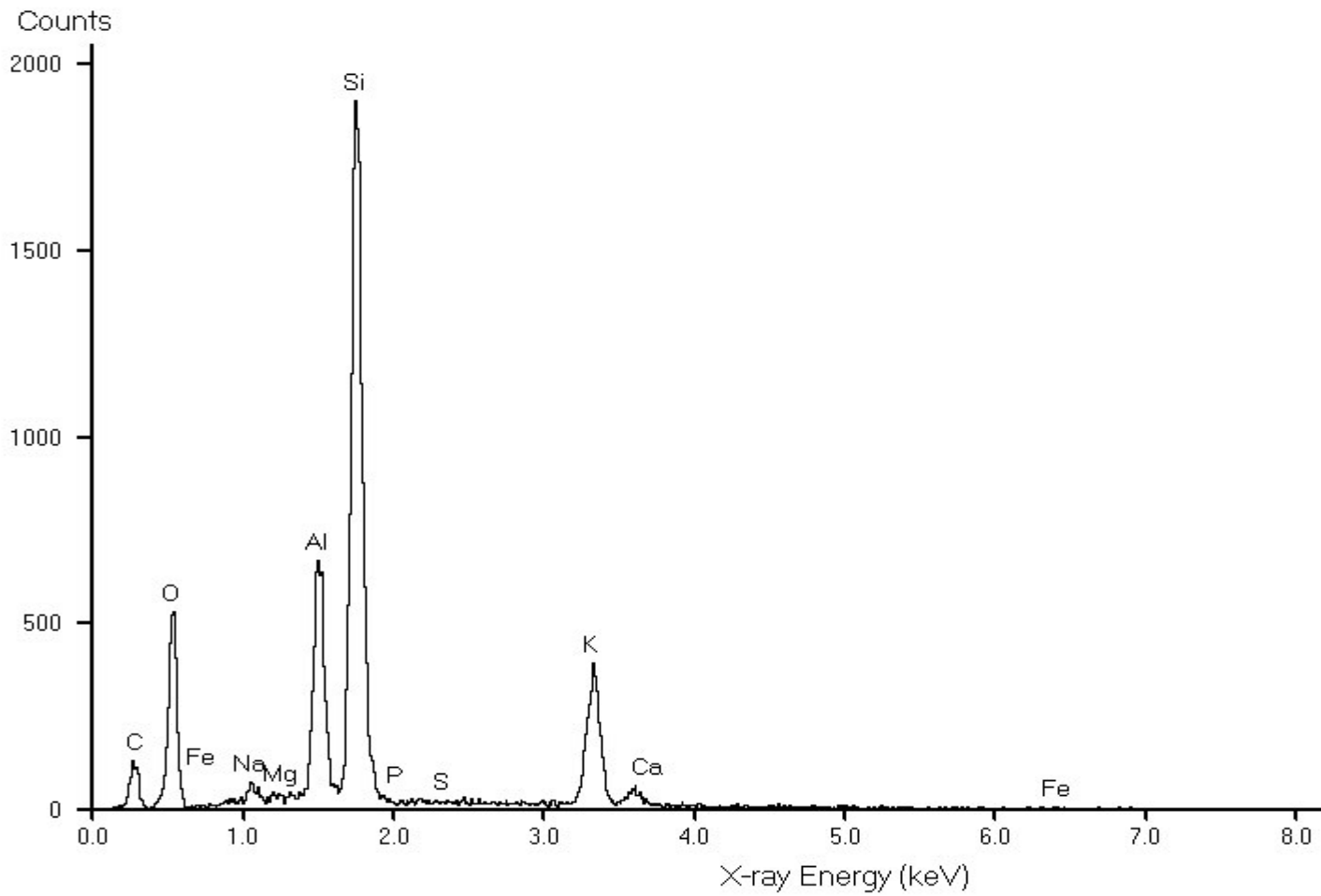
Homogenised dig-out samples of coal and ash taken from the gasifier

**Table D1:** XRD analysis of the dig-out samples taken from the different zones of the gasifier (%)

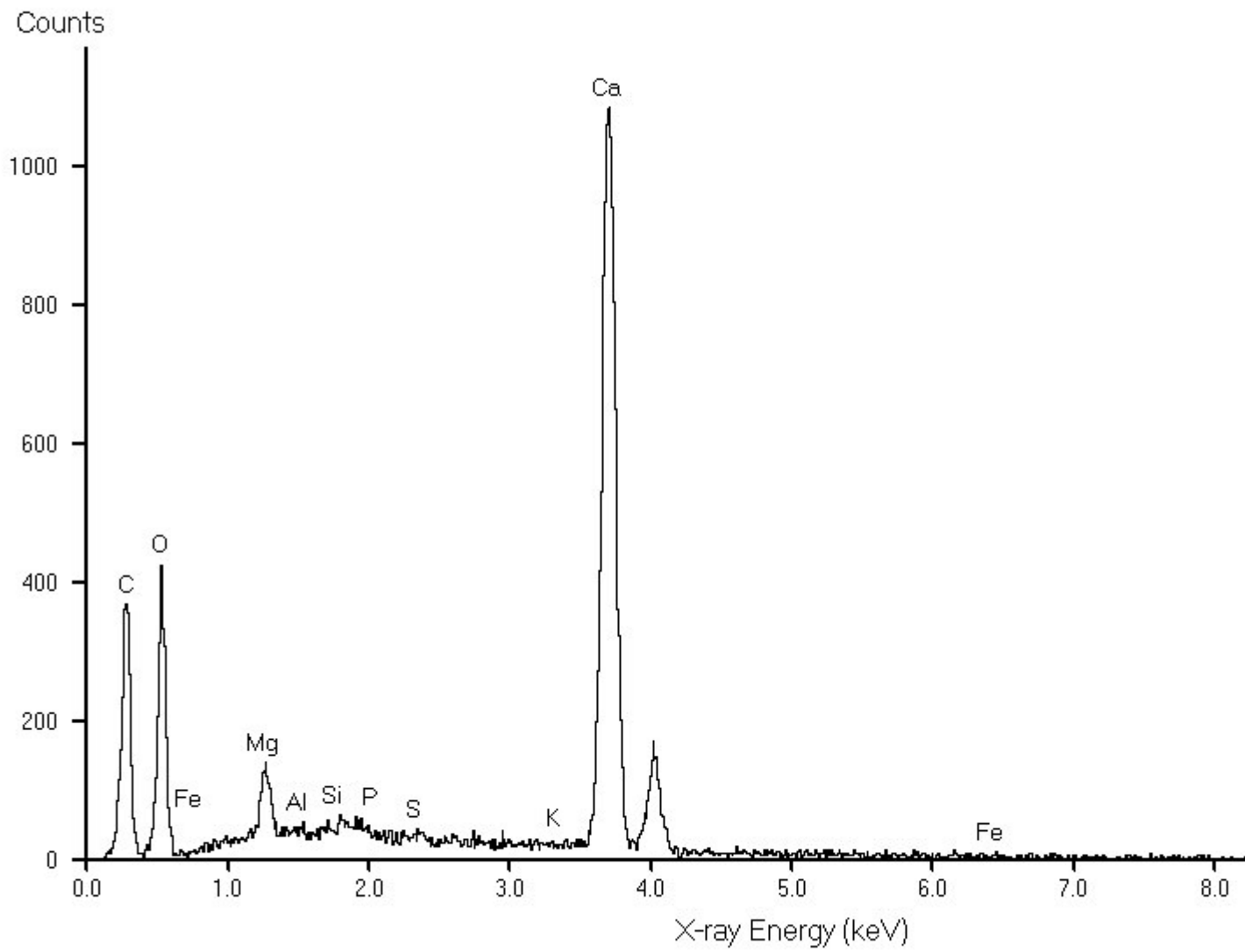
<b>Samples (dig-out)</b>	<b>1D</b>	<b>3D</b>	<b>5D</b>	<b>6D</b>	<b>7D</b>	<b>9D</b>	<b>11D</b>
Quartz	6.1	6.0	8.7	11.0	11.8	10.8	17.4
Kaolinite	13.7	11.6	1.5	0.5	0.1	0.3	-
Muscovite/ Illite	1.6	1.0	0.3	-	-	-	-
Feldspar	-	-	0.2	-	-	0.3	-
Pyrite	0.6	0.6	0.1	-	-	-	-
Calcite	1.2	1.0	4.4	2.1	1.3	1.5	0.3
Dolomite	1.9	2.0	0.2	0.1	-	-	-
Rutile	0.1	0.1	0.1	0.8	-	0.2	0.3
Cristobalite	-	-	-	2.6	3.8	1.4	2.7
Mullite	-	-	0.1	10.3	16.2	19.9	20.7
Anorthite	-	-	-	2.9	11.3	6.7	7.4
Gehlenite	-	-	-	-	1.2	1.7	0.1
Diopside	-	-	-	1.2	1.1	0.7	0.7
Periclase	-	-	-	-	0.2	0.3	-
Amorphous glass & carbon content	74.8	77.7	84.4	68.5	53.0	56.1	50.4
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>



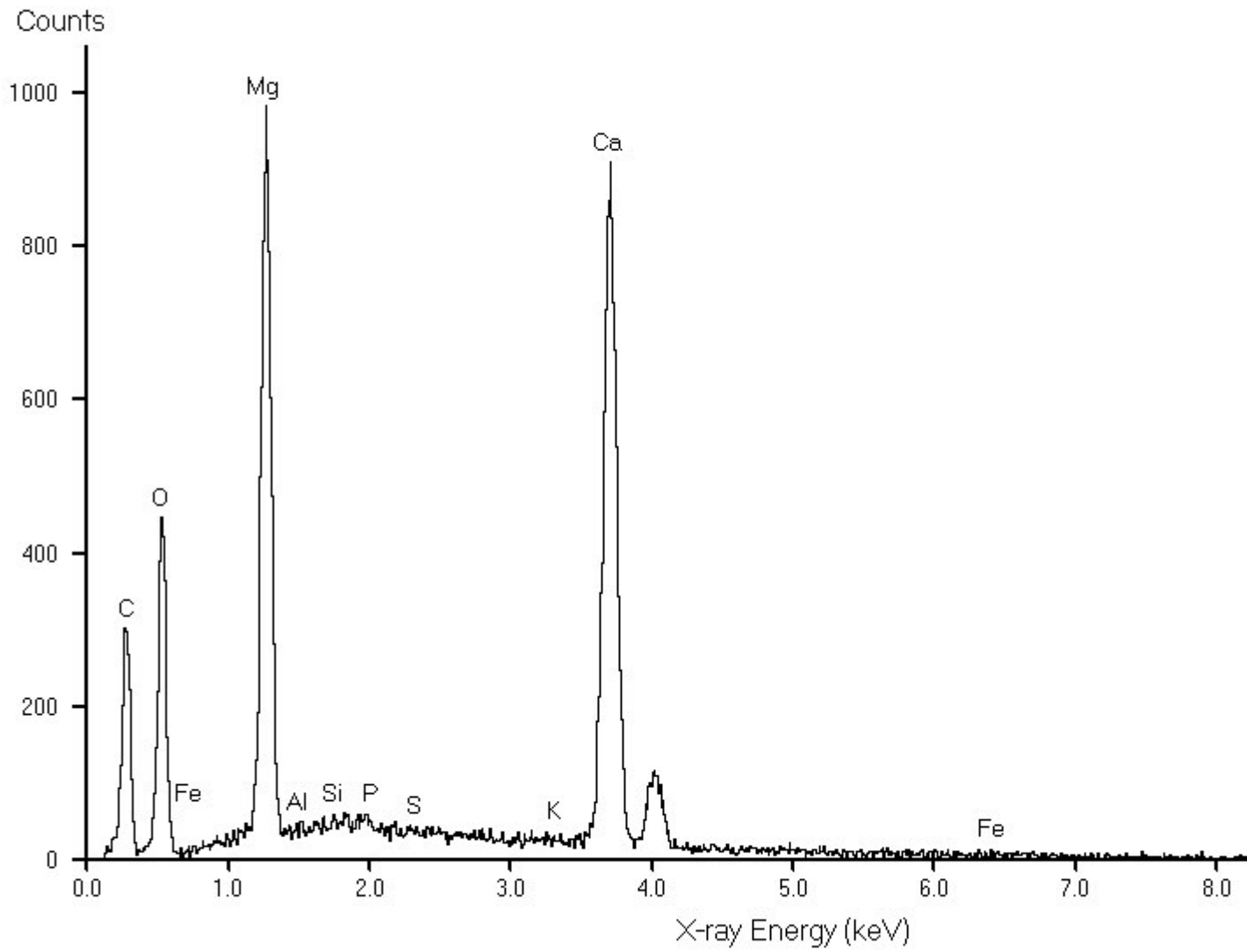
**Figure E1:** Typical X-ray spectrum of kaolinite in coal sample taken from the dig-out test.



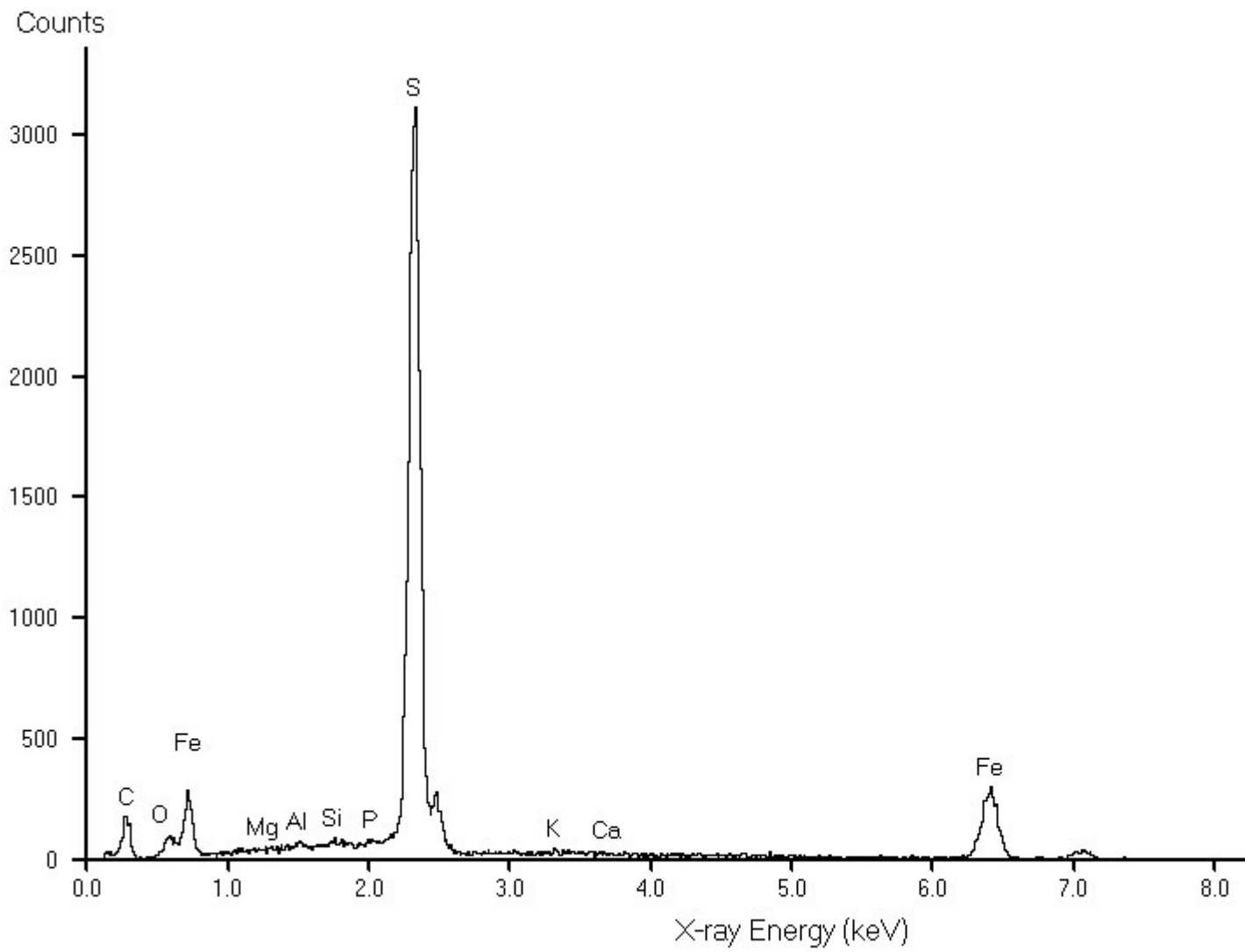
**Figure E2:** Typical X-ray spectrum of potassium feldspar in rock fragments taken from coal sample 1 during the dig-out test.



**Figure E3:** Typical X-ray spectrum of calcite cleats taken from coal sample 1 during the dig-out test.



**Figure E4:** Typical X-ray spectrum of dolomite cleats taken from coal sample 1 during the dig-out .....test.



**Figure E5:** Typical X-ray spectrum of pyrite cleats taken from coal sample 1 during the dig-out test.

## APPENDIX F

Sink fraction, float fraction, clinkers and heated rock fragments particles hand-picked from the dig-out samples 6D and 7D

**Table F1:** Predicted mass of equilibrium phases in sink fraction calculated at 1000 °C by FactSage model

<b>T</b>	=	1100	°C
<b>P</b>	=	1.00E+00	atm
<b>V</b>	=	0.00E+00	dm <sup>3</sup>
<b>STREAM</b>	<b>CONSTITUENTS</b>	<b>AMOUNT/gram</b>	
	Na <sub>2</sub> O	3.00E-01	
	Al <sub>2</sub> O <sub>3</sub>	2.14E+01	
	SiO <sub>2</sub>	5.67E+01	
	TiO <sub>2</sub>	1.10E+00	
	CaO	6.80E+00	
	MgO	1.30E+00	
	FeO	5.10E+00	
	K <sub>2</sub> O	9.00E-01	
	P <sub>2</sub> O <sub>5</sub>	0.00E+00	
<b>EQUIL PHASE:</b>	<b>AMOUNT</b>	<b>MASS FRACTION</b>	<b>ACTIVITY</b>
	<b>Slag-liq (gram)</b>	<b>gram</b>	
	MgO	4.44E-04	8.26E-04
	FeO	3.08E-02	6.48E-01
	Na <sub>2</sub> O	2.12E-02	4.13E-16
	SiO <sub>2</sub>	7.40E-01	7.68E-01
	TiO <sub>2</sub>	5.32E-03	4.37E-02
	Ti <sub>2</sub> O <sub>3</sub>	7.93E-07	3.71E-05
	CaO	3.77E-02	2.92E-06
	Al <sub>2</sub> O <sub>3</sub>	1.01E-01	1.28E-03
	K <sub>2</sub> O	6.37E-02	1.98E-18
	Fe <sub>2</sub> O <sub>3</sub>	8.81E-07	7.18E-05
<b>TOTAL:</b>	<b>1.41E+01</b>	<b>1.00E+00</b>	<b>1.00E+00</b>
<b>PHASE:</b>	<b>CORDIERITE</b>	<b>MASS FRACTION</b>	<b>ACTIVITY</b>
	Al <sub>4</sub> Fe <sub>2</sub> Si <sub>5</sub> O <sub>18</sub>	6.43E-01	3.83E-01
	Al <sub>4</sub> Mg <sub>2</sub> Si <sub>5</sub> O <sub>18</sub>	3.57E-01	1.45E-01
<b>TOTAL:</b>	<b>2.63E+01</b>	<b>1.00E+00</b>	<b>1.00E+00</b>
<b>PHASE:</b>	<b>MULLITE</b>	<b>GRAM FRACTION</b>	<b>ACTIVITY</b>
	Al <sub>2</sub> O <sub>3</sub>	7.19E-01	1.05E+01
	SiO <sub>2</sub>	2.81E-01	1.38E-03
<b>TOTAL:</b>	<b>0.00E+00</b>	<b>1.00E+00</b>	<b>4.66E-01</b>

PHASE	gram	ACTIVITY	
CaAl <sub>2</sub> Si <sub>2</sub> O <sub>8</sub> _anorthite(s2)	3.11E+01	1.00E+00	
SiO <sub>2</sub> _tridymite(h)(s4)	2.02E+01	1.00E+00	
(FeO)(TiO <sub>2</sub> )_ilmenite(s)	1.95E+00	1.00E+00	
TiO <sub>2</sub> _rutile(s)	0.00E+00	1.83E-01	
SiO <sub>2</sub> _tridymite(l)(s3)	T	0.00E+00	1.51E-02

**Table F2:** Predicted mass of equilibrium phases in the float fraction calculated at 1100 °C by FactSage model

T	=	1100	°C
P	=	1.00E+00	atm
V	=	0.00E+00	dm3

STREAM	CONSTITUENTS	AMOUNT/gram	
	Na <sub>2</sub> O	1.00E+00	
	Al <sub>2</sub> O <sub>3</sub>	3.09E+01	
	SiO <sub>2</sub>	4.42E+01	
	TiO <sub>2</sub>	2.20E+00	
	CaO	8.60E+00	
	MgO	3.10E+00	
	FeO	2.20E+00	
	K <sub>2</sub> O	7.00E-01	
	P <sub>2</sub> O <sub>5</sub>	0.00E+00	

EQUIL PHASE:	AMOUNT ?Slag-liq	MASS FRACTION gram	ACTIVITY
	MgO	4.14E-02	2.87E-04
	FeO	5.22E-01	4.26E-02
	Na <sub>2</sub> O	1.00E+00	3.57E-15
	SiO <sub>2</sub>	1.05E+01	6.60E-01
	TiO <sub>2</sub>	1.23E+00	2.39E-01
	Ti <sub>2</sub> O <sub>3</sub>	7.09E-04	1.99E-05
	CaO	1.07E+00	4.68E-07
	Al <sub>2</sub> O <sub>3</sub>	3.81E+00	1.08E-02
	K <sub>2</sub> O	4.20E-02	6.96E-19
	Fe <sub>2</sub> O <sub>3</sub>	7.88E-04	1.72E-05
	TOTAL:	1.82E+01	1.00E+00

PHASE:	CORDIERITE	MASS FRACTION	ACTIVITY
	Al <sub>4</sub> Fe <sub>2</sub> Si <sub>5</sub> O <sub>18</sub>	7.56E+00	2.54E-01
	Al <sub>4</sub> Mg <sub>2</sub> Si <sub>5</sub> O <sub>18</sub>	2.22E+01	7.46E-01
	TOTAL:	2.98E+01	1.00E+00

PHASE:	MULLITE	MASS FRACTION	ACTIVITY
	Al <sub>2</sub> O <sub>3</sub>	2.56E+00	7.20E-01
	SiO <sub>2</sub>	9.97E-01	2.80E-01
	TOTAL:	3.56E+00	1.00E+00

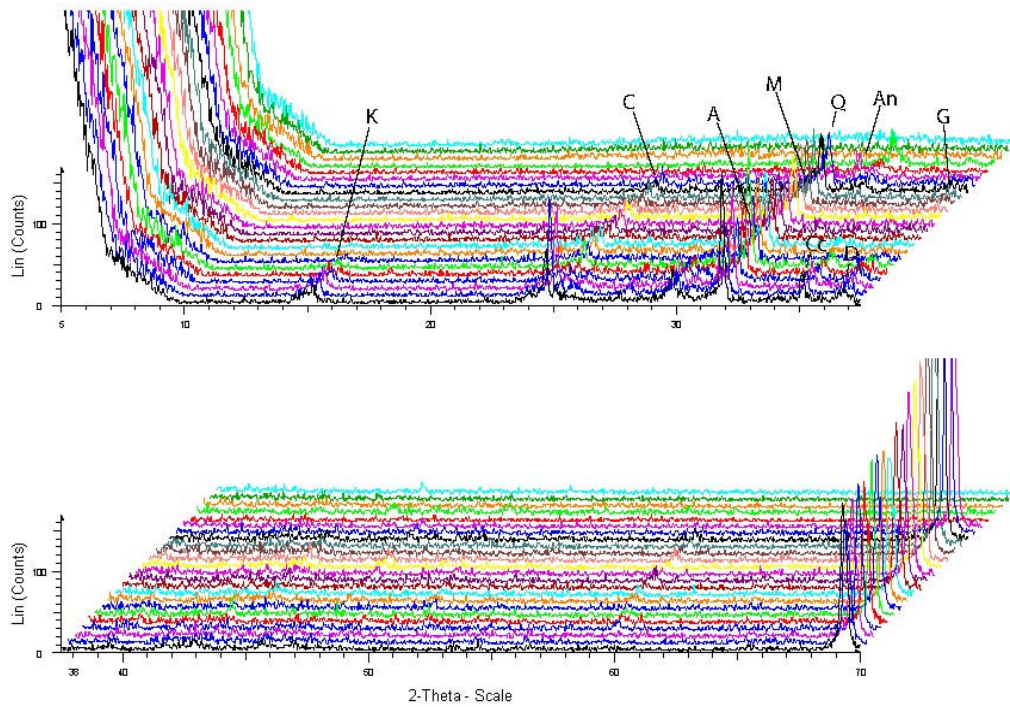
PHASE	AMOUNT (gram)	MASS FRACTION	ACTIVITY
CaAl <sub>2</sub> Si <sub>2</sub> O <sub>8</sub> _anorthite(s2)	3.74E+01	1.00E+00	
KAlSi <sub>2</sub> O <sub>6</sub> _leucite(rhf)(s2)	3.05E+00	1.00E+00	
TiO <sub>2</sub> _rutile(s)	9.71E-01	1.00E+00	
Mg <sub>2</sub> Al <sub>4</sub> Si <sub>5</sub> O <sub>18</sub> _cordierite(s)	0.00E+00	5.85E-01	
KAlSi <sub>2</sub> O <sub>6</sub> _leucite(rhf)(s)	T	0.00E+00	1.87E-01

**Table F3:** Predicted mass of equilibrium phases in the heated rock fragment at 1100°C by FactSage model

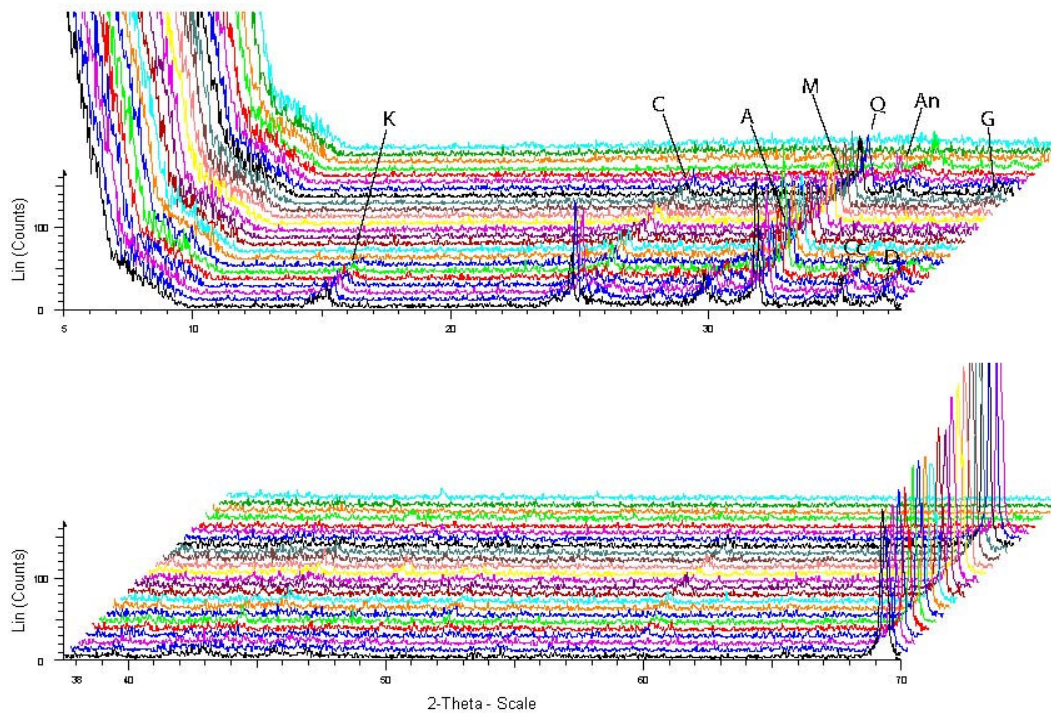
T	=	1100
P	=	1.00E+00
V	=	0.00E+00
<b>STREAM</b>	<b>CONSTITUENTS</b>	<b>AMOUNT/gram</b>
Na <sub>2</sub> O	4.00E-01	
Al <sub>2</sub> O <sub>3</sub>	3.84E+01	
SiO <sub>2</sub>	5.87E+01	
TiO <sub>2</sub>	6.70E-01	
CaO	4.20E-01	
MgO	0.00E+00	
FeO	3.20E-01	
K <sub>2</sub> O	1.09E+00	
P <sub>2</sub> O <sub>5</sub>	0.00E+00	
<b>EQUIL PHASE:</b>	<b>AMOUNT ?Slag-liq</b>	<b>MASS FRACTION gram</b>
FeO	2.46E-02	1.40E-03
Na <sub>2</sub> O	4.00E-01	2.27E-02
SiO <sub>2</sub>	1.41E+01	7.99E-01
TiO <sub>2</sub>	2.59E-01	1.47E-02
Ti <sub>2</sub> O <sub>3</sub>	3.10E-06	1.76E-07
CaO	1.06E-01	6.01E-03
Al <sub>2</sub> O <sub>3</sub>	1.66E+00	9.43E-02
K <sub>2</sub> O	1.09E+00	6.20E-02
Fe <sub>2</sub> O <sub>3</sub>	3.44E-06	1.96E-07
TOTAL:	1.76E+01	1.00E+00
<b>PHASE:</b>	<b>Cordierite</b>	<b>MASS FRACTION</b>
Al <sub>4</sub> Fe <sub>2</sub> Si <sub>5</sub> O <sub>18</sub>	0.00E+00	1.00E+00
TOTAL:	0.00E+00	1.00E+00
<b>PHASE:</b>	<b>MULLITE</b>	<b>MASS FRACTION</b>
Al <sub>2</sub> O <sub>3</sub>	3.62E+01	7.20E-01
SiO <sub>2</sub>	1.41E+01	2.80E-01
TOTAL:	5.03E+01	1.00E+00
<b>PHASE</b>	<b>AMOUNT</b>	<b>MASS FRACTION</b>
SiO <sub>2</sub> _tridymite(h)(s4)	2.99E+01	1.00E+00
CaAl <sub>2</sub> Si <sub>2</sub> O <sub>8</sub> _anorthite(s2)	1.56E+00	1.00E+00
(FeO)(TiO <sub>2</sub> )_ilmenite(s)	6.24E-01	1.00E+00
TiO <sub>2</sub> _rutile(s)	8.30E-02	1.00E+00
SiO <sub>2</sub> _tridymite(l)(s3)	T	0.00E+00

## APPENDIX G

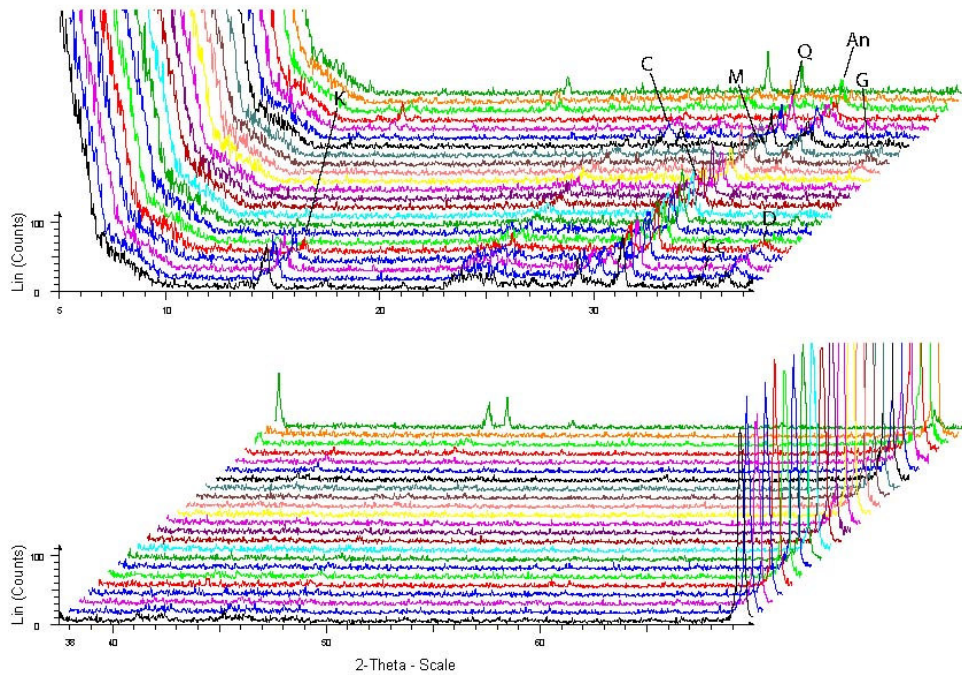
Feed coal to coal-conversion processes



**Figure G1:** High temperature XRD Scan of minerals in the LTA of feed coal during thermal treatment.



**Figure G2:** High temperature XRD Scan of minerals in the LTA of fine float coal fraction during thermal treatment.



**Figure G3:** High temperature XRD Scan of minerals in the LTA of fine sink coal fraction during thermal treatment.

**Note:** K = Kaolinite, C = Cristobalite, CC = Calcite, An = Anorthite, M = Mullite, D = Dolomite G = Gehlenite, A = Bassanite or Anhydrite, Q = Quartz

**Table G1:** Showing in and out temperatures of the various phases during HT-XRD runs of LTA samples of feed coal, sink and float fractions (°C)

Minerals	32		LTA of Sink		LTA Float	
	In	Out	In	Out	In	Out
Kaolinite		600		700		600
Quartz		1400		1300		1300
Dolomite		600		700		750
Calcite		600		650		400
Mullite	1050	1300	950	1250	1000	1400
Anorthite	1100	1450	1150	1400	950	1450
bassanite	400	750	450	900	400	1000
Gehlenite	950	1300	1000	1350	900	1200
Cristobalite	1250	1400	1150	1250	1100	1250

**Note:** 32 = In and out temperatures of phases in LTA of sample 32T (feed coal to gasification)  
LTA of fine sink = In and out temperatures of phases in LTA of fine sink particles of sample  
LTA of Float = In and out temperatures of phases in LTA of fine float particles of sample 32

## APPENDIX H

Distribution of inorganic elements in the minerals and macerals in the coals

**Table H1:** Calculated concentrations of organic and inorganic elements obtained from all macerals in the coal sample from different Highveld collieries when using electron microprobe and optical microscope analyses (wt%)

Elements	Mine 1	Mine 2	Mine 3	Mine 4	Mine 5	Mine 6
C	56.84	54.23	50.39	55.11	55.46	55.76
H	2.63	2.43	1.95	2.58	1.72	3.34
N	0.88	0.59	1.08	0.73	0.94	1.13
O	8.09	6.46	8.71	6.78	7.98	10.90
Na	0.00	0.00	0.00	0.00	0.00	0.00
Mg	0.01	0.03	0.01	0.01	0.02	0.01
Al	0.13	0.09	0.24	0.03	0.14	0.19
Si	0.15	0.08	0.24	0.03	0.12	0.16
P	0.00	0.00	0.00	0.00	0.00	0.00
S	0.26	0.26	0.30	0.17	0.34	0.21
K	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.08	0.08	0.07	0.07	0.09	0.14
Ti	0.08	0.06	0.06	0.06	0.01	0.02
Fe	0.00	0.00	0.00	0.00	0.00	0.00
Total	69.14	64.31	63.05	65.58	66.82	71.85

**Table H2:** Calculated concentrations of inorganic elements present in the minerals in coal samples from different Highveld collieries (CCSEM analysis) (wt%)

Elements	Mine 1	Mine 2	Mine 3	Mine 4	Mine 5	Mine 6
C	0.72	0.70	1.20	0.97	0.84	0.83
H	0.22	0.32	0.32	0.28	0.19	0.20
N	0.00	0.00	0.00	0.00	0.00	0.00
O	14.89	18.55	19.31	17.70	16.10	13.92
Na	0.00	0.00	0.00	0.00	0.01	0.00
Mg	0.30	0.30	0.45	0.34	0.30	0.34
Al	2.98	4.57	4.41	3.91	2.88	2.79
Si	6.63	7.84	6.67	7.01	7.43	5.70
P	0.02	0.04	0.02	0.01	0.03	0.02
S	1.73	0.79	0.82	0.89	1.58	1.27
K	0.10	0.24	0.33	0.20	0.32	0.07
Ca	1.43	1.47	2.67	2.15	1.93	1.74
Ti	0.11	0.13	0.12	0.11	0.11	0.07
Fe	1.66	0.69	0.53	0.82	1.40	1.14
<b>Total</b>	<b>30.78</b>	<b>35.64</b>	<b>36.85</b>	<b>34.39</b>	<b>33.11</b>	<b>28.12</b>