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CHANGES IN GAS COMPOSITION DURING COAL SEAM DRAINAGE AND LABORATORY TESTING

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ABSTRACT: Analysis of gas emissions from underground-to-inseam (UIS) gas drainage boreholes located in the Bulli seam found methane gas liberated from the coal in preference to carbon dioxide gas, particularly in mixed gas (CH_4 and CO_2) conditions. The rate of emission of the methane gas component from the *in situ* coal seam was also found to be greater than the rates observed during laboratory gas desorption testing on coal cores recovered during the drilling of the UIS gas drainage boreholes. The nature of changes in the composition of the gas mixture liberated from coal, and the relative differences in gas composition determined by fast and slow desorption testing, and UIS gas production, may have a potentially significant impact on outburst risk assessment and coal seam gas reservoir assessment. Results of gas composition measurement from the three sources are presented and discussed.

INTRODUCTION

A comprehensive investigation was conducted in an underground coal mine, operating in the Bulli seam in the southern Sydney basin, which focussed on gas emissions and the factors that impact gas emissions from coal. Part of the investigation analysed coal core samples and included a comparative analysis of the content and composition of gases desorbed from coal samples during fast desorption (FD) and slow desorption (SD) testing in accordance with AS3980:1999 (SAA, 1999). The investigation also measured flow rate and composition of gas produced from underground-to-inseam (UIS) gas drainage boreholes. The term "gas composition" used in this paper refers to the mixture of methane (CH_4) and carbon dioxide (CO_2) gas contained in the coal.

Gas liberated from the core samples and UIS boreholes was analysed using a Hewlett Packard quad micro gas chromatograph to determine the relative concentrations of the gases, CH_4, CO_2, N_2, O_2, C_2H_6, CO and C_2H_4. In addition to the individual component gases, air dilution and the gas composition [$CH_4/(CH_4+CO_2)$] was calculated. The flow rate of gas produced from UIS boreholes was measured using orifice plate measuring sets and the volume of gas desorbed from core samples was measured in the laboratory using a calibrated gas volume measurement apparatus. Both the gas chromatograph and the volume measurement apparatus, shown in Figure 1, are located in the University of Wollongong Gas Research Laboratory.

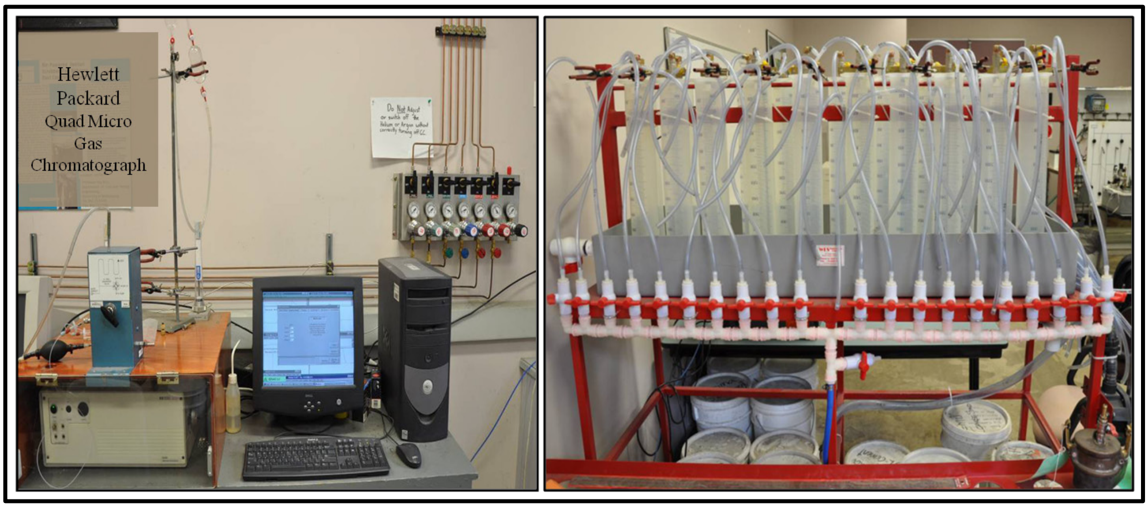

Figure 1: Testing equipment located in the Gas and Outburst Research Laboratory, University of Wollongong

Analysis of gas composition data from the three sources, (a) FD (quick crush) testing, (b) SD testing, and (c) UIS gas drainage boreholes, indicated differences in the rate of emission of CH_4 and CO_2 from coal core samples and *in situ* coal. This paper discusses the results of gas content and gas composition measurements from core samples and the UIS

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boreholes from which the core samples were collected. Following recovery from the borehole and completion of initial $Q2_{field}$ gas emission testing, each core sample was divided, with half used for FD testing and half used for SD testing.

Details of the coal core samples and the corresponding UIS gas drainage borehole from which they were collected are listed in Table 1, and the location of the core samples along each UIS borehole are shown in Figure 2.

Table 1: Reference numbers of coal core samples collected during drilling of UIS boreholes

UIS BOREHOLES	COAL CORE SAMPLES
519-18/9	WE1183; WE1189
519-21/8	WE1205; WE1208
519-33A/2	WE1191; WE1199
519-33A-4	WE1201; WE1202; WE1203; WE1209; WE1210
519-33A/6	WE1308; WE1309

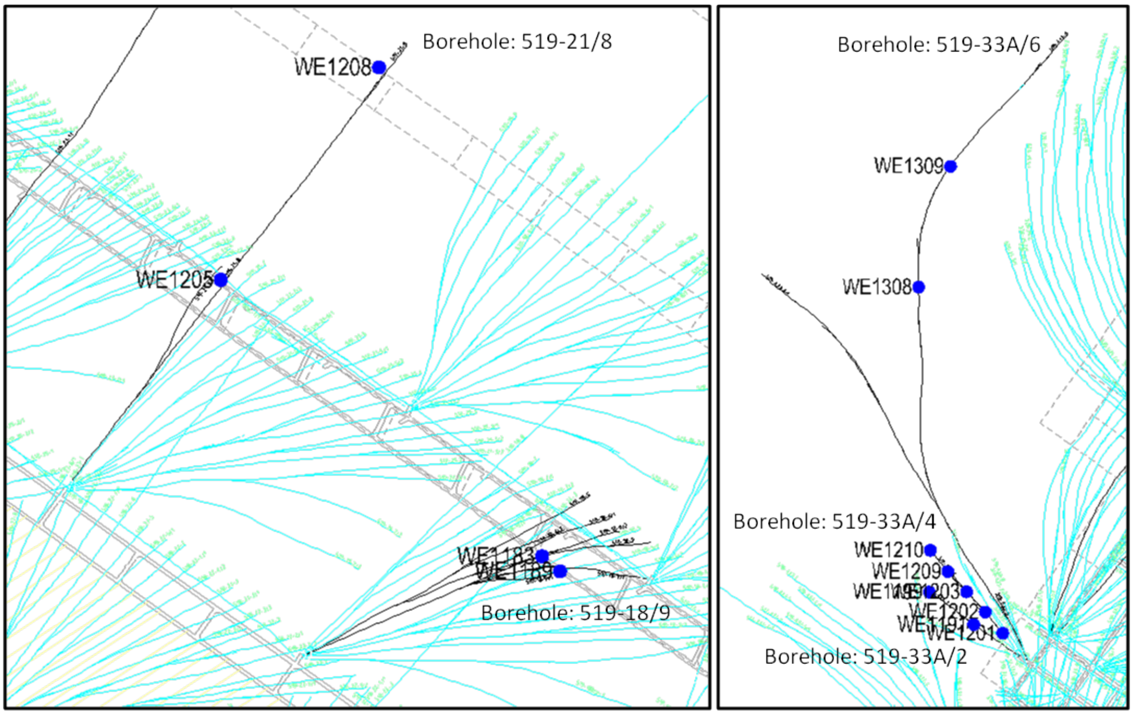

Figure 2: Location of coal core samples along UIS gas drainage boreholes

ANALYSIS OF GAS MIXTURE COMPOSITION FROM UIS BOREHOLES AND COAL CORE SAMPLES

Figure 3 shows the location of core samples along UIS boreholes 519-18/9 and 519-21/8 relative to (a) gas content contours and (b) gas composition contours generated using data collected from gas analysis of coal samples collected from the Bulli seam during surface-based exploration drilling. The proximity of the exploration boreholes, S1399, S1437, S1462, S1488, S1488, S1791, are shown relative to the UIS boreholes.

Figure 4 shows the location of core samples along UIS boreholes 519-33A/2, 519-33A/4, and 519-33A/6 relative to (a) gas content contours and (b) gas composition contours generated using data collected from gas analysis on coal samples collected from the Bulli seam during surface-based exploration drilling. The proximity of the exploration boreholes, S1126, S1454, S1716, and S1840, are shown relative to the UIS boreholes.

It can be seen that the gas content values determined from FD testing on UIS core samples varies relative to the contoured gas content values generated using gas content data from adjacent exploration boreholes. The FD gas content values are shown to be lower than individual exploration contours in the areas of borehole 519-18/9 and 519-21/8 while being substantially higher in the area of borehole 519-33A. Three potential reasons for the differences include (a) inaccurate estimation of the Q1 gas content component desorbed from the core samples during drilling and extraction of the samples from the coal seam, (b) gas content contours generated from exploration data may not be truly representative of the distribution of gas content within these areas of the Bulli seam, and (c) the vertical coal seam section collected by exploration drilling may contain plies that have variable gas content that was not present in the seam section sampled by UIS drilling.

Details of the gas content value determined from FD testing of the core samples collected from UIS boreholes 519-18/9 and 519-21/8, and the estimated gas content value at each core location, based on contoured exploration data, are listed in Table 2 and Table 3 respectively.

Details of the gas content values determined from FD testing of the core samples collected from UIS boreholes 519-33A/2, 519-33A/4, and 519-33A/6, and the estimated gas content value at each core location, based on contoured exploration data, are listed in Table 4, Table 5 and Table 6 respectively.

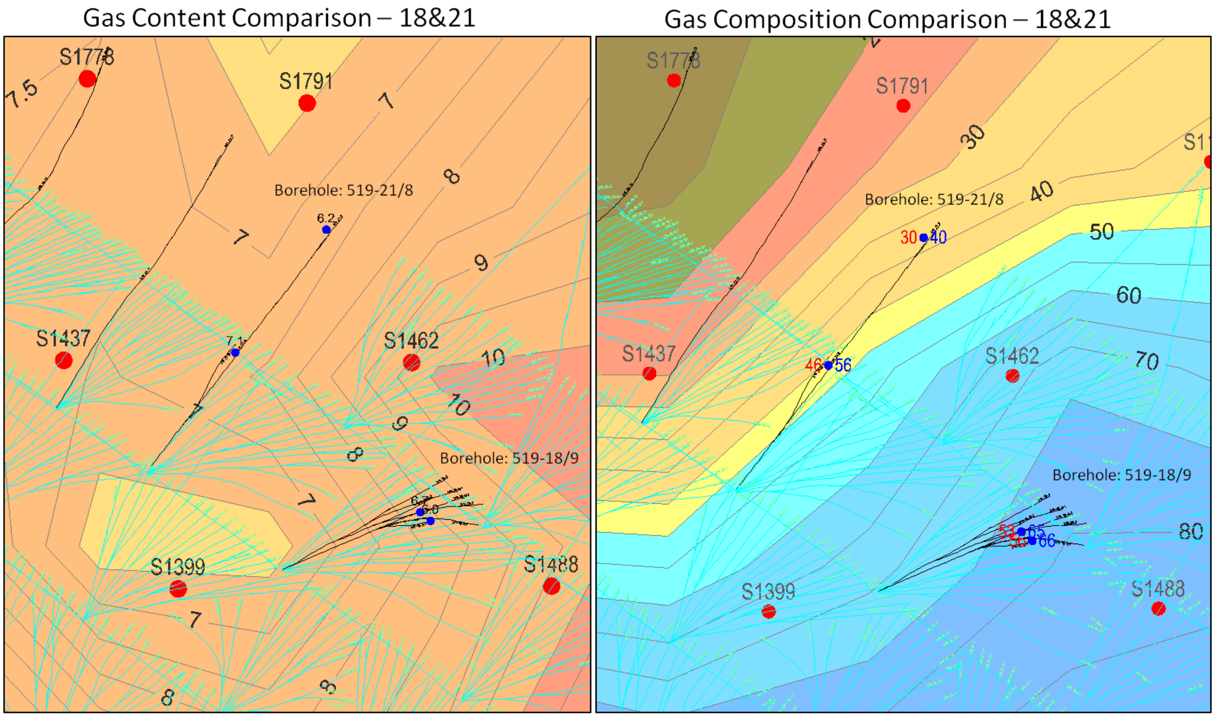

Figure 3: UIS boreholes (519-18/9 and 519-21/8) and gas data relative to exploration gas content and composition (CH4:CO2 ratio) contours

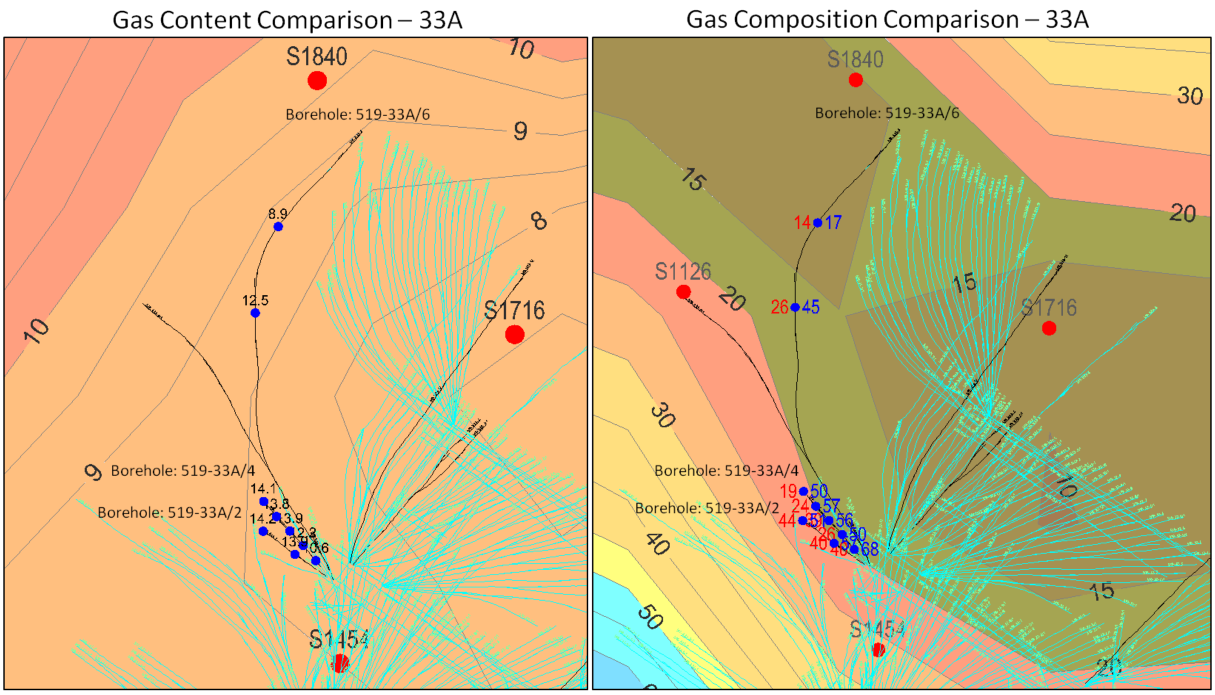

Figure 4: UIS boreholes (519-33A/2, 519-33A/4 and 519-33A/6) and gas data relative to exploration gas content and composition [$CH_4 \div (CH_4+CO_2)$ %] contours

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GAS DATA RECORDED ALONG UIS BOREHOLE 519-18/9

The total length of UIS borehole 519-18/9 was 676m and based on gas composition contours generated from exploration boreholes, located less than 300m from this borehole, the CH_4 component [CH_4/(CH_4+CO_2)] of the seam gas along the length of the borehole varied between 70% to 80%, as shown in Figure 3.

Two core samples, WE1183 and WE1189, were collected during the drilling of this borehole. The CH_4 component of the gas released from the core samples determined by FD testing was 53% and 56% respectively. The average CH_4 component of the gas desorbed from the core samples WE1183 and WE1189 recorded during SD testing over a period of 151 days and 341 days was 65% and 66% respectively. The CH_4 component of the gas released from the two core samples during SD testing varied between 53% and 69% (WE1183) and 58% and 69% (WE1189), as shown in Figure 5.

One gas composition measurement was taken during gas production from UIS boreholes 519-18/9 on day 24 and the CH_4 component at that time was 57%, as indicated in Figure 5. Additional gas composition monitoring was conducted on adjacent UIS boreholes 519-18/6 and 519-18/7 that recorded CH_4 component values ranging between 56% and 62% from 519-18/6 (59% average) between day 120 and 155, and 63% and 75% from 519-18/7 (68% average) between day 31 and 157. The results of periodic gas composition measurement from these two boreholes are shown in Figure 6.

Table 2 provides a summary of the gas composition values recorded from FD testing, and the average gas composition values recorded during SD testing, on the core samples collected from UIS borehole 519-18/9 along with the estimated gas composition values based on contoured exploration data and the average composition of the gas produced from the UIS borehole.

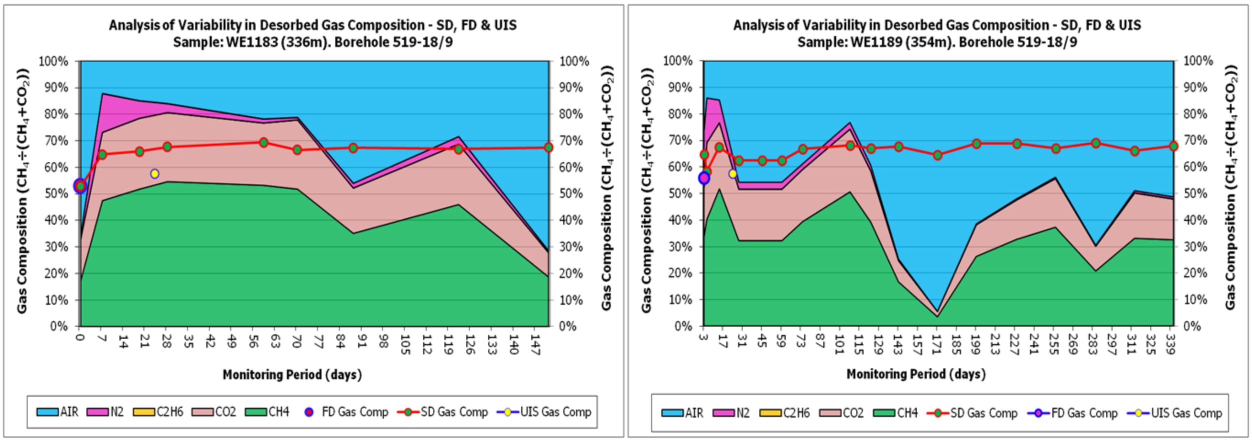

Figure 5: Recorded gas composition during SD testing of WE1183 and WE1189 including FD and UIS gas composition values

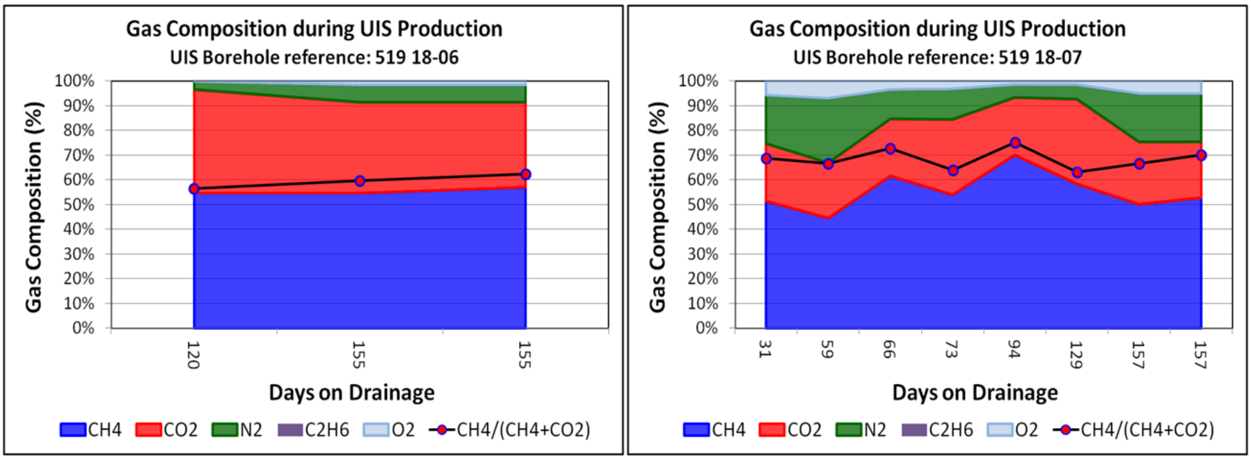

Figure 6: Recorded gas composition during gas production from UIS boreholes 519-18/6 and 519-18/7

Table 2: Summary gas content and gas composition data at core sample locations in UIS borehole 519-18/9

Reference Borehole: 519-18/9

UIS Core Samples	Gas Content (m^3/t)		Gas Composition (CH_4÷{CH_4+CO_2})(%)			
	Exploration contours (est.)	UIS Gas Content	Exploration contours (est.)	Fast Desorption	Slow Desorption (average)	UIS Gas Production (average)
WE1183	8.3	6.7	77	53	65	57
WE1189	8.3	6.0	78	56	66	57
Note: Average gas composition from adjacent boreholes:					519-18/6	59
					519-18/7	68

The CH_4 component of gas desorbed from WE1183 and WE1189 during SD testing was 12% and 10% greater than the composition measured during the FD test. The increased CH_4 detected during SD suggest CH_4 desorbs from coal samples at a faster rate than CO_2, with CO_2 being retained within the sample and potentially not being released until late stage desorption or until the coal sample is crushed (e.g. Q3 gas content measurement during FD testing).

The increased CH_4 component indicated by the contoured exploration gas data may be the result of sections of the coal seam (coal plies) containing elevated levels of CH_4 being present in the exploration core sample. Details of gas composition testing on vertical section of the Bulli seam were not available therefore the potential variability in gas composition within vertical section of the Bulli seam cannot be confirmed.

GAS DATA RECORDED ALONG UIS BOREHOLE **519-21/8**

The total length of UIS borehole 519-21/8 was 865m and based on gas composition contours generated from exploration boreholes located less than 350m from this borehole, the CH_4 component along the length of the borehole ranges from 37% to 52%, as shown in Figure 3.

Two core samples, WE1205 and WE1208, were collected during the drilling of this borehole. The CH_4 component of the gas released from the core samples determined by FD testing was 46% and 30% respectively. The average CH_4 component of the gas desorbed from core samples WE1205 and WE1208 during SD testing over a period of 140 days and 110 days was 56% and 40% respectively. The CH_4 component of the gas released from the two core samples during SD testing varied between 49% and 64% (WE1205) and 29% and 46% (WE1208), as shown in Figure 7.

Three gas composition measurements were taken during gas production from UIS borehole 519-21/8, on day 1, day 71 and day 99, and the recorded CH_4 component progressively increased from 67% (day 1) to 82% (day 99), as indicated in Figure 7. Additional gas composition monitoring was conducted on adjacent UIS boreholes 519-21/5 and 519-21/7 that recorded CH_4 component values ranging between 50% and 71% from 519-21/5 (59% average) between day 8 and day 127, and 44% and 55% from 519-21/7 (48% average) between day 36 and day 120. The results of periodic gas composition measurements from these two boreholes are shown in Figure 8. The recorded CH_4 component of the gas produced from the three UIS boreholes was consistently greater than the values recorded from core sample testing. In this area, the UIS boreholes may have been drilled through sections of the coal seam containing elevated CH_4 levels. Should this be the case, it is reasonable to assume that CH_4 would be preferentially desorbed from the coal, particularly in the comparatively high CH_4 zones, and the total component volume of CH_4 would exceed the volume of the CO_2 desorbed from the less CH_4 rich sections of the borehole. Details of incremental gas composition measurements along the length of the UIS boreholes were not available therefore the potential variability in gas composition and increased emission rate from possible CH_4 rich zones cannot be confirmed.

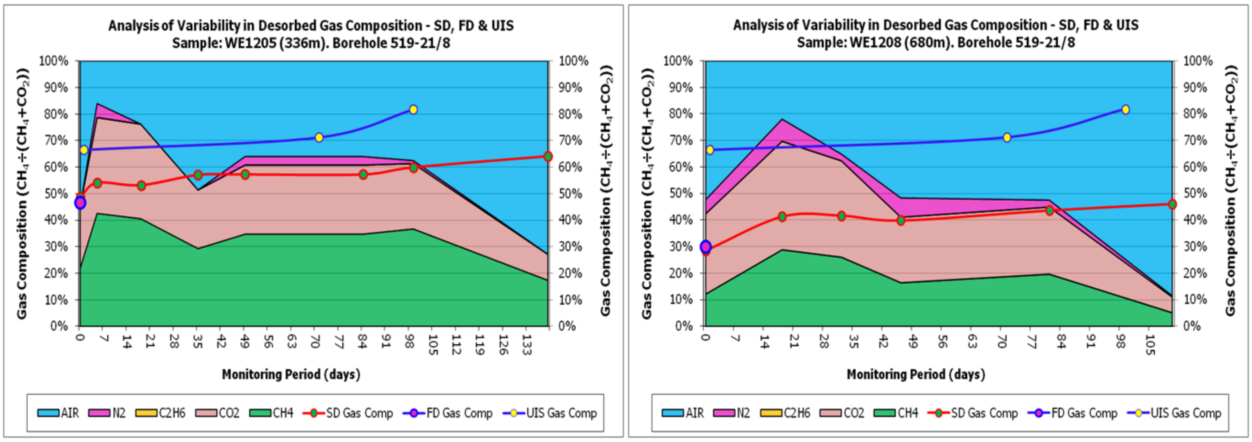

Figure 7: Recorded gas composition during SD testing of WE1205 and WE1208 including FD and UIS gas composition values

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Table 3 provides a summary of the gas composition values recorded from FD testing, and the average gas composition values recorded during SD testing, on the core samples collected from UIS borehole 519-21/8 along with the estimated gas composition values based on contoured exploration data and the average composition of the gas produced from the UIS borehole.

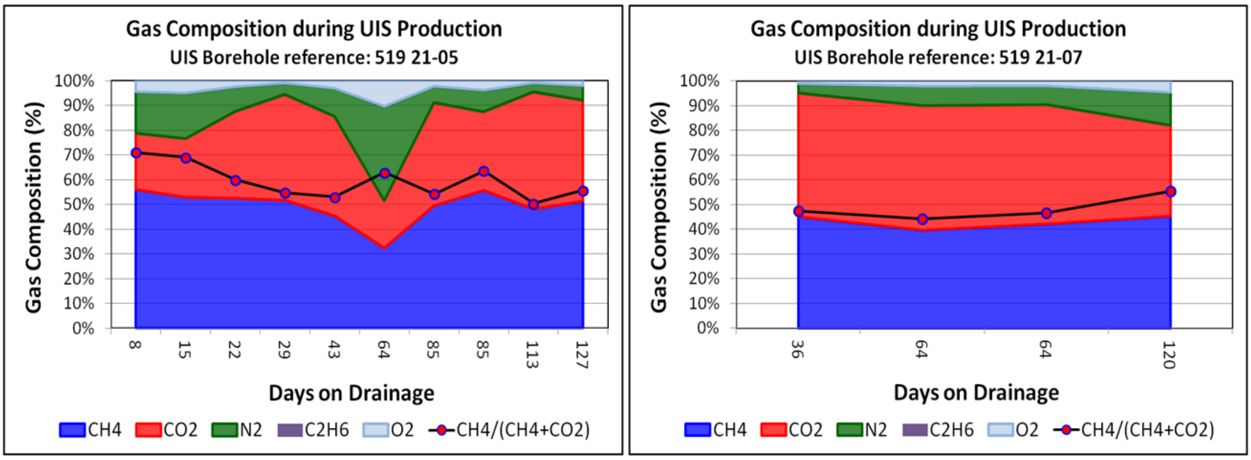

Figure 8: Recorded gas composition during gas production from UIS boreholes 519-21/5 and 519-21/7

Table 3: Summary gas content and gas composition data at core sample locations in UIS borehole 519-21/8

Reference Borehole: 519-21/8

UIS Core Samples	Gas Content (m^3/t)		Gas Composition (CH_4÷{CH_4+CO_2})(%)			
	Exploration contours (est.)	UIS Gas Content	Exploration contours (est.)	Fast Desorption	Slow Desorption (average)	UIS Gas Production (average)
WE1205	7.3	7.1	46	46	56	73
WE1208	7.3	6.2	37	30	40	73
Note: Average gas composition from adjacent boreholes:					519-21/5	59
					519-21/7	48

The CH_4 component of gas desorbed from WE1205 and WE1208 during SD testing was 10% greater than the composition measured during the FD test. The increased CH_4 detected during SD suggest CH_4 desorbs from coal samples at a faster rate than CO_2, with CO_2 being retained within the sample and potentially not being released until late stage desorption or until the coal sample is crushed (e.g. Q3 gas content measurement during FD testing).

In this area of the Bulli seam the CH_4 composition indicated by the contoured exploration gas data is similar to the values determined during FD testing.

GAS COMPOSITION DATA RECORDED ALONG UIS BOREHOLE 519-33A/2

The total length of UIS borehole 519-33A/2 was 162m and based on gas composition contours generated from exploration boreholes located less than 700m from this borehole, the CH_4 component along the length of the borehole ranges from 20% to 25%, as shown in Figure 4.

Two core samples, WE1191 and WE1199, were collected during the drilling of this borehole. The CH_4 component of the gas released from the core samples during FD testing was 40% and 44% respectively. The average CH_4 component of the gas desorbed from core samples WE1191 and WE1199 during SD testing over a period of 383 days and 264 days was 57% and 51% respectively. The CH_4 component of the gas released from the two core samples during SD testing varied between 50% and 60% (WE1191) and 39% and 58% (WE1199), as shown in Figure 9.

Ten gas composition measurements were taken during gas production from UIS borehole 519-33A/2, commencing day 1 of gas production, with periodic measurement to day 140. The average CH_4 component of the seam gas progressively increased from 66% (day 0) to 73% (day 49) and then progressively decreased to 67% (day 126) prior to the final measurement on day 140 that recorded 76%. The results of gas composition measurement from borehole 519-33A/2 are presented in Figure 10 and shown relative to the SD results from the two core samples in Figure 9.

The recorded CH_4 component of the gas produced from the UIS borehole was consistently greater than the values recorded from core sample testing. In this area, the UIS borehole may have been drilled through sections of the coal seam containing elevated CH_4 levels. Should this be the case, it is reasonable to assume that CH_4 would be preferentially desorbed from the coal, particularly in the comparatively high CH_4 zones, and the total component volume of CH_4 would exceed the volume of the CO_2 desorbed from the less CH_4 rich sections of the borehole. Details of incremental gas composition measurement along the length of the UIS boreholes were not available therefore the potential variability in gas composition and increased emission rate from possible CH_4 rich zones cannot be confirmed.

Table 4 provides a summary of the gas composition values recorded from FD testing, and the average gas composition values recorded during SD testing, on the core samples collected from UIS borehole 519-33A/2 along with the estimated gas composition values based on contoured exploration data and the average composition of the gas produced from the UIS borehole.

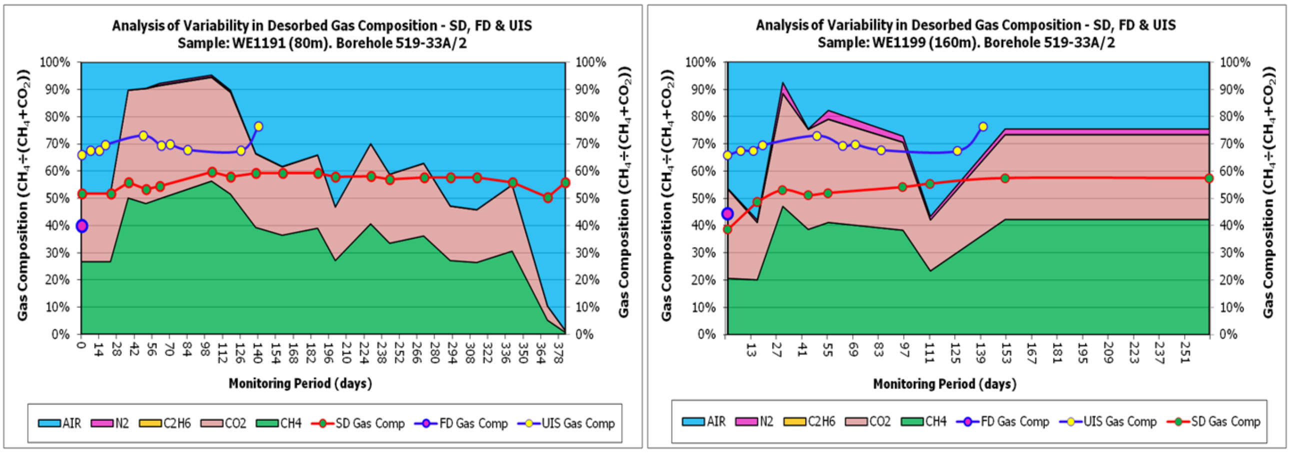

Figure 9: Recorded gas composition during SD testing of WE1191 and WE1199 including FD and UIS gas composition values

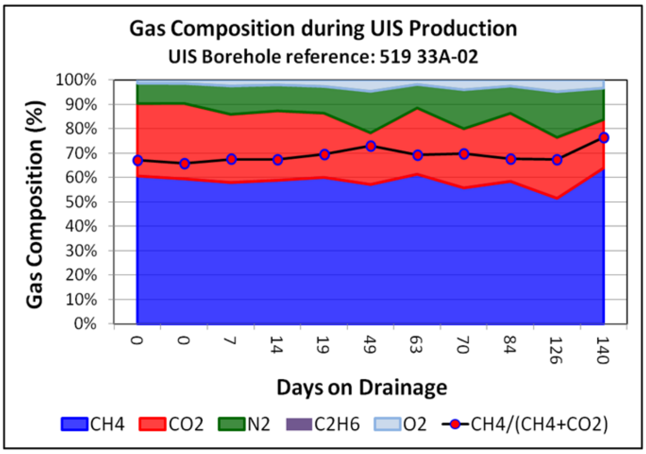

Figure 10: Recorded gas composition during gas production from UIS boreholes 519-33A/2

Table 4: Summary gas content and gas composition data at core sample locations in UIS borehole 519-33A/2

Reference Borehole: 519-33A/2

UIS Core Samples	Gas Content (m^3/t)		Gas Composition (CH_4÷{CH_4+CO_2})(%)			
	Exploration contours (est.)	UIS Gas Content	Exploration contours (est.)	Fast Desorption	Slow Desorption (average)	UIS Gas Production (average)
WE1191	8.3	13.9	20	40	57	69
WE1199	8.5	14.2	23	44	51	69

The CH_4 component of gas desorbed from WE1191 and WE1199 during SD testing was 17% and 7% greater than the composition measured during the FD test. The increased CH_4 detected during SD suggest CH_4 desorbs from coal samples at a faster rate than CO_2, with CO_2 being retained within the sample and potentially not being released until late stage desorption or until the coal sample is crushed (e.g. Q3 gas content measurement during FD testing).

In this area of the Bulli seam the CH_4 component indicated by the contoured exploration gas data is approximately 20% lower than the values determined during FD testing. The results suggest this borehole is located in an isolated zone where the seam gas contains increased concentrations of CH_4.

GAS DATA RECORDED ALONG UIS BOREHOLE **519-33A/4**

The total length of UIS borehole 519-33A/4 was 204m and based on gas composition contours generated from exploration boreholes located less than 700m from this borehole, the CH_4 component of the seam gas along the length of the borehole ranges from 19% to 21%, as shown in Figure 4.

Five core samples, WE1201, WE1202, WE1203, WE1209, and WE1210, were collected during the drilling of this borehole. The CH_4 component of the gas released from the core samples during FD testing was 70%, 26%, 39%, 24%, and 19% respectively. The average CH_4 component of the gas desorbed from the five core samples during SD testing was 68% (WE1201, 647 days), 50% (WE1202, 145 days), 66% (WE1203, 627 days), 57% (WE1209, 112 days), and 50% (WE1210, 613 days), as shown in Figure 11. The CH_4 component of the gas released from the core samples during SD testing varied between 64% and 80% (WE1201), 43% and 57% (WE1202), 47% and 63% (WE1203), 52% and 62% (WE1209), and 47% and 62% (WE1210).

Six gas composition measurements were taken during gas production from UIS borehole 519-33A/4, commencing day 1 of gas production, with periodic measurement to day 72. The average CH_4 component of the seam gas was 66% and varied between 60% and 69% during the monitoring period. The results of gas composition measurement from borehole 519-33A/4 are presented in Figure 12 and shown relative to the SD results from the two core samples in Figure 11.

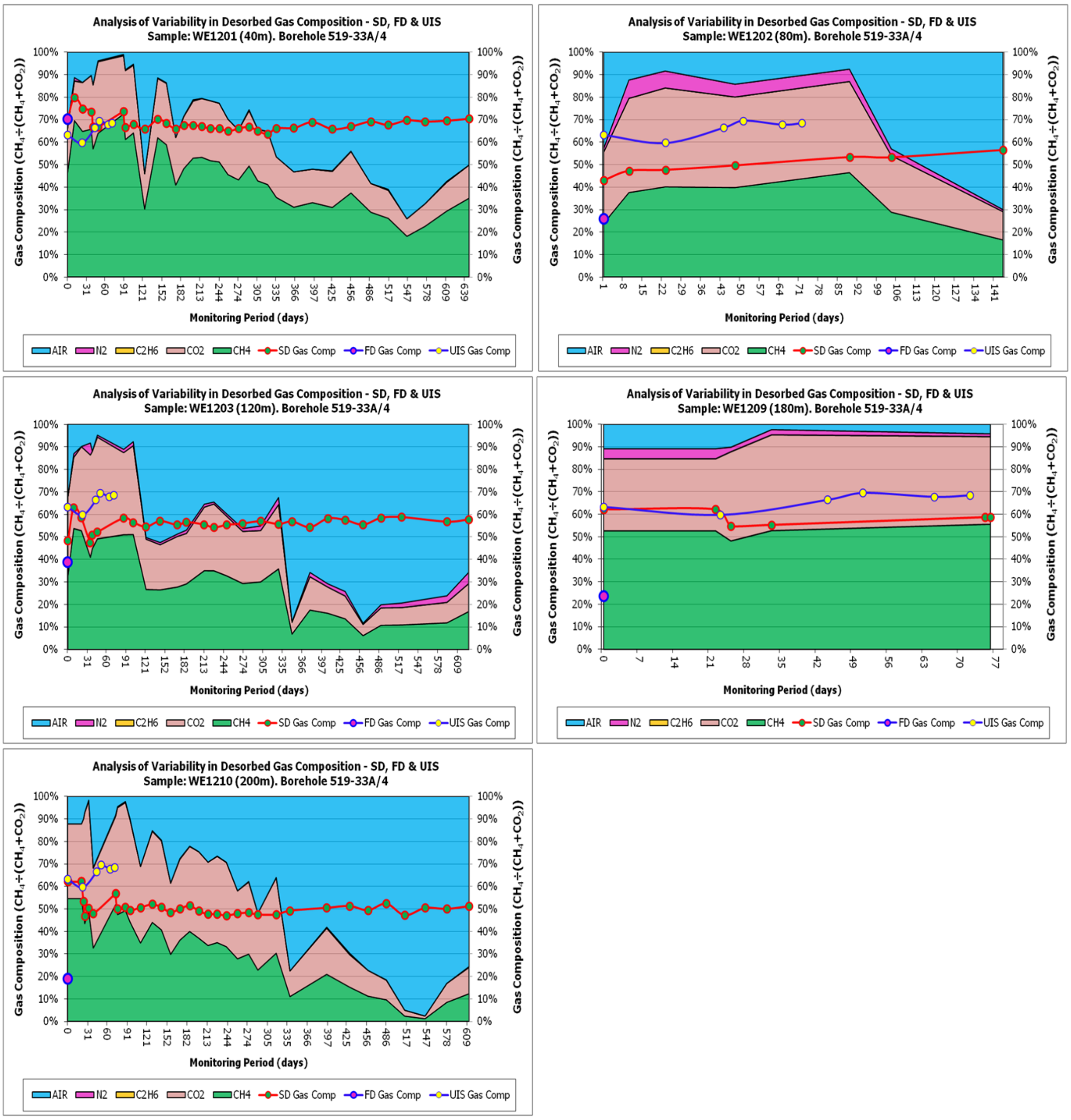

Figure 11: Recorded gas composition during SD testing of WE1201, WE1202, WE1203, WE1209 and WE1210 including FD and UIS gas composition values

The recorded CH_4 component of the seam gas produced from the UIS borehole varied relative to the values determined from testing on the five core samples collected along the length of the borehole. The average CH_4 component recorded during SD testing from core WE1201 was 2% greater than the average value recorded from the UIS borehole, while the average CH_4 component recorded from the other four core samples was between 9% and 16% less than the borehole average. This result suggests a large portion of the total gas produced from borehole 519-33A-04 is likely to have originated from the coal seam adjacent to core sample WE1201 and/or from sections along the length of the UIS borehole containing comparatively high CH_4 levels.

Table 5 provides a summary of the gas composition values recorded from FD testing, and the average gas composition values recorded during SD testing, on the core samples collected from UIS borehole 519-33A/4 along with the estimated gas composition values based on contoured exploration data and the average gas composition of the gas produced from the UIS borehole.

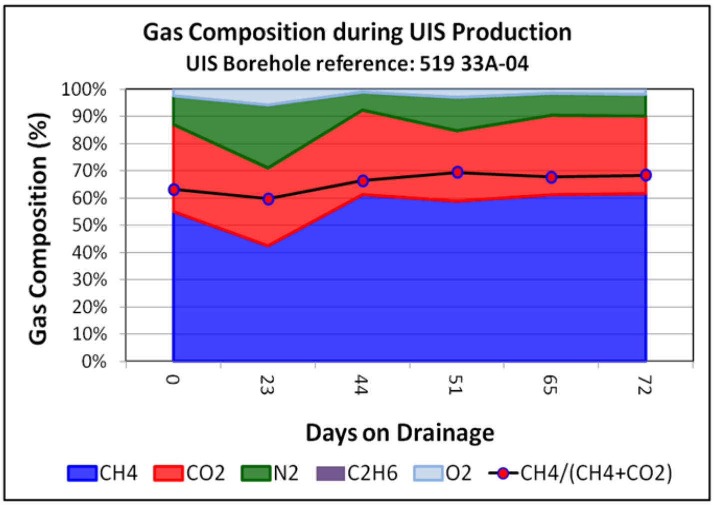

Figure 12: Recorded gas composition during gas production from UIS boreholes 519-33A/4

Table 5: Summary gas content and gas composition data at core sample locations in UIS borehole 519-33A/4

Reference Borehole: 519-33A/4

UIS Core Samples	Gas Content (m^3/t)		Gas Composition (CH_4÷{CH_4+CO_2})(%)			
	Exploration contours (est.)	UIS Gas Content	Exploration contours (est.)	Fast Desorption	Slow Desorption (average)	UIS Gas Production (average)
WE1201	8.3	10.6	20	70	68	66
WE1202	8.3	12.2	19	26	50	66
WE1203	8.4	13.9	20	39	56	66
WE1209	8.4	13.8	20	24	57	66
WE1210	8.5	14.1	20	19	50	66

The CH_4 component of gas desorbed from the five core samples during SD testing was between 17% and 31% greater than the composition measured during the FD test. The increased CH_4 detected during SD suggest CH_4 desorbs from coal samples at a faster rate than CO_2, with CO_2 being retained within the sample and potentially not being released until late stage desorption, or until the coal sample is crushed (e.g. Q3 gas content measurement during FD testing).

In this area of the Bulli seam the CH_4 composition indicated by the contoured exploration gas data varies from being approximately 1% higher to approximately 20% lower than the values determined during FD testing. The results suggest the outbye section of this borehole is located in an isolated zone where the seam gas contains increased concentrations of CH_4.

GAS DATA RECORDED ALONG UIS BOREHOLE **519-33A/6**

The total length of UIS borehole 519-33A/6 was 1500m and based on gas composition contours generated from exploration boreholes located less than 750m from this borehole, the CH_4 component of the gas present in the coal seam along the length of the borehole varied between 14% to 23%, as shown in Figure 4.

Two core samples, WE1308 and WE1309, were collected during the drilling of this borehole. The CH_4 component of the gas released from the core samples during FD testing was 26% and 14% respectively. The average CH_4 component of the gas desorbed from core samples WE1308 and WE1309 during SD testing over a period of 196 days and 391 days was 45% and 17% respectively. The CH_4 component of the gas released from the two core samples during SD testing varied between 36% and 53% (WE1308) and 15% and 21% (WE1309), as shown in Figure 13.

One gas composition measurement was taken during gas production from UIS boreholes 519-33A/6 on day 18 and the CH_4 component at that time was 62%, as indicated in Figure 13. Additional gas composition monitoring was conducted on adjacent UIS borehole 519-33A/5 that recorded CH_4 component values ranging between 57% and 69% (65% average) between day 42 and day 182 of gas production from that borehole.

The recorded CH_4 component of the gas produced from 519-33A/6, and adjacent UIS boreholes, was consistently greater than the values recorded from core sample testing. In this area, it appears likely that 519-33A/6 was drilled through sections of the coal seam containing highly variable CH_4 levels, with high CH_4 levels present in the outbye end of the borehole and low CH_4 levels present at the inbye end of the borehole. Should this be the case, it is reasonable to assume that CH_4 would be preferentially desorbed from the coal, particularly in the comparatively high CH_4 zones, and the total component volume of CH_4 would exceed the volume of the CO_2 desorbed from the less CH_4 rich sections of the borehole. Details of incremental gas composition measurement along the length of the UIS boreholes were not available however the results of FD and SD gas content testing from core samples collected from the 519-33A boreholes, presented in Figure 14, show a decreasing CH_4 component from the outbye most samples (WE1201) to the inbye most sample (WE1309).

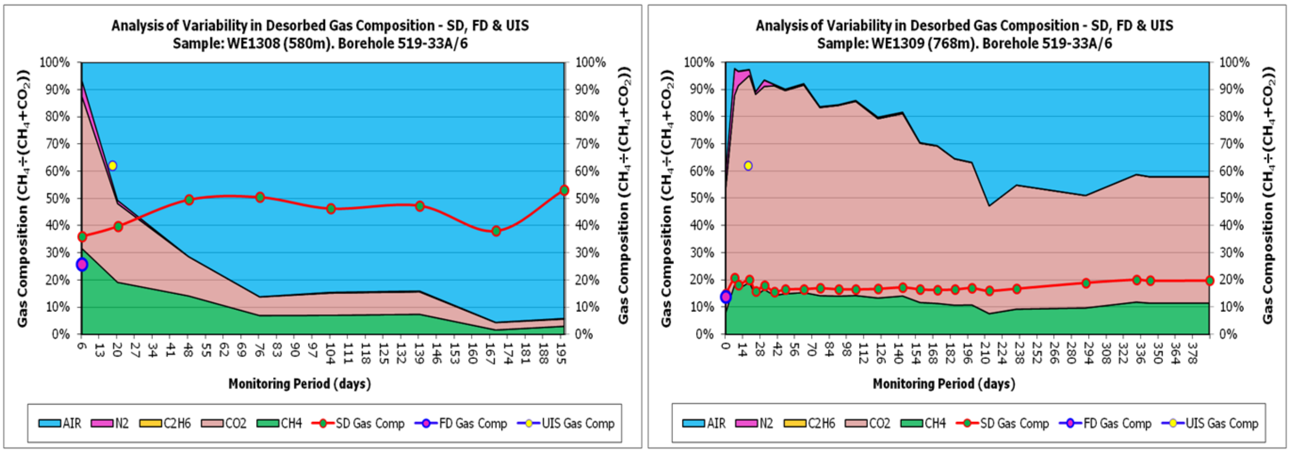

Figure 13: Recorded gas composition during SD testing of WE1308 and WE1309 including FD and UIS gas composition values

Table 6 provides a summary of the gas composition values recorded from FD testing, and the average gas composition values recorded during SD testing, on the core samples collected from UIS borehole 519-33A/6 along with the estimated gas composition values based on contoured exploration data and the average gas composition of the gas produced from the UIS borehole.

Table 6: Summary gas content and gas composition data at core sample locations in UIS borehole 519-33A/6

Reference Borehole: 519-33A/6

UIS Core Samples	Gas Content (m^3/t)		Gas Composition (CH_4÷{CH_4+CO_2})(%)			
	Exploration contours (est.)	UIS Gas Content	Exploration contours (est.)	Fast Desorption	Slow Desorption (average)	UIS Gas Production (average)
WE1308	8.8	12.5	14	26	45	62
WE1309	8.9	8.9	17	14	17	62

The CH_4 component of gas desorbed from the two core samples during SD testing was between 3% and 19% greater than the composition measured during the FD test. The increased CH_4 detected during SD suggest CH_4 desorbs from coal samples at a faster rate than CO_2, with CO_2 being retained within the sample and potentially not being released until late stage desorption or until the coal sample is crushed (e.g. Q3 gas content measurement during FD testing).

In this area of the Bulli seam the CH_4 component of the seam gas indicated by the contoured exploration gas data varies from being approximately 3% higher to approximately 12% lower than the values determined during FD testing. The results suggest the outbye section of this borehole is located in an isolated zone where the seam gas contains increased concentrations of CH_4.

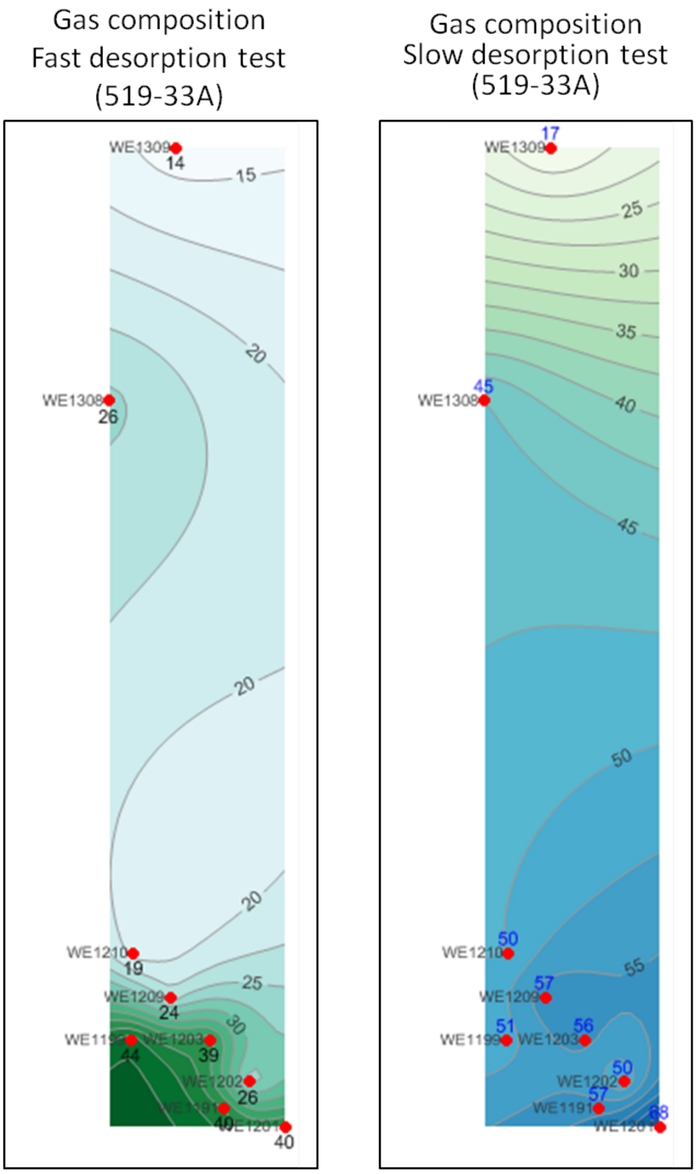

Figure 14: CH_4÷(CH_4+CO_2) (%) values from FD and SD testing on core samples from 519-33A boreholes

SUMMARY

Analysis of gas composition data collected during FD and SD testing on coal core samples collected from the Bulli seam while drilling UIS gas drainage boreholes has clearly shown that in the 13 core samples used for duplicate testing that the CH_4 component of the gas desorbed from the core during SD testing was an average of 20% greater with the difference ranging between 3% and 33%.

Figure 15 shows gas content and CH_4 component determined by FD and SD testing on 18 coal core samples collected from the Bulli seam. The results show similar gas content values were obtained using the two methods while the CH_4 component determined from FD testing was consistently lower than the values recorded during SD testing.

The increased CH_4 component of the gas released from the core during the SD test suggests the preferential release of CH_4 from the intact core sample with a preference for the CO_2 component to be retained within the coal matrix. At the completion of the SD test analysis of the composition of gas released during Q3 testing was not performed therefore the predicted decreased CH_4 component cannot be confirmed. This observation is consistent with previous work conducted by Crosdale (1998) who reported reduced CH_4 concentration of gas liberated from coal during residual gas content testing following the completion of SD testing.

Composition analysis of the seam gas produced from the UIS gas drainage boreholes from which the 13 core samples were collected also showed that in all but one case the CH_4 component was greater than the average values recorded during SD testing. The CH_4 component of the seam gas produced from the five UIS boreholes was on average 16%

greater than the average value determined from SD testing on the core samples, with the difference ranging from being 2% lower (WE1201) to 45% higher (WE1309).

Figure 16 shows median CH_4 component values determined from composition analysis on gas produced from UIS boreholes drilled into the Bulli seam from 20 drill stubs located along gateroads within the mine. The CH_4 components of the gas from individual core samples collected from those boreholes, tested using the FD method, are shown. The CH_4 component values obtained from FD and SD testing on duplicate coal core test samples that were collected from nine of the boreholes is also shown. The results clearly show that the in all 20 cases the CH_4 concentration of the gas produced from UIS boreholes is greater than CH_4 concentration recorded from core samples collected from those boreholes. The difference is particularly significant in mixed gas zones where the naturally occurring levels of CO_2 in the coal seam exceed 20-30%.

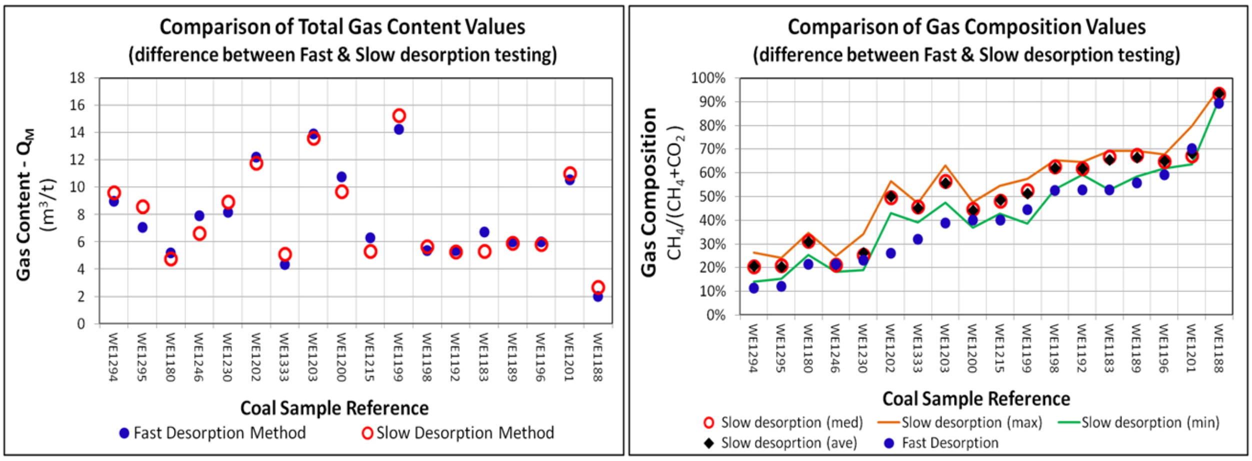

Figure 15: Results of FD and SD gas content and composition testing on duplicate Bulli seam coal core samples

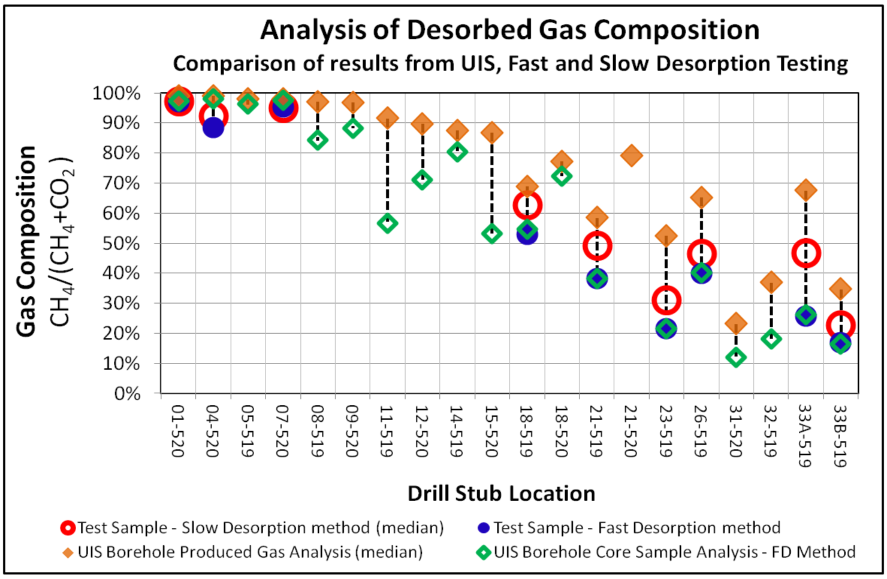

Figure 16: CH_4:(CH_4+CO_2) ratio values from duplicate FD and SD testing with values from FD testing and UIS gas production from boreholes drilled into the Bulli seam from gateroad drill stubs

Gas desorption measurements during mixed gas isotherm studies conducted by Mavor *et al.* (1992), Harpalani and Pariti (1993) and Greaves *et al.* (1993), cited in Crosdale (1998), suggest coal's affinity for CO_2 results in preferential liberation of CH_4 in response to reducing pressure, with coal retaining CO_2 until the pressure was less than 0.7 MPa. Mavor *et al.* (1992) suggest the significance of this behaviour is that boreholes producing predominantly CH_4 during the early periods of operation may produce an increased concentration of CO_2 as the reservoir becomes depleted.

The composition of the seam gas produced from the five UIS boreholes included in this study, whilst variable, did not show any clear sign of CO_2 enrichment during late stage desorption, as proposed by Mavor *et al.* (1992). The monitoring period was however relatively short, less than 150 days, therefore it is possible that during the monitoring period the reservoir pressure remained above the 0.7 MPa threshold level proposed by Mavor.

It is also quite probable that during the initial gas production phase from the UIS boreholes that gas is preferentially released from zones of comparatively higher CH_4 composition, in addition to the preferential liberation of CH_4 from the coal seam containing a mix of CH_4 and CO_2.

CONCLUSIONS

This study has clearly shown that in this area of the Bulli seam, where the seam gas contains a variable mix of CH_4 and CO_2, that the CH_4 component of the gas produced from UIS boreholes is greater than the CH_4 component of the gas liberated from cores samples collected from the UIS boreholes and tested using the SD method. The CH_4 component of the gas produced during SD testing was also found to be greater than the CH_4 component of the gas released from the core samples during FD testing.

The results of this study have highlighted a number of potentially significant factors that should be considered by mine planners when assessing the potential impact of coal seam gas on mine operations. The potential impacts, particularly in areas where seam gas is a mix of CH_4 and CO_2, include:

- *Potential inaccurate estimation of gas content and composition when contouring between measured data points obtained by surface-based exploration*. This study has shown that in eight of the nine locations considered, the gas content, determined by FD testing of core samples collected during UIS drilling, was at least 2.0 m^3/t greater than the values indicated by contour values generated using values measured by testing core samples collected during surface exploration drilling. The contours of the CH_4 component of the seam gas, generated using data obtained from surface exploration drilling and testing was also, in the majority of cases, less than the values measured during testing on core samples collected during UIS drilling. The results highlight the non-uniform distribution of gas content and composition of seam gas within coal seams and the potentially significant difference that may exist between actual conditions and the conditions that are indicated by contouring surface exploration data.
- *FD testing on coal core samples will potentially understate the level of CH_4 present in the produced gas, particularly in mixed gas conditions*. This study has shown that the CH_4 component of gas measured during FD testing was less than (a) the CH_4 component measured during SD testing, and (b) less than the CH_4 component of the gas produced from the UIS boreholes from which the core samples were collected. In such areas, where FD testing understates the actual CH_4 levels released during mining, there is a risk that CH_4 emissions will exceed expected levels.
- *Preferential release of CH_4 from the coal seam may result in increased levels of CO_2 being naturally retained within the coal seam*. If CO_2 is preferentially retained within the coal seam, what potential impact does such a condition have on outburst risk and the determination of appropriate outburst threshold limit? Further investigation is therefore warranted to closely monitor variations in gas composition during SD testing of coal samples containing a mix of CH_4 and CO_2 and to assess the significance of any potential reduction in CH_4 component of the gas remaining in the core samples determined during Q3 testing.

REFERENCES

Crosdale, P J, 1998. Degassing of methane and carbon dioxide: prediction of gas composition, Australian Coal Association Research Program, Project Report C5037.

Harpalani, S and Pariti, U M, 1993: Study of coal sorption using a multi-component gas mixture; Paper 9356; International Coalbed Methane Symposium, May 17-21, Tuscaloosa, Alabama, USA

Standards Association of Australia (SAA), 1999. Guide to the determination of gas content of coal – direct desorption method, Australian Standard, AS3980:1999.

Mavor, M J, Close, J C and Pratt, T J, 1992. Review of recent US coalbed natural gas reservoir research, in Proceedings of the Symposium on Coalbed Methane Research and Development in Australia, Coalseam Gas Research Institute – James Cook University, Townsville, November 19-21, Volume 2, pp 109-152.