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Abstract

The volumetric changes in the coal matrix (Coal Shrinkage), permeability under various gas environment conditions as well as perographical properties were studied in the laboratory. The shrinkage and permeability of coal were examined with respect to changing gas type and confining pressures. The shrinkage tests were carried out in high-pressure bombs while the permeability study was conducted in a specially constructed high-pressure chamber. Methane (CH4), carbon dioxide (CO2), nitrogen, (N2) and a 50%-50% volume mixture of CO2/CH4 gas were used in the study. The tests showed that under different pressure levels gas type affected permeability and shrinkage characteristics of coal. This paper presents a case study of Tahmoor Colliery, NSW, Australia and an overall discussion on coal shrinkage, permeability and coal petrography data of Tahmoor that permits a better understanding of the gas regime in this mine. The results are important to the further understanding of the inter-relationship between gas flow, the coal matrix and permeability in 'normal' and 'tight' coal conditions (locally referred to as disturbed coal).

Keywords

mine, tahmoor, study, case, mines, australia, regime, nsw, gas, impacts, petrography, coal, permeability, shrinkage

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Impacts of coal shrinkage, permeability and petrography on gas regime in mines Case study: Tahmoor coal mine, NSW, Australia

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Abstract

The volumetric changes in the coal matrix (Coal Shrinkage), permeability under various gas environment conditions as well as perographical properties were studied in the laboratory. The shrinkage and permeability of coal were examined with respect to changing gas type and confining pressures. The shrinkage tests were carried out in high-pressure bombs while the permeability study was conducted in a specially constructed high-pressure chamber. Methane (CH_4), carbon dioxide (CO_2), nitrogen, (N_2) and a 50% - 50% volume mixture of CO_2/CH_4 gas were used in the study. The tests showed that under different pressure levels gas type affected permeability and shrinkage characteristics of coal. This paper presents a case study of Tahmoor Colliery, NSW, Australia and an overall discussion on coal shrinkage, permeability and coal petrography data of Tahmoor that permits a better understanding of the gas regime in this mine. The results are important to the further understanding of the inter-relationship between gas flow, the coal matrix and permeability in 'normal' and 'tight' coal conditions (locally referred to as disturbed coal).

Keywords: *Coal, Methane, Permeability.*

1. Introduction

There are a number of factors that can contribute to the coal/gas regime. The physical structure of coal has a significant influence on gas storage and its sorption. Also, the gas retention characteristics of coal for any type of gas are strongly influenced by the composition and mineralization of the coal. A better knowledge of the coal mineralization and composition constitute a realistic way to gain a better understanding of the role of coal composition in the gas regime in the mine. This can be realized in practice by petrographic study on coals.

2. Site investigations

A program of site studies were undertaken to relate the changes in geological conditions to gas storage characteristics of the coal. Core samples were collected from two different locations in Tahmoor mine (Figure 1). Two areas, which were identified for the study, were designated as 800 and 900 locations. The geology of the Bulli coal seam in the area of 800 panel, from where the 'normal' coal in terms of drainability comes, could be described as benign, with normal conjugate cleat sets and no adverse geological structures and thus the mining conditions were considered as favourable. The 900 panel on the other hand was in a difficult to drain area. The 900 panel could be described as being geologically disturbed, with significant alteration of coal cleat directions, calcite infill into the matrix structure, readily seen near the top of the seam, major geological structures such as thrust faulting of nominal size, as well as igneous dyke activity. Mining conditions were therefore not favorable, and at times the mine resorted to the grouching (drill and blast) method of heading development, particularly in areas where the gas content levels were greater than the allowable

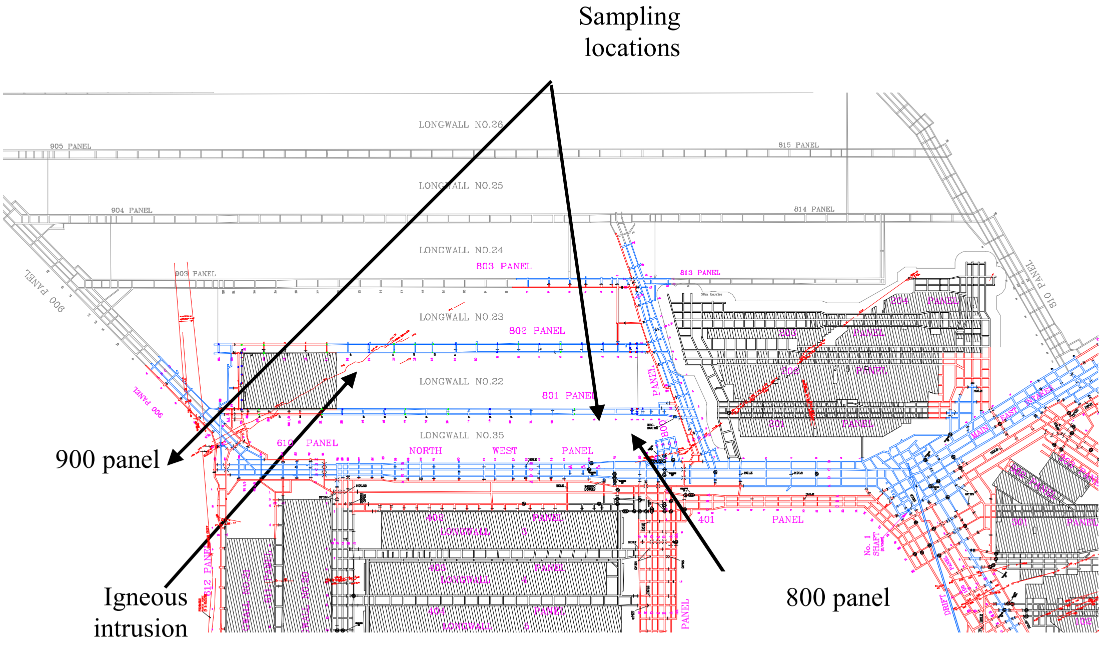

Figure 1. Tahmoor coal mine

From the above it is obvious that there exist significant differences in the permeability of the coal from one area to the other. In practical terms, this difference manifests as a relative difference in gas content after in seam drainage, if an overall inseam drainage time of 2–3 months is assumed. Table 1 shows the in situ gas content and composition around the 800 and 900 panels after gas drainage.

Table 1: Gas content and composition around 800 and 900 panels after in seam drainage [1]

	Panel Number	
	900	800
Total (m^3/tonne)	11.1	4.48
Methane (%)	20.4	6.5
Carbon Dioxide (%)	79.6	93.5

Of significance one the 900 panel samples which come from adjacent to the thrust fault and also from a non-structured area, both of which have significantly altered and mineralised coal. The programme of study undertaken to examine the parameters affecting the gas drainage capability of the coal from both locations included an analysis of the gas content and gas composition, as well as determining the shrinkage and permeability characteristics of coal.

3. Coal petrography tests

Petrographic study involves the microscopic analysis of the mineral and maceral content of coal, such as vitrinite and inordinate. For undergoing these tests each sample was crushed to –2mm and a representative sub sample mounted in polyester resin to form a block. Each block was cut in half perpendicular to any density separation, and the cut face from one of the halves polished. The macarel composition of each sample was determined by the method outlined in the Australian Standard AS2856.2-1998: Coal Petrography –Maceral Analysis. Maceral analyses for the samples are given in Figure 2.

Petrographically, the eight samples have similar organic components with vitrinite contents ranging from 56% to 78 %, inertinite from 18% to 32% and negligible liptinite.

Petrographically, the eight samples have similar organic components with vitrinite contents ranging from 56% to 78 %, inertinite from 18% to 32% and negligible liptinite. However, the mineral contents of the samples are quite different. All of the 900 panel coals have a higher mineral content than the 800 panel coals, while two in particular contain a significantly higher mineral content. In each of the three samples, carbonate and clay filled the cleats and also some of the pores in the inertinite macerals. If the mineral content and species is common for the coal as a whole in 900 panel, the permeability and degassing problems associated with this panel can be explained in terms of petrography.

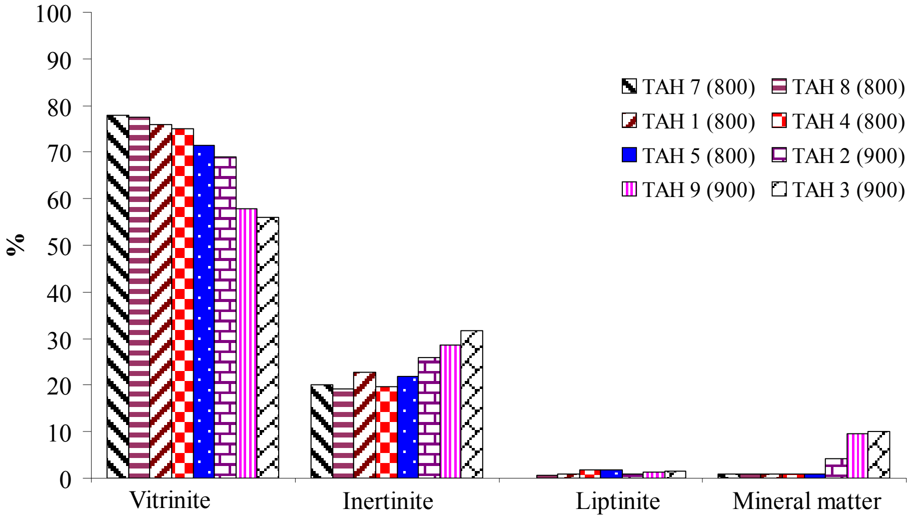

Figure 2. Maceral analyses of coal samples used in tests

4. Shrinkage tests

These tests of present study primarily concerned with experimental studies related to coal volume change under various gas types and pressures. Coal swelling and shrinkage tests were conducted in special bombs in an adsorption/desorption apparatus as described elsewhere by Lama and Bartosiewicz [2] and later by Aziz and Ming-Li [3]. All these tests were performed at a constant normal temperature of 25ºC. The gases used in the study were CH_4, CO_2, CH_4/CO_2 (50-50%), and N_2. All tests were conducted at incremental pressure changes of0.5 MPa .

Eight samples were tested for shrinkage, five samples were tested from 800 panel and three from 900 panel. Figures 3 and 4 show the incremental change in volumetric strain corresponding to the progressive reduction of gas pressure in the coal samples. It can be seen that the volumetric change for 800 panel samples was consistently higher than that for the geologically disturbed 900 panel.

5. Permeability tests

The permeability measurement of coal, under different loading conditions and gas type, was studied in purpose designed pressure chamber which is completely described by Sereshki et al. [4]. By this equipment and its facilities following items can be carried out:

- Apply and monitor axial load on coal samples placed in the pressure chamber.
- Monitor strain in coal by using strain gauges mounted on the sample
- Charge and maintain circumferential gas pressures around the coal sample and
- Monitor gas flow rate through the coal at suction.

By conducting tests the effect of stress as well as gas pressure on the permeability of coal samples were determined. The results show a marked difference in permeability between the 800 and 900 panel coals. The difference in permeability between 800 panel and the 900 panel coal for each of carbon dioxide and methane (Figures 5 and 6) is quite significant, with 800 panel having approximately three times greater permeability when compared to the 900 panel coals.

6. The test results and analysis

Results of the petrography tests on Tahmoor coal samples are summarized in the Figures 7 to 9. As it can be seen from Figure 7, the vitrinite content of coals from panel 800 were 20% times more than coals from 900 panel.

On the other hand the 900 samples had more inertinite than 800 coals, around 30% more. Analysis of mineral matter indicated that the main minerals, carbonate and clay were found more in 900 samples than 800 coal samples (near 7 times as much). It may be noticed that there is not much difference between vitrinite values for the two panels, therefore the mineral matter and inertinite content (as a result of the contained mineral matter) is influencing the permeability and shrinkage characteristics of coals from the two panels.

Figure 8 illustrates that the shrinkage of Tahmoor coal samples increased 5 fold by

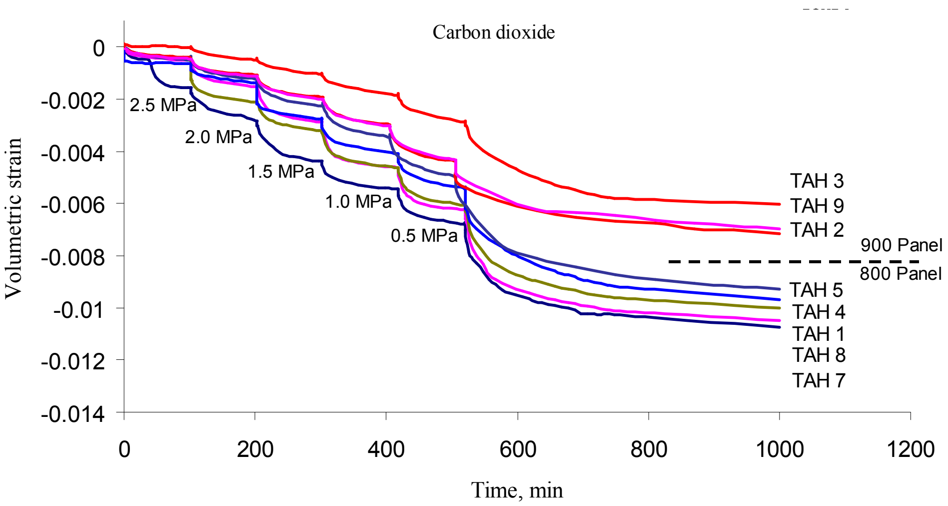

Figure 3. Volumetric strain for CO_2 and pressure reductions at increments of 0.5 MPa

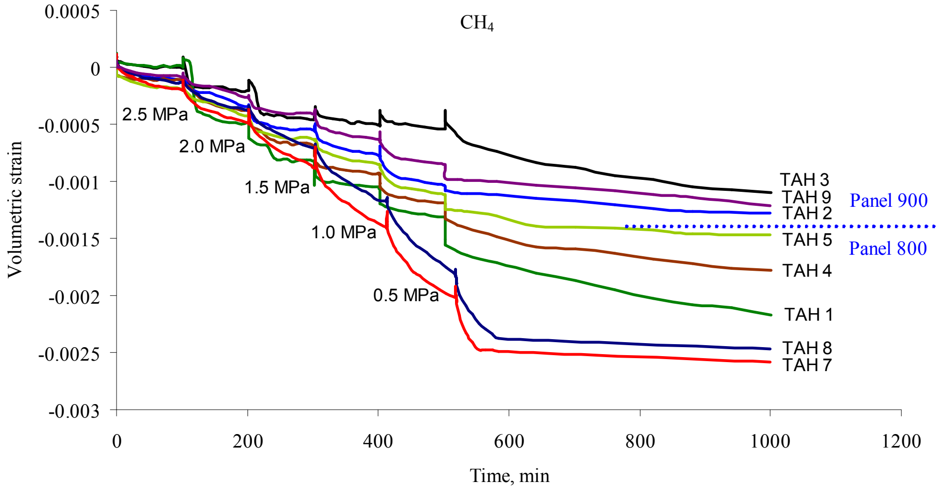

Figure 4. Volumetric strain for CH_4 and pressure reductions at increments of 0.5 MPa

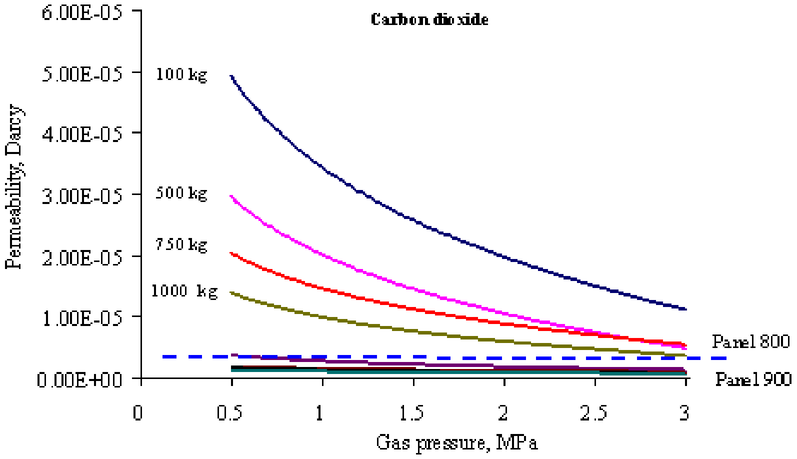

Figure 5. Permeability of samples from 800 and 900 panels to carbon dioxide at different axial loads

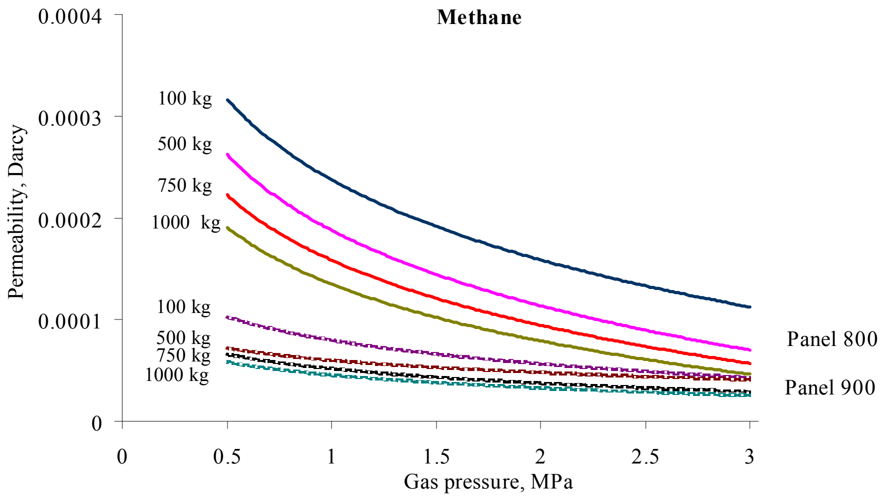

Figure 6. Permeability of samples from 800 and 900 panels to methane at different axial loads.

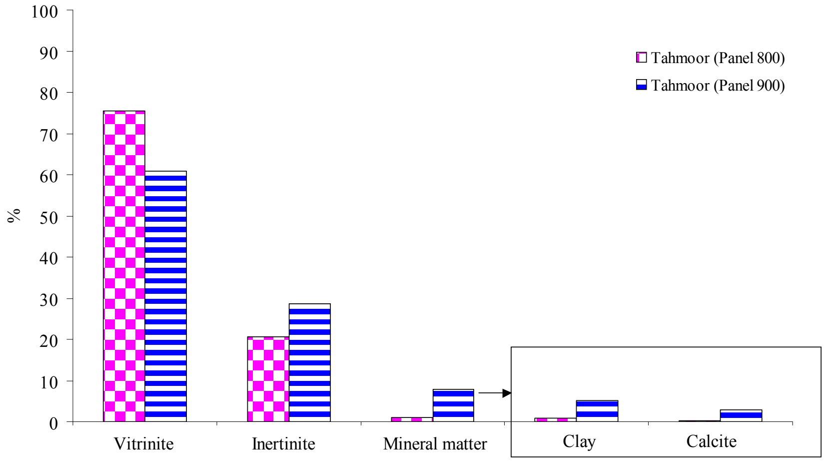

Figure 7. The petrographical test results for Tahmoor Colliery coal samples

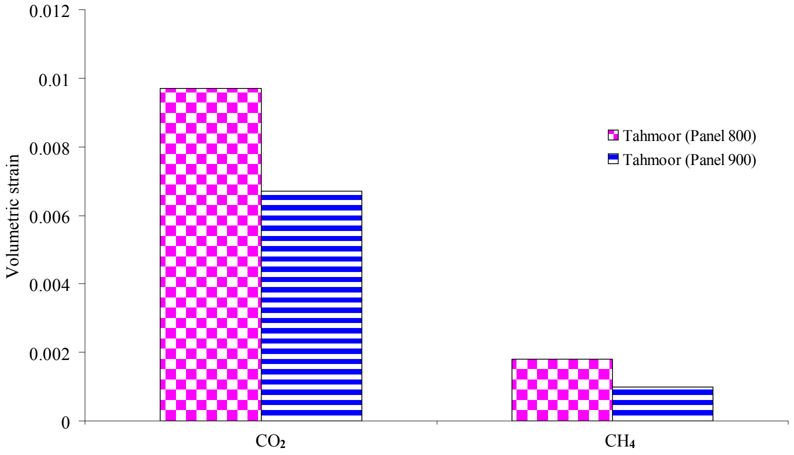

Figure 8. The shrinkage test results for coal samples from 800 and 900 panels (Tahmoor Colliery) under different gas environments.

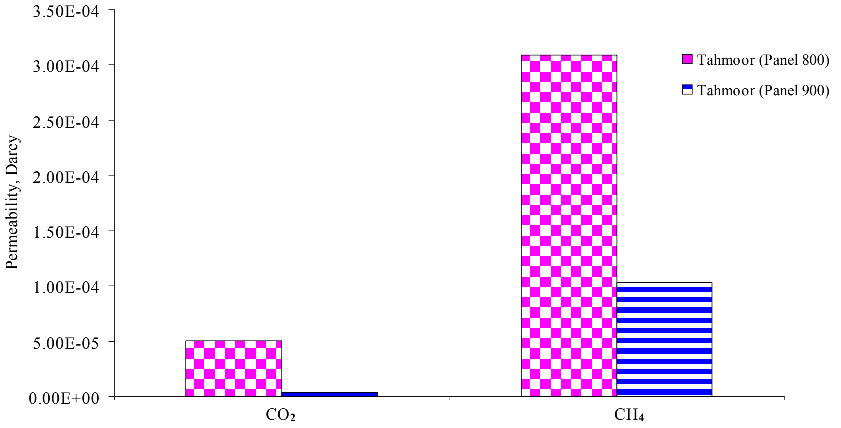

Figure 9. The permeability test results for 800 and 900 panels coal samples (Tahmoor Colliery) under 100 kg axial load and 0.5 MPa gas pressure.

changing the gas environment from CH_4 to CO_2. The effect of changing the tested gas on shrinkage of coal can be attributed to the affinity of gases to the coal. The insitu gas drainage flow rates in the mine were between 0.1 l/m to 8.67 l/m (average around of 2 -3 l/m) for 800 panel, and in the range of 0.8 l/m and 2.6 l/m for 900 panel [1]. From insitu observations and analysis of the flow rates from 900 panel it was apparent that CO_2 being dissolved in water results in lower coal matrix shrinkage and less drainage rates in comparison with 800 panel.

With the greater volume change occurring in 800 panel, the experiment clearly demonstrates that coal in this region has a greater capacity for inseam gas drainage than that of 900 panel, exactly what was experienced by the mine drainage system.

The 900 panel was considered to be a ‘difficult to drain’ area as it was highly stressed due to geological structures. After instigation of inseam drainage, the effective stress will change by a lesser magnitude as does the pore pressure, but not to the extent that free flowing drainage could be achieved. Unlike in the 800 panel area, which has shrinkage nearly twice that of the 900 panel area, this causes good drainage and greater change in effective stress from pore pressure is envisaged, particularly in the CO_2 environment.

The permeability tests results (Figure 9) for both carbon dioxide and methane show that the 900 panel coals have much lower permeability than the 800 panel coals.

Since permeability is a function of a number of parameters including size, distribution and frequency of cleats, any phenomenon that reduces cleat porosity will decrease permeability. Given that 900 panel coals contain a much higher mineral matter content than the 800 panel coals, and also have the lowest permeability, it is suggested that the reduced porosity of the 900 panel coals is due to the infilling of the cleats with carbonate. The reduced permeability also explains why the 900 panel area is much harder to drain. The carbonate and clay infilled cleats restrict the movement of gases from the surrounding coal to the gas drainage holes. This is in agreement with the Titheridge [5] explanation for the low permeability of Tahmoor coal samples. Also from Figure 9 it can be found that the permeability of 800 coal samples to CO_2 were near 16 times more than 900 samples however this ratio was decreased to 4 by switching the tested gas to CH_4. Analysis of the results suggested that inertinite rich coal would show better drainability characteristics than those that were vitrinite rich. This hypothesis, supported by the work of the Crosdale et al. [6], Gamson and Beamish [7], Curl [8] and Creedy [9], but not by the work of Clarkson and Bustin [10], is generally accepted for Australian coals. Analysis of Figure 7 to 9, however, does not support this view, as the inertinite rich coals of Tahmoor 900 panel are more difficult to drain than the vitrinite rich coals of 800 panel. Thus it can be concluded, that although under ‘normal’ circumstances, inertinite rich coals have higher permeability, when local alteration takes places (such an increase in mineral content) the opposite may occur. This is the situation for Tahmoor 900 panel, where a localised intrusion caused significant alteration to the coal in that immediate area.

7. Summary and overall discussion

By observing the data from coal shrinkage tests, it was demonstrated that under the same testing conditions all samples showed higher shrinkage in a CO_2 environment than a CH_4 environment. Based on analysis it can be concluded that, in general, with increasing inertinite content of coal the volumetric strain increases, however the relative increase for CH_4 was less than that CO_2. Micropore structure of coal and cause a high amount of shrinkage for methane desorption. It should be considered that it is possible for a coal sample to have relatively good permeability to methane but if the dominant gas is carbon dioxide, there isn't any guarantee that the coal still demonstrates good drainability characteristics.

8. Conclusion

The material reported in this paper has demonstrated the degree of influence factors such as gas type and pressure, and in particular coal composition have on permeability dependent on gas type and pressure. Carbon dioxide gas appears to cause the highest volume change. This is understandable in view of the fact that coal has higher affinity for carbon dioxide gas than the other gases tested.

Coals in the 800 locality have higher shrinkage coefficients than those obtained from the 900 area, suggesting that 800 area is more easily drained in comparison to 900 area. Permeability and petrographic data, as well as previously reported shrinkage results, confirm that the coals from the 900 and 800 panel area are markedly different. This has had consequential results for the efficiency of the mining cycle in these two areas of the mine.

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