PS Seismic and Strain Relevance of Coal to Its Shrinkage and Swelling Rate during the Sorption Process of CH_4 and CO_2*

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Abstract

Highly porous bituminous coals have a high adsorptive capacity for CO_2 and CH_4. This experiment aims to find the adsorption and desorption for coal with CH_4 and CO_2 gases under in situ pressures. Since coal undergoes volumetric deformation during the sorption process, this experiment targets to find the relevance of coal deformation with respect to strain measurements and the change of seismic properties of coal specimen.

METHODOLOGY

Throughout the experiment, three major components are integrated: coal sorption setup, strain gauge setup, and seismic transducers with digital phosphor oscilloscope.

Coal sorption setup: About 1 cubic inch of a coal sample is subjected to gas (N_2, CH_4, and CO_2) pressures of up to 1,400 psi in a reactor cell. A reference cell is used for step-up and step-down procedures. Finally, a mixing cell is used for mixing different gas compositions in the desired ratios. These three cells are interconnected with 1/4" steel pipelines and gas flows are controlled by operating valves. High precision pressure gauges are also attached in each cell for monitoring gas pressure readings.

Strain gauge setup: A Tee Rosette type of 120 Ω resistance is glued to the sample. This gauge is wired to a CR10X data logger through a 120 Ω module, which aids in completing a Wheatstone bridge configuration for accurate strain measurements.

Transducers with digital phosphor oscilloscope: Contact ultrasonic transducers are used to generate and receive longitudinal waves through the sample with a 5077PR pulser/ receiver. The travel time for these pulses through coal is observed in the oscilloscope and is used to calculate seismic velocity and attenuation.

RESULTS AND DISCUSSION

On a raw basis, powdered Drywood coal having particle size of <20 mesh at 72.0 °F has a methane content of 11.4 scc/ gms. This is according to Langmuir's coefficient under gas pressures of 4.17MPa. In this experiment, we attain adsorption and desorption isotherms under temperatures of around 80.0 °F and under gas pressures of 9.6 MPa. Coal undergoes shrinkage and swelling during adsorption of CO_2 and desorption of CH_4. These volumetric deformations are measured through contact transducers and biaxial strain gauges. Comparing the sorption results with seismic analysis would enhance predictions of coal behavior in the field for CO_2 sequestration.

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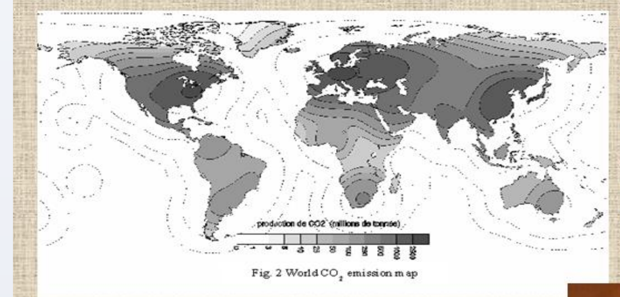
Background



Source: Prof. eng. Alexandru Naghiu, PhD

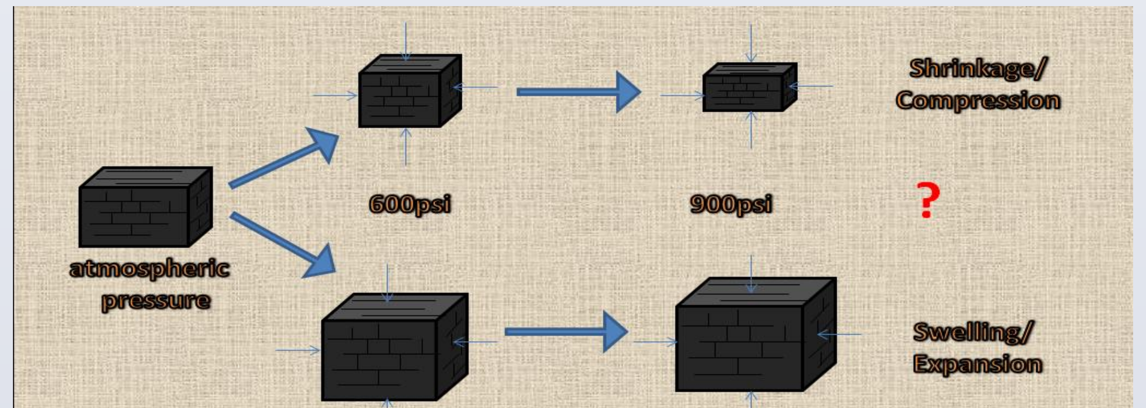
Our prolonged dependency on Cement and Energy has continuously led to an increase in CO_2 levels in the atmosphere; one of the green house gases. Alternative approaches to alleviate the levels of CO_2 has led to findings of several permanent potential CO_2 sinks.

Researchers are making constant effort in finding the accuracy and performance of such CO_2 sinks.

One such is the behavior of thin unmineable coal beds. Carbon Sequestration is a relatively new concept to inject CO_2 and drive off the remaining CH_4 molecules (Enhanced Coal Bed Methane).

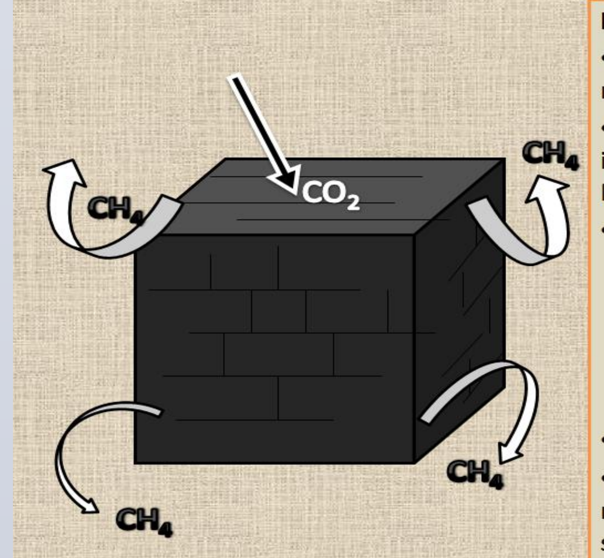
Source: Stephen Leahy, IPS

Hypothesis



The Hypothesis is that when Coal is subjected to increasing gas pressures, mechanical deformation occurs and if sorption of gas in the coal matrix occurs, the acoustic travel time changes and so does the strain experienced.

CH_4, CO_2 & Coal



Bituminous Coal

- A porous sedimentary rock made of macerals
- Formed in the carboniferous period in the late Paleozoic era (359 Ma to 299 Ma).
- Has a well defined cleat system
  - face cleat : runs parallel to the bedding plane
  - butt cleat: runs perpendicular to bedding plane and terminates at face cleat.
- Contains 50-60% of carbon.
- Also contains hydrogen, oxygen, nitrogen and a varying amounts of sulfur.

Previous Studies

Sinkinson and Turner 1914

In a powdered state higher grade coal adsorbs more CO_2 than does lower grade. Water saturated with CO_2 is more readily adsorbed by coal than CO_2 gas.

Carolus 1980

Thickness of coal slabs can be measured through ultrasonic acoustic transducers.

Levine 1996

CO_2 causes a greater degree of coal matrix swelling than does CH_4

Tarasevich 2001

High adsorptive ability of coal is aided by the micro and meso pores in coal. This unique structure adsorbs various organic molecules from water.

L. J. Pekot; S. R. Reeves 2002

Coal matrix shrinkage and swelling can cause profound changes in porosity and permeability.

Karacan 2007

Microlithotypes with maceral compositions that are higher in vitrinite, mineral & clay have higher porosity than compared to vitrinite and liptite.

Majewska, Zofia; Ziętek, Jerzy2008

Acoustic emission is a good indicator to determine the physical deformation of coal.

Experimental Setup

The Experimental Setup

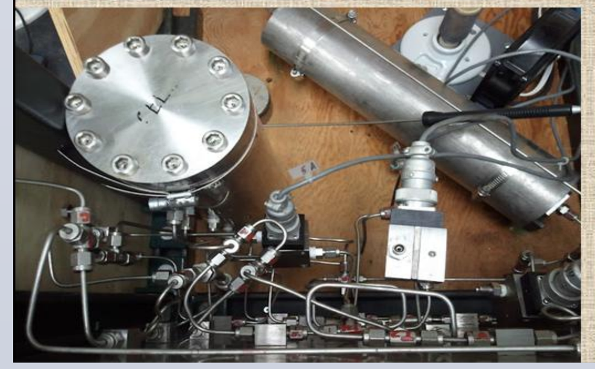
1. Adsorption Chamber: For pressurizing the specimen with gases.
2. CR10X data logger: To read and log the voltage output from the gages.
3. Digital Phosphorous Oscilloscope: To read and capture images of ultrasonic waveforms.

Sample Preparation

1.A block of Mulky coal cut to required specimen size
2. Specimen size of 1"-1.5" cube was maintained.
3. Smooth and clean surface was achieved according to strain gauge application guidelines.

Carefully selected measuring side which had well developed & noticeable fractures/ cleat system.

Sorption Device



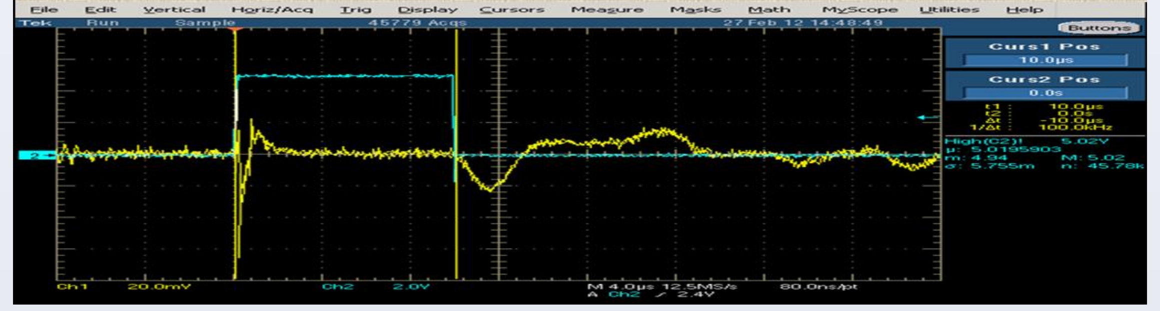
Adsorption Chamber

- Storage Cell
- Sample Cell
- Reference Cell
- ¼" steel pipe network the entry and exit operated through valves
- Highly sensitive pressure gauges

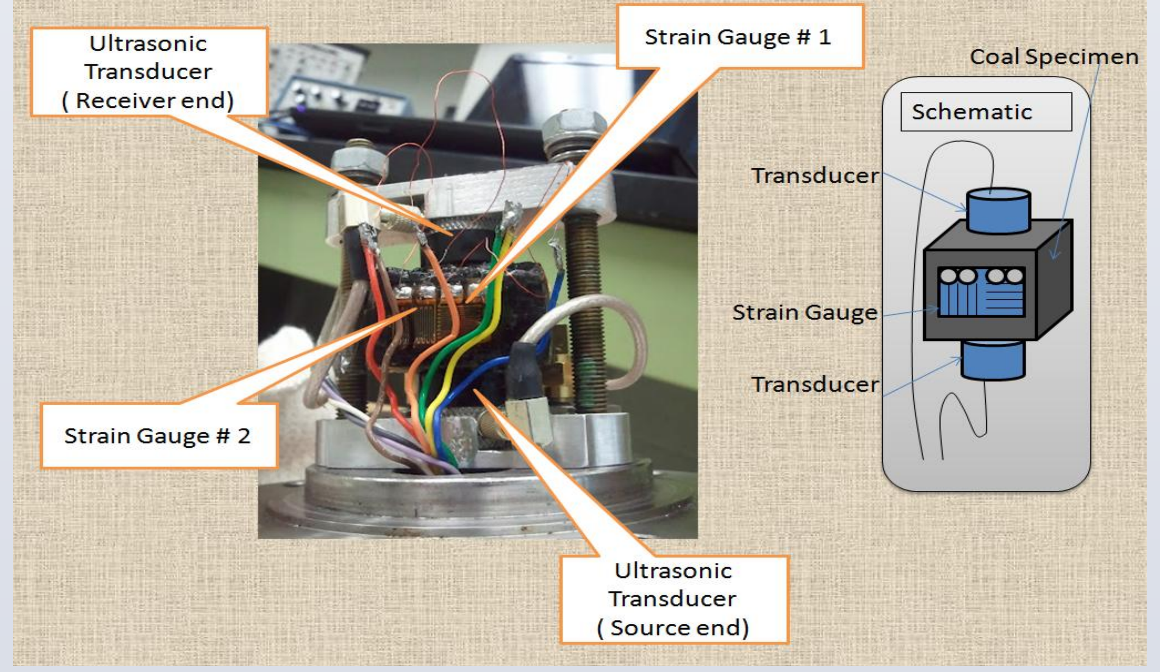
Seismic Testing

DIGITAL PHOSPHOROUS OSCILLOSCOPE (MODEL 5032B)

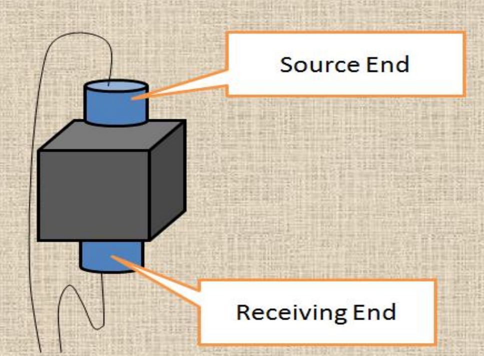
- Electronic plotter of the X-Y plane
- Shows variations in voltage on Y-axis along time on X-axis
- Different color traces for different inputs or signal types or even parts of the displayed signal than compared to the traditional oscilloscope.



Specimen Setup



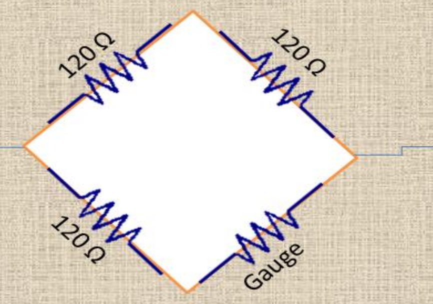
Acoustic Data Interpretation



The source end transducer sends a 1MHz pulse through the medium and the pulse is received by the transducer in the receiving end.

First arrival is the peak which arrives first at the receiving transducer

Strain Data Interpretation



$$\mu\text{-Strain} = \frac{K * Vr}{(GF * (DenFac))}$$

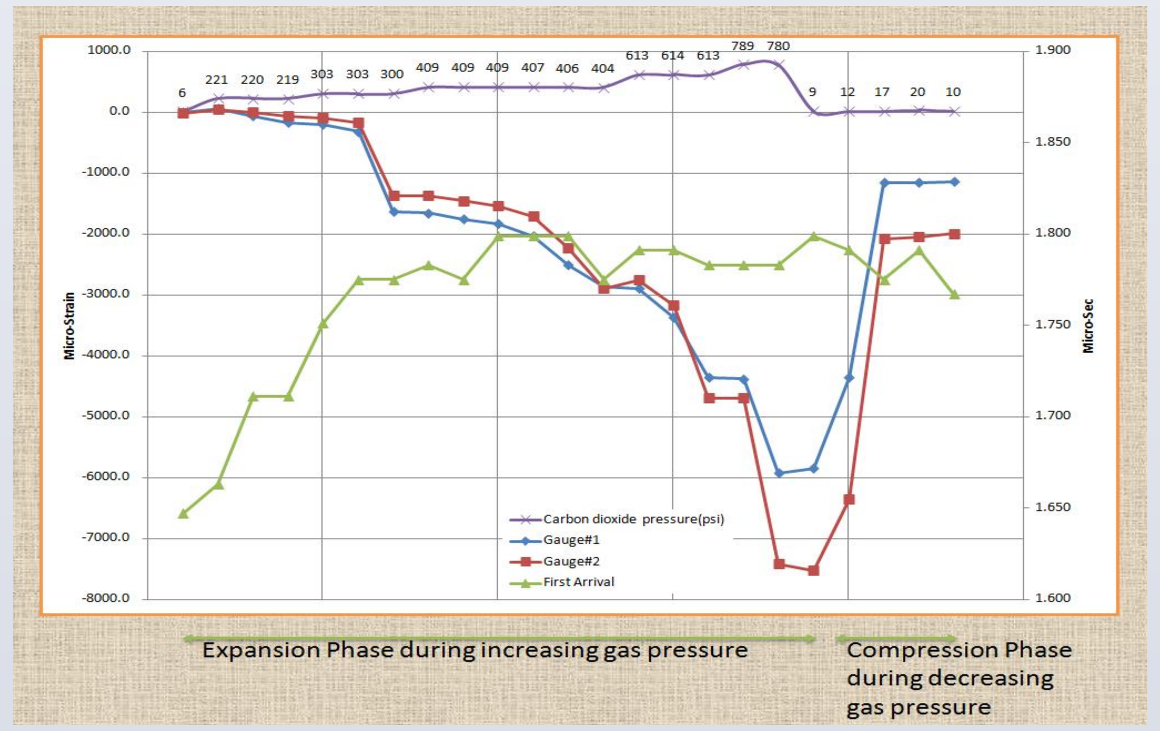
Vr = 0.001* (Voltage output final- Voltage output initial)

K= -4000000, Gage Factor= 2, DenFac= 1+2*Vr

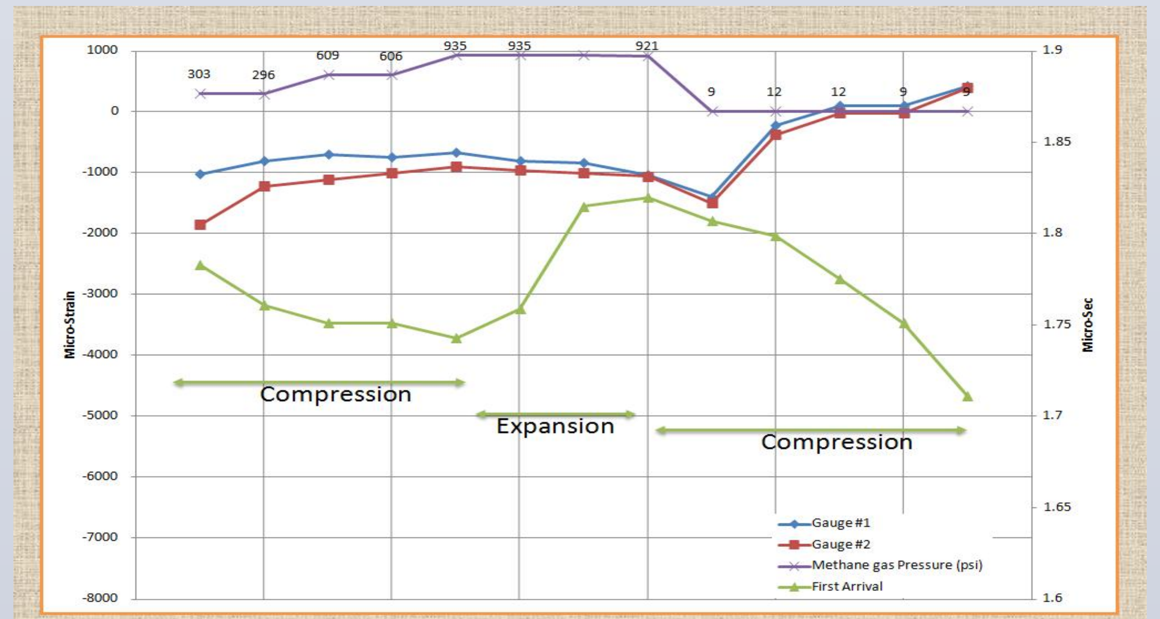
If Micro-Strain is sloping towards negative axis then the sample is in the expansion phase.

If Micro-Strain is sloping towards positive axis then the sample is in the compression phase.

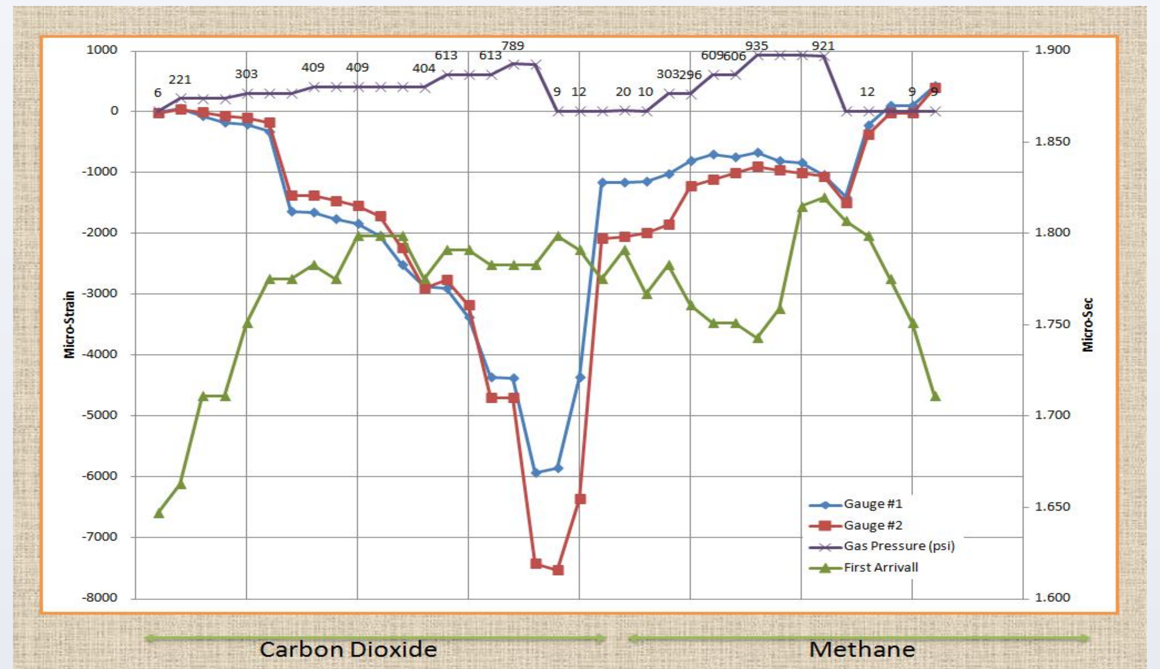
Results (CO_2 Cycle)



Results (CH_4 Cycle)



Results (CO_2 Cycle and CH_4 Cycle)



Conclusions

- The specimen experienced expansion when subjected to increasing CO_2 gas pressures which is congruent with increasing travel time and increasing strain.
- While depressurizing of CO_2 gas the specimen experienced compression, again congruent with decreasing travel time and decreasing strain.
- It is observed that during CH_4 cycle the initial increase in pressure resulted in compression of specimen but at higher pressures expansion took over, although a clear compression is observed during depressurizing the specimen in this CH_4 cycle.

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