Characterisation of Surat Basin interburden and overlying sandstone

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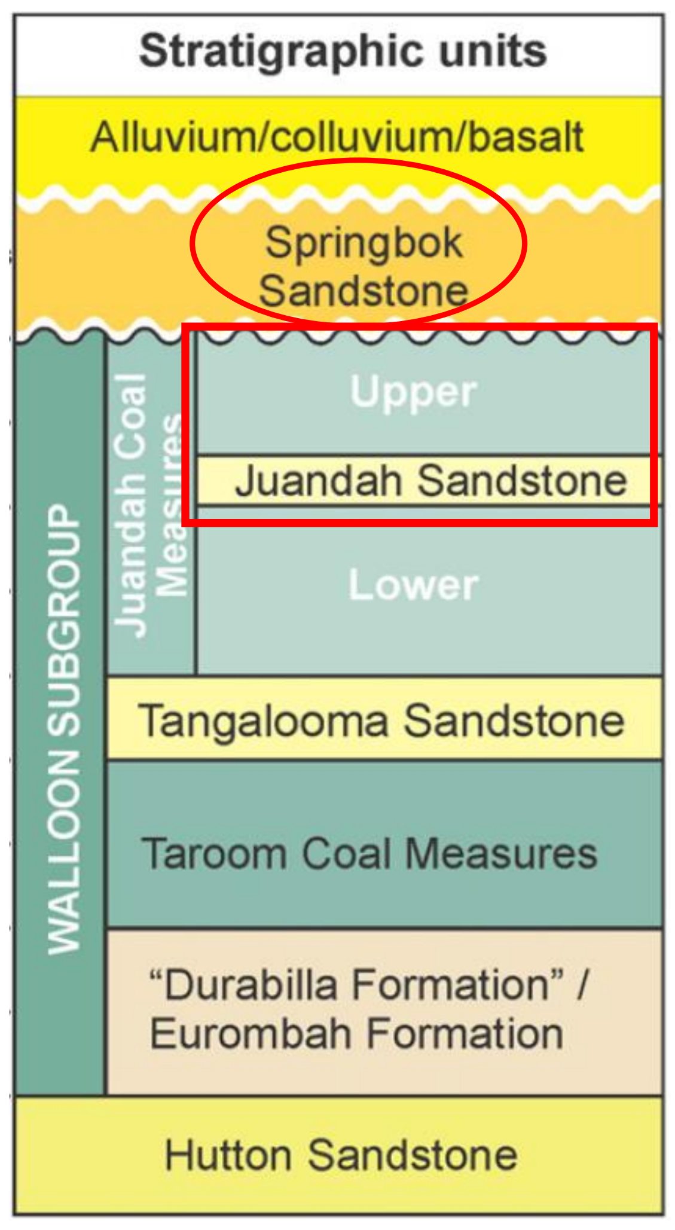
Problem definition

The Surat Basin is one of the world’s premier producers of natural gas from coal seams. This project investigates the:

- The potential for clay-rich interburden in the upper Juandah to hold or produce gas.
- The origin of historic gas shows in the Springbok Sandstone an overlying aquifer.



S.No.	Sample depth (m)
1	43
2	53.3
3	55.8
4	61.25
5	78
6	99
7	111.8
8	129.4
9	140
10	145.8
11	281.53
12	295.3
13	307
14	322.2
15	327.8
16	342.15
17	583.6

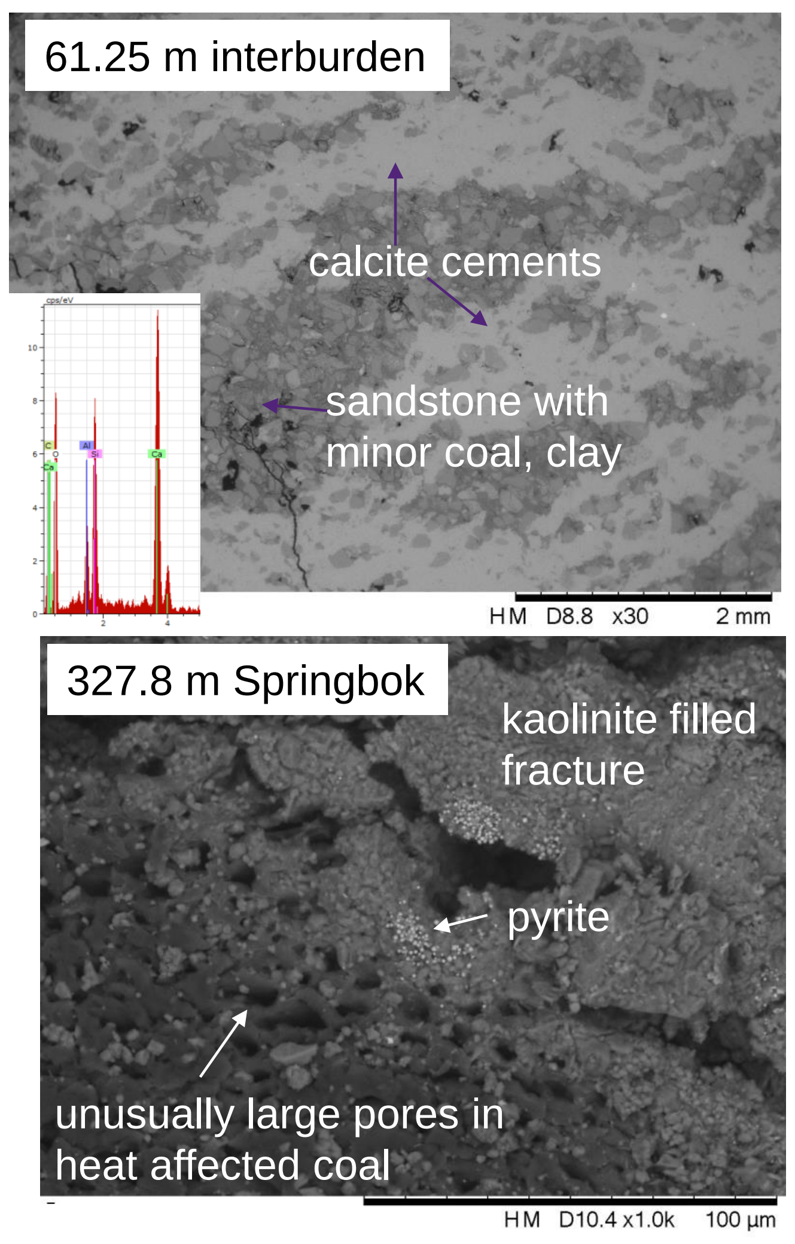


***Figure 1:** Walloon Subgroup stratigraphic sub-units (modified from K.A. Baublys et al. International Journal of Coal Geology 147–148 (2015) 85–104). Core sample depths are also shown. SEM images and EDS spectra are shown for calcite cemented sandstone 61.25 m, and unusually large pores in likely fracture-heat affected coal in the Springbok which may have affected gas release. Note: Juandah and Springbok sampled from different well cores hence why Springbok samples are from greater depths here.*

Methodology

Characterisation of seventeen samples from various depths of two well cores:

1. Gas adsorption capacity
   - High pressure methane adsorption
2. Gas permeability
   - Triaxial stress permeameter
3. Pores characterisation
   - Mercury intrusion porosimetry
   - Helium pycnometry
4. Carbon analysis
   - Total carbon contents (TOC)
5. Physical structure and elemental analysis
   - Scanning electron microscopy (SEM) and energy-Dispersive X-ray spectroscopy (EDS)
6. Mineral (including clay analysis)
   - Quantitative powder X-Ray Diffraction with quantitative clay analysis
   - X-ray fluorescence (XRF) major elements + lost on ignition (LOI)

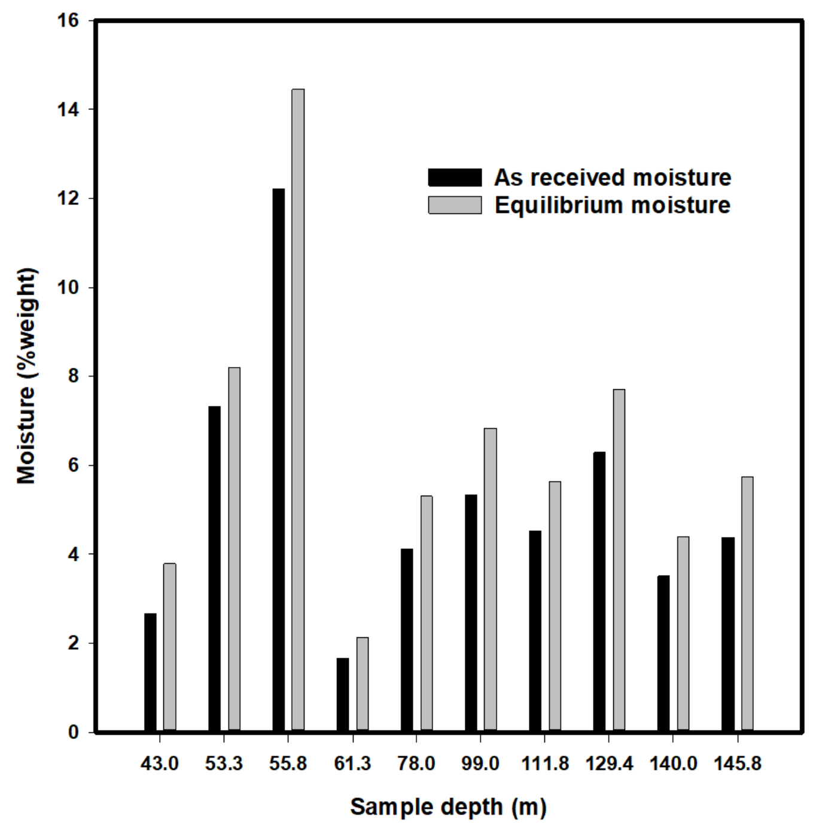
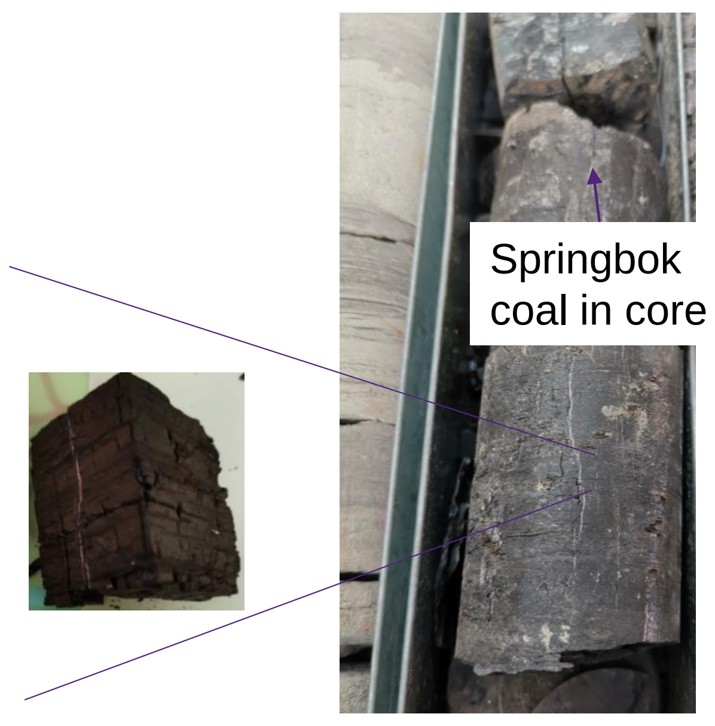


***Figure 2:** Moisture comparison between ‘as received’ and ‘Equilibrium moist’ samples. Equilibrium moisture achieved following ASTM D1412 standard using samples in wet K_2SO_4 environment in a vacuum desiccator at 30ºC. Below, a Springbok sandstone coal section.*



Absolute methane adsorption isotherm

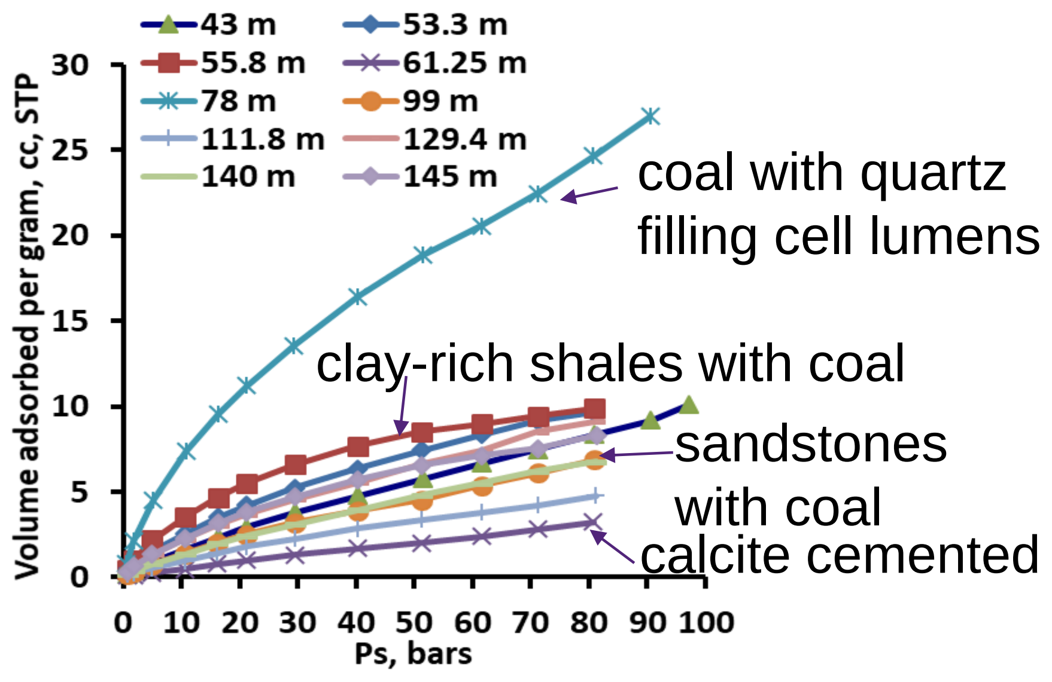


***Figure 3:** The methane isotherm for the tested samples from various depths. Generally the coal rich samples adsorbed more methane compared to other samples. The volumetric method is used for adsorption measurement with a HPVA II apparatus at 30ºC up to 90 bars. Prior to the analysis, the samples were crushed to ≤212 micron and vacuum dried for 8 hours at 105⁰C. The excess adsorption measured by the HPVA II converted to absolute adsorption using the helium free space measurement, corrected gas density and compressibility factor.*

Gas permeability

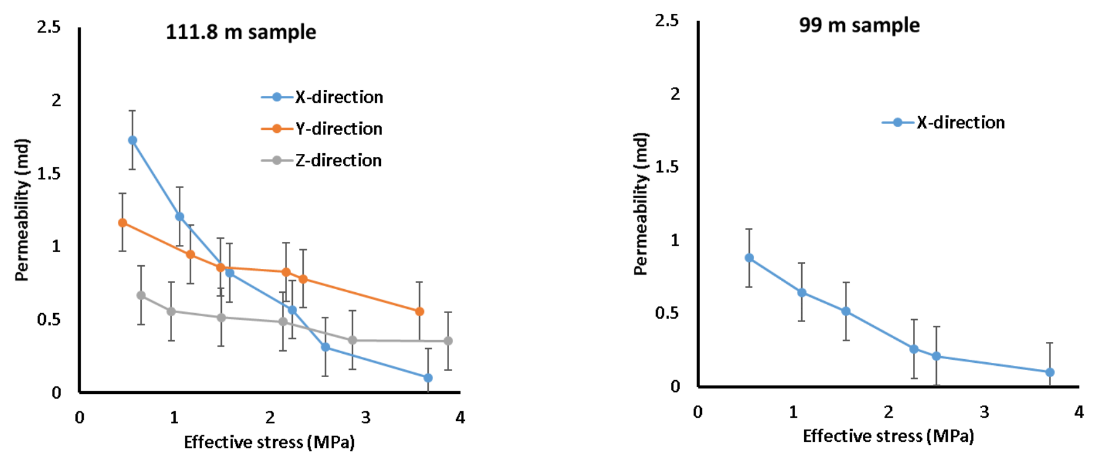


Figure: Anisotropic permeability (x,y, and z directions) permeability of 111.8 m sample shows maximum difference of <1.5 md, while 99m’s permeability change from ~1md to 0.1 which effective stress increased to ~4MPa

Pore characterisation

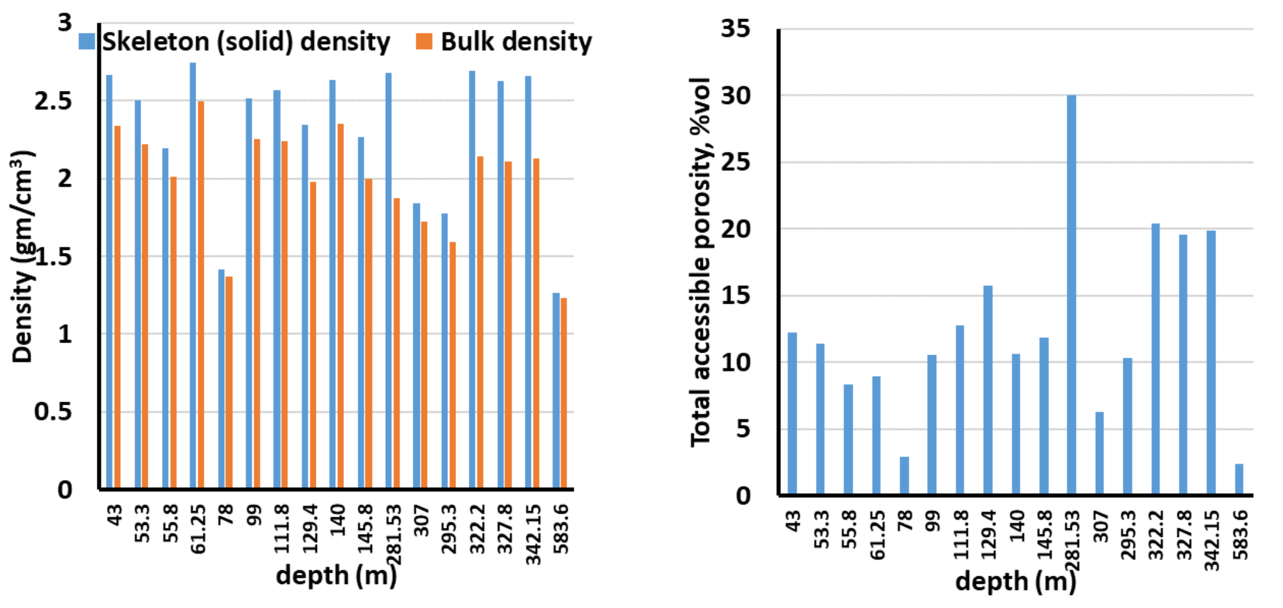


***Figure 4:** The skeleton density (ΦHe) and bulk density (ΦHg) is measured using helium pycnometry (AccuPyc II using ASTM D4892), and Mercury intrusion porosimetry (AutoPore IV using ASTM D4404), respectively. Only the densities of 78m and 583.6 m samples are measured close to coal density. The total accessible porosity (Φ) is calculated using the following equation (Gao, et al. 2017).*

$$\phi(\%) = \frac{\rho_{He} - \rho_{Hg}}{\rho_{He}} \times 100$$

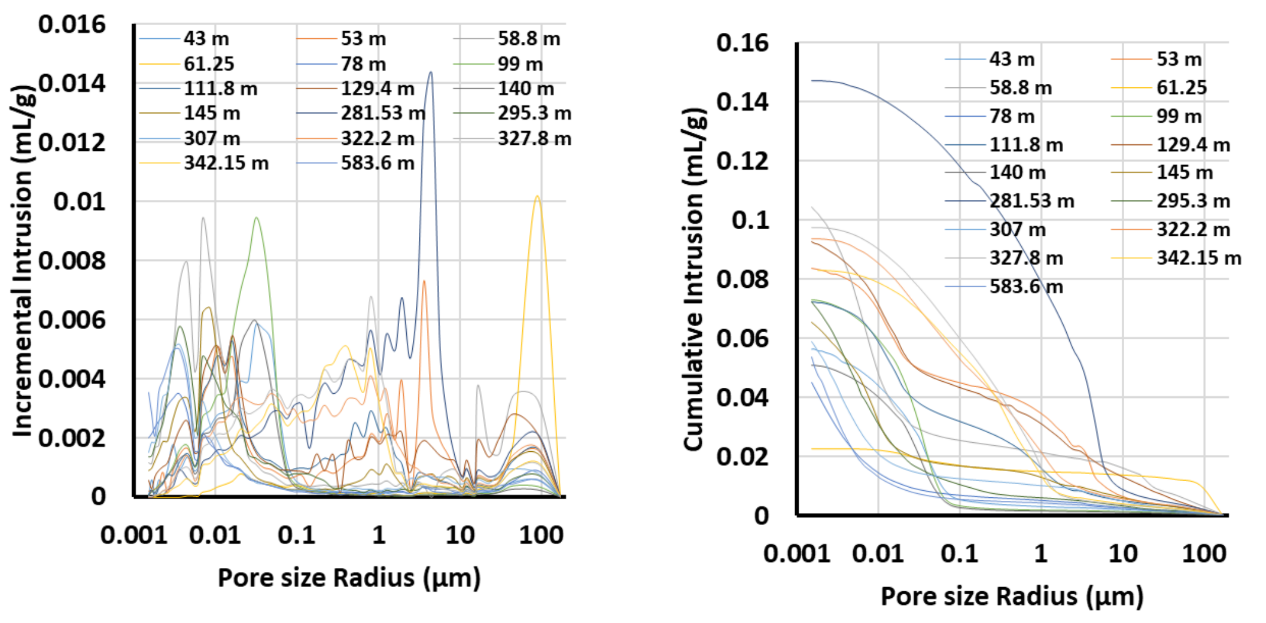
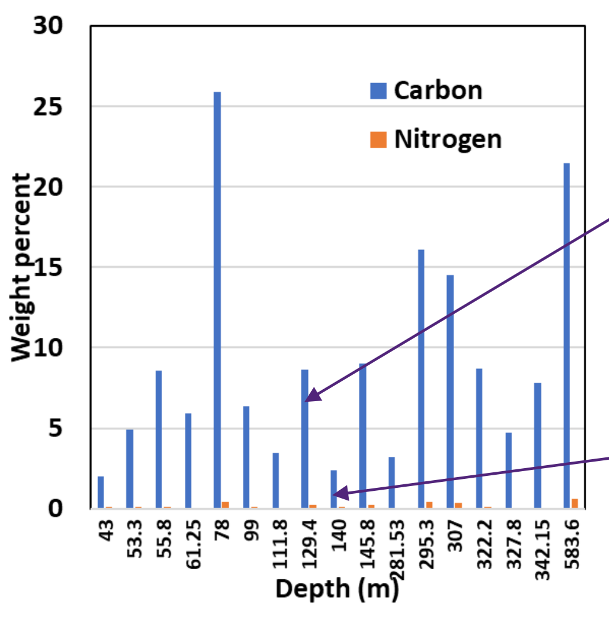


***Figure 5:** Pore size distribution of the samples plotted in term of incremental and cumulative pore volume using mercury intrusion porosimetry.*

Total carbon contents



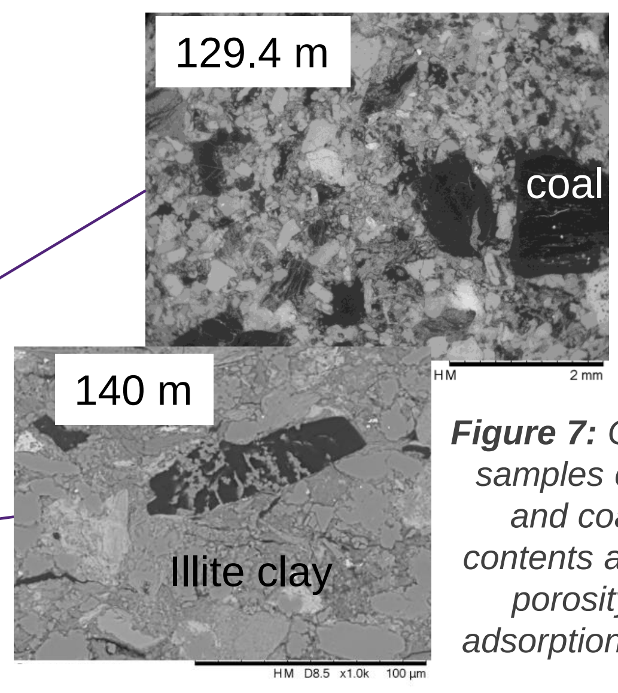


***Figure 7:** Core samples clay and coal contents affect porosity, adsorption etc.*

***Figure 8:** Above (left) showing the total carbon (TC) present in the sample measured using the ASTM 5357 standard in Elementar vario MACRO cube apparatus. The highest TC of ~26% is measured in 78m depth sample which may be dominated by organic carbon as highest methane adsorption measured on the same sample. (right) SEM images showing the coal and Illite clay presence in the 129.4 m and 140m samples, respectively.*

Quantitative XRD, Clay analysis

Table of phase abundances (nominal wt%, absolute)

Sample depth (m)	61.25	129.4	140	281.35	327.8
Quartz	15.9	14.2	30.1	44.6	22.9
Calcite	40.4				
Calcite-Mg	2.9				
Siderite		1.4	1.6		
Clinopyroxene					1.8
Plagioclase (An0-25)			7	9.8	8.7
Plagioclase (An50-65)	11.1	26.7		9.5	23.4
K-Feldspar				8.4	6.2
Chlorite	0.2	0.3	2.9		1.8
Smectite	7.8	30.1		10.8	8.4
Illite-smectite			10.5		
Illite/mica	3.2	3.9	17	3.8	5.1
Kaolinite	9.4	1.9	15.6	12.4	6
Amorphous	9.1	21.3	15.2	0.7	16.1

Table of fine fraction (clay phase) identification

Sample depth (m)	61.25	129.4	140	281.35	327.8
Illite/mica	trace	trace	minor	trace	trace
Kaolinite	abundant	major	major	abundant	abundant
Chlorite	trace	trace	minor	trace	trace
Illite-smectite			major		
Smectite	major	abundant		major	major

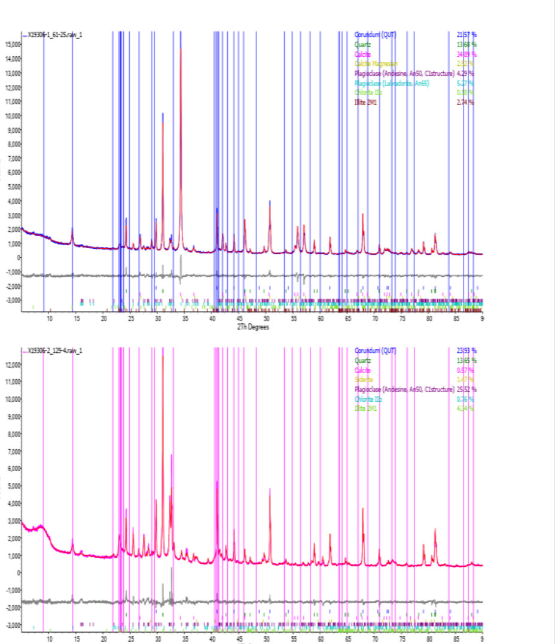


***Figure 8:** Rietveld refinement model (red line) of the XRD data (colored line) and their difference (grey line) for 61.25 m sample.*

Abundant > 40 wt%
Major >10 wt%, <40 wt%
Minor >1 wt%, < 10 wt%
Trace <1 wt%

Conclusions

- Methane potentially adsorbed in volumetrically significant clay-rich interburden. Core sample clay and coal contents affect porosity, adsorption volume etc. The interburden may become a more important gas source when coal seams are depleted.
- Springbok Sandstone well core investigated here contains sections of coal (and clays) which may be an in situ source of adsorbed methane. Coals near natural calcite and kaolinite filled fractures contained unusually large (possibly hydrothermal fluid heat affected) pores. This may have affected historic or recent in situ gas generation or release. Natural fractures were also observed in drill core of underlying units, potentially related to historic fault movement.
- We suggest future work to extend this to other drill core locations and other shallow aquifers especially where historic or recent gas shows have been questioned.

Research with real world impact

REDUCE COST
INCREASE SUPPLY
ENVIRONMENTAL PERFORMANCE
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