



Study of Viability of Seismic Imaging for Site Selection and Monitoring of CO₂ Sequestration in Illinois Thin Coal Seams

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Presentation Outline

- Motivation
- Problems
- Technology Needs
- Project Objectives
- Scope of Work
- Summary of Results
- Future Work
- Conclusions and Recommendations



Motivation

- Coalbed methane in Illinois is a sizeable natural gas resource (14-21 Tcf)
- Unmineable coal seams offer a safe and permanent target for sequestration of carbon dioxide
- Sequestration of carbon dioxide in coals liberates the adsorbed methane that can be economically produced. (Enhanced Coal Bed Methane recovery – ECBM)



Problems

Factors influencing CBM production :

- **Uncontrollable:** Thickness, lateral continuity, rank of coal , gas content, permeability, depth, structures, (in-situ conditions)
- **Controllable:** Site selection, well location and well completion techniques.
- **CBM Production to be successful**
 - Coal seams continuity at the site essential.
 - Wells must be placed along high permeability trends.



Problems *Continued*

➤ CO₂ Sequestration

- The target seams must extend over a large enough area to accommodate large volume of CO₂ over a long period of time
- It is important that the host coal seams be free from faults and dislocations that could cause migration of the injected CO₂ into unintended zones
- It is therefore imperative to map the candidate coal seams very accurately prior to site selection and monitor the gas front movement throughout the life of a project



Technology Needs

- Advanced seismic technology is potentially capable of resolving these issues

- Seismic techniques have been used successfully for reliable subsurface imaging and monitoring of gas cap movements in conventional oil and gas reservoirs, however, because of the internal properties of coal, the degree of applicability of the technology to coal is not certain.



Project objectives

Field Investigation

- **Investigate resolution limits of seismic techniques relative to thin coal seams and detection of small discontinuities.**

Laboratory Investigation

- **Investigate changes in bulk elastic properties of coals due to changes in saturation.**



Resolution

The resolution of seismic techniques is rarely better than 5m (~16.4 ft).

Van Reil (1986) has shown that coal beds as thin as 0.75 m (2.46 ft) can be resolved by reflection seismic methods.

(Widess et. al., 1986) concluded that the thickness of a bed must be at least 1/8 of the dominant seismic wavelength to be resolvable.



Resolution *Continued*

Thus, a key question to be addressed was whether advanced seismic techniques could identify individual coal seams within a coal ‘package’ ?

Or whether the overall low frequency signal from the ‘package’ would mask the individual high frequency events?



Scope of Work

- Developed customized seismic survey techniques for CO₂ sequestration and CBM production site selection
 - Detailed surface survey
 - VSP
 - Crosshole seismic survey
- Lab work to investigate the viability of monitoring CO₂ front in coal seams
 - Measure changes in elastic properties of coal resulting from addition of a gas phase into the cleat system (Wst.)

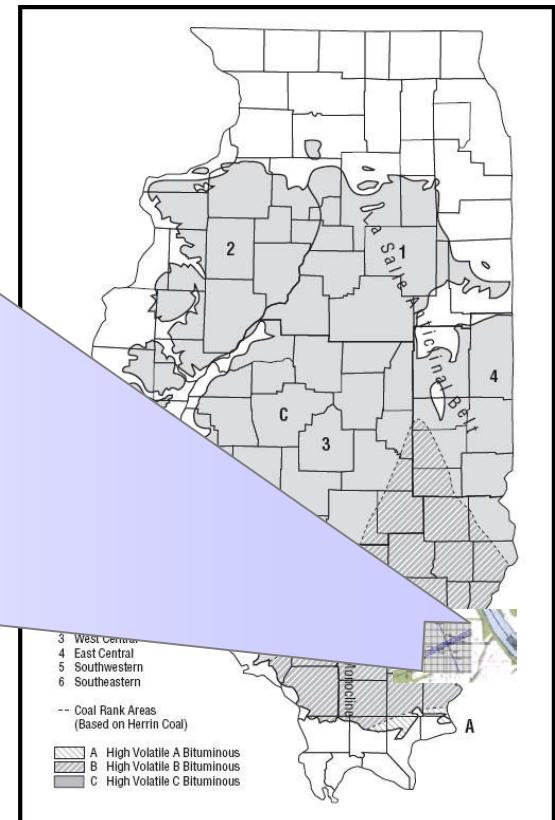
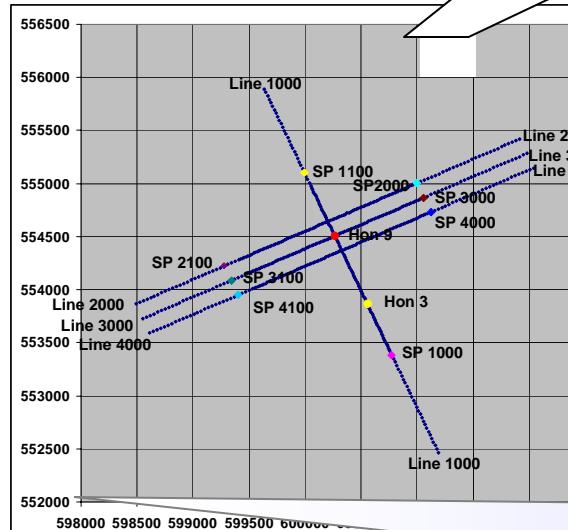


Location

White County, Illinois

500ft

500ft



Map of 4 seismic lines and
wells used for crosswells survey

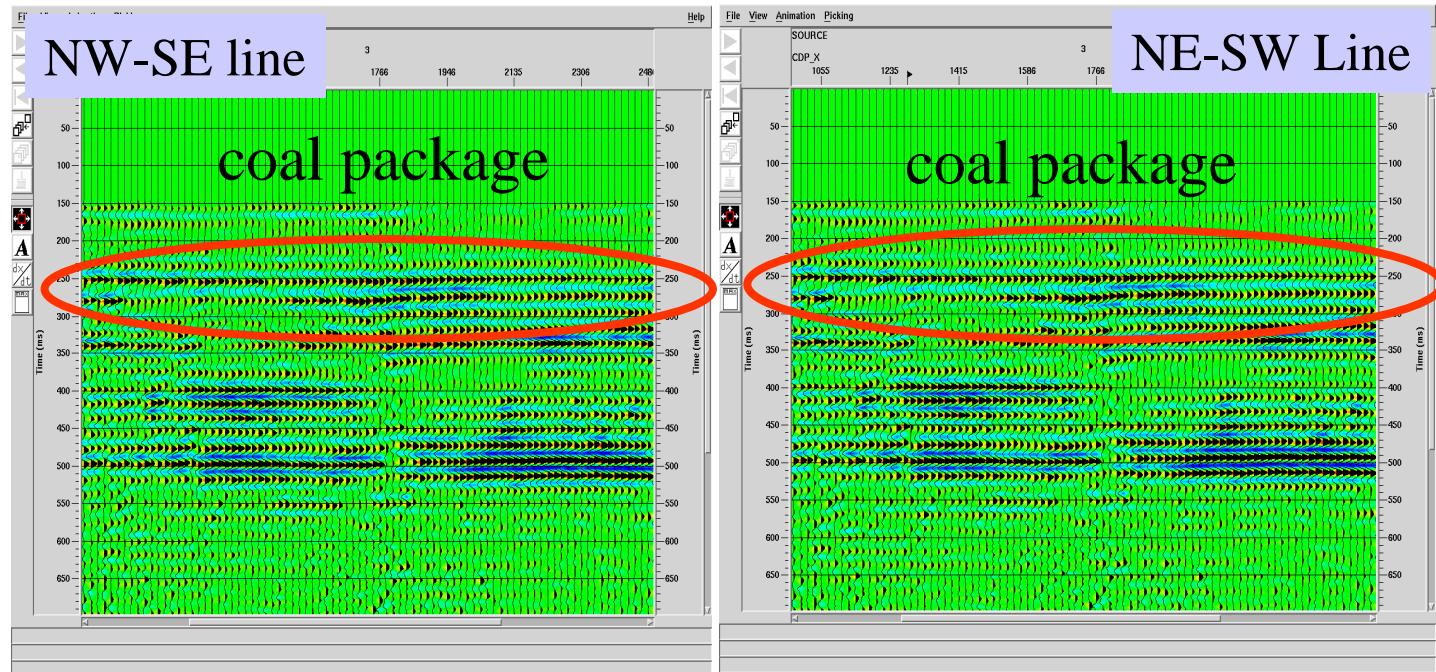
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Surface Seismic Survey Result

Final Processed Broadband Seismic Sections



Seismic Section for Line 1000

Seismic Section for Line 2000

Individual coal seams have been transparent



Crosswell Seismic Imaging

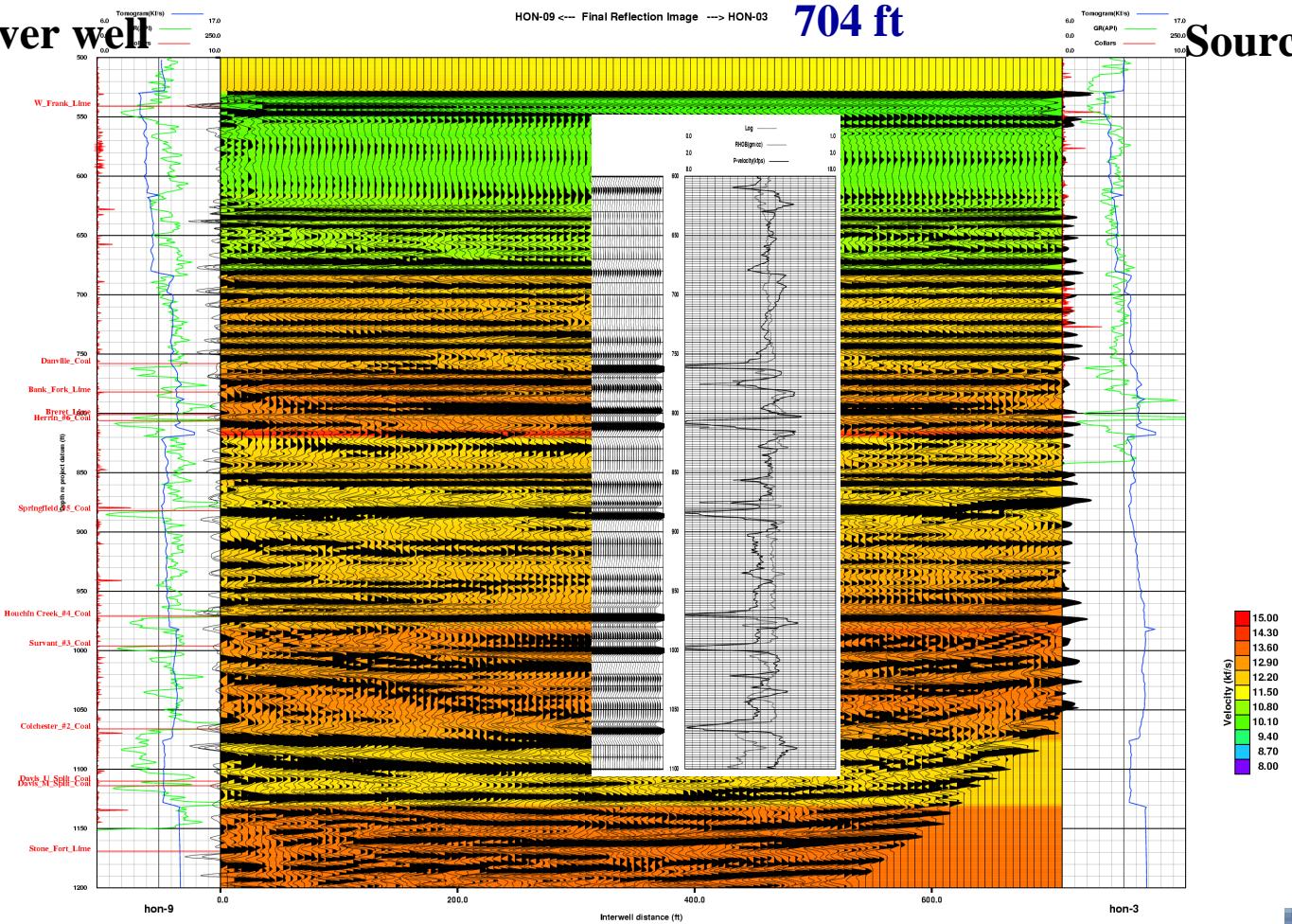
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Final Crosswell Reflection Image

Hon 3

Receiver well

Source well

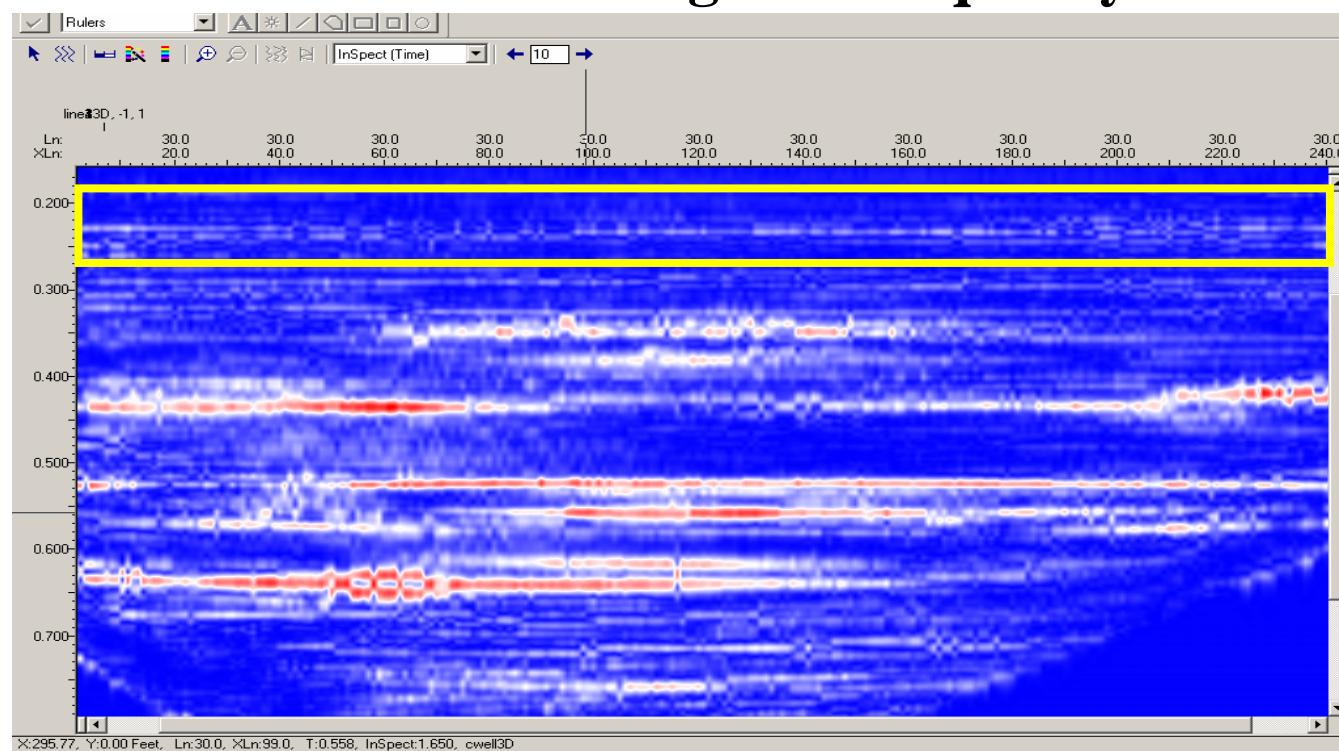


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Advanced Seismic Data Processing

In order to identify the dominant frequency for coal seams and to determine changes in frequency with depth

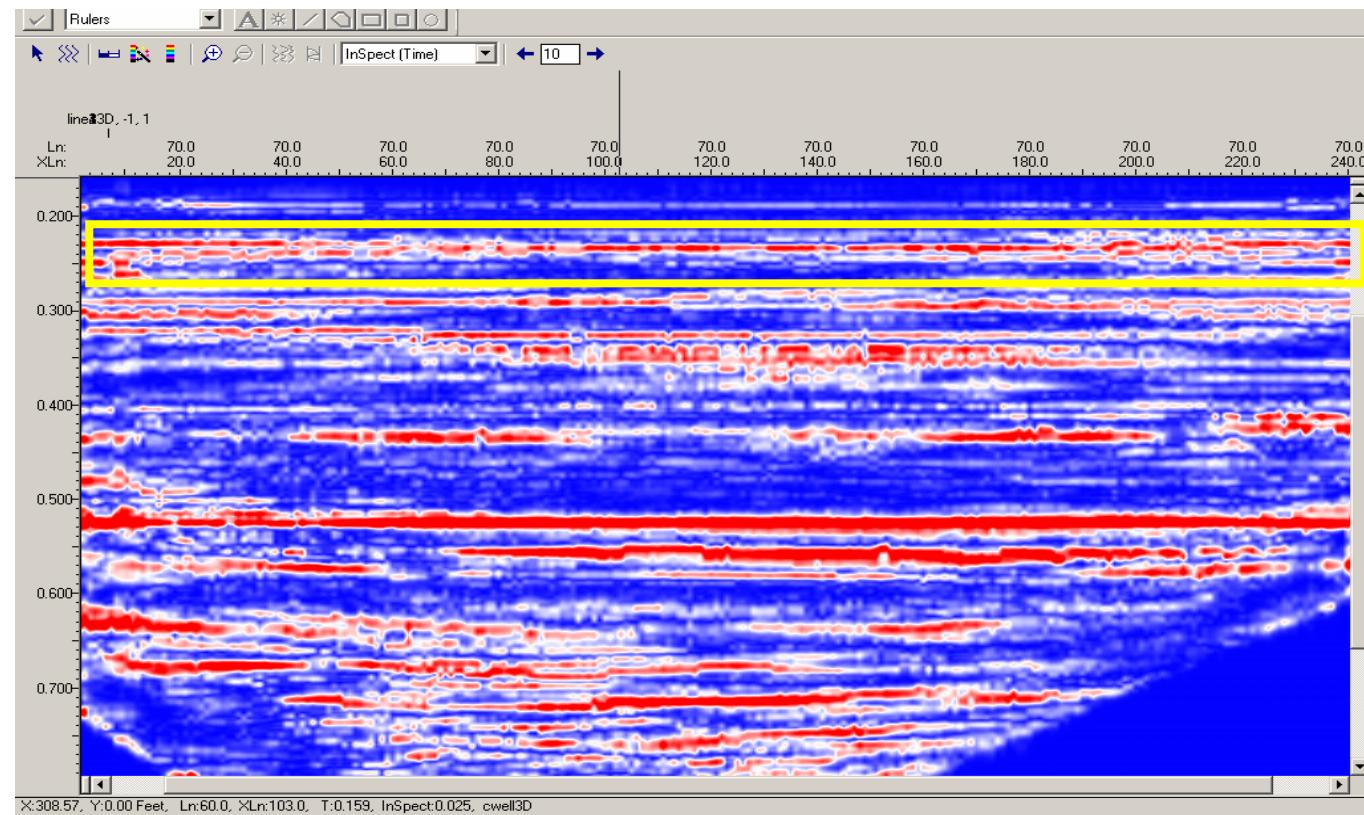


Spectrally Decomposed Data at 30 Hz



Advanced Seismic Data Processing

Spectrally Decomposed Data at 70 Hz

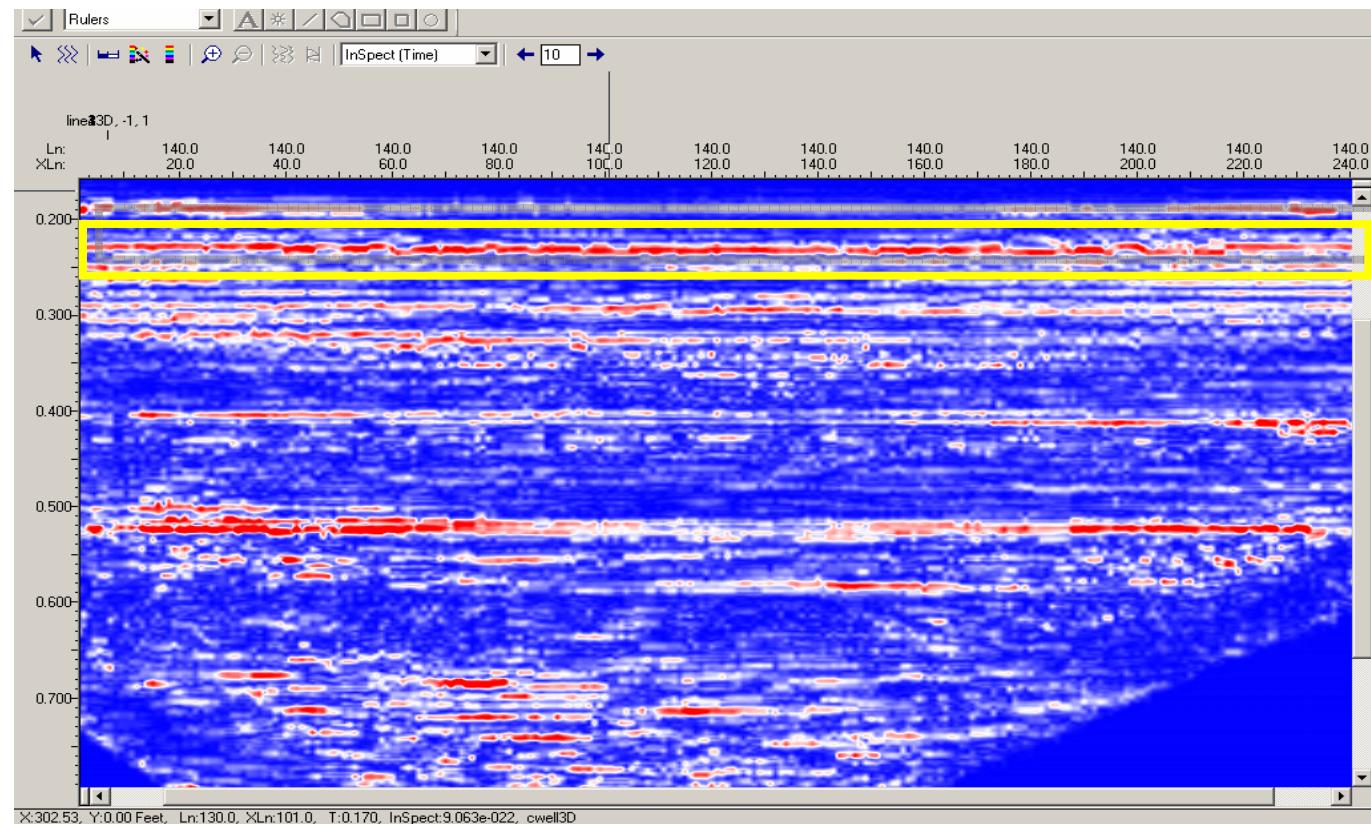


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Advanced Seismic Data Processing

Spectrally Decomposed Data at 140 Hz

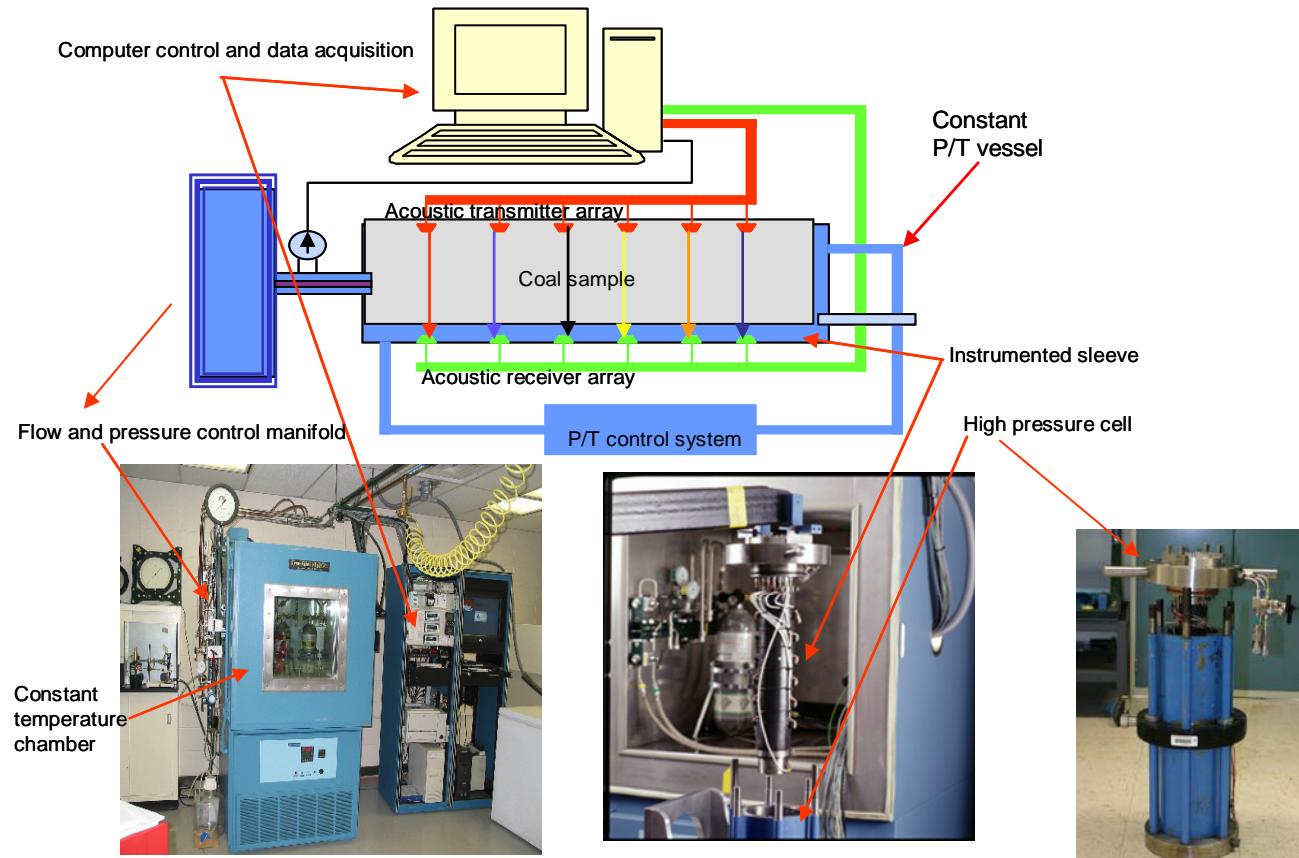


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Laboratory work

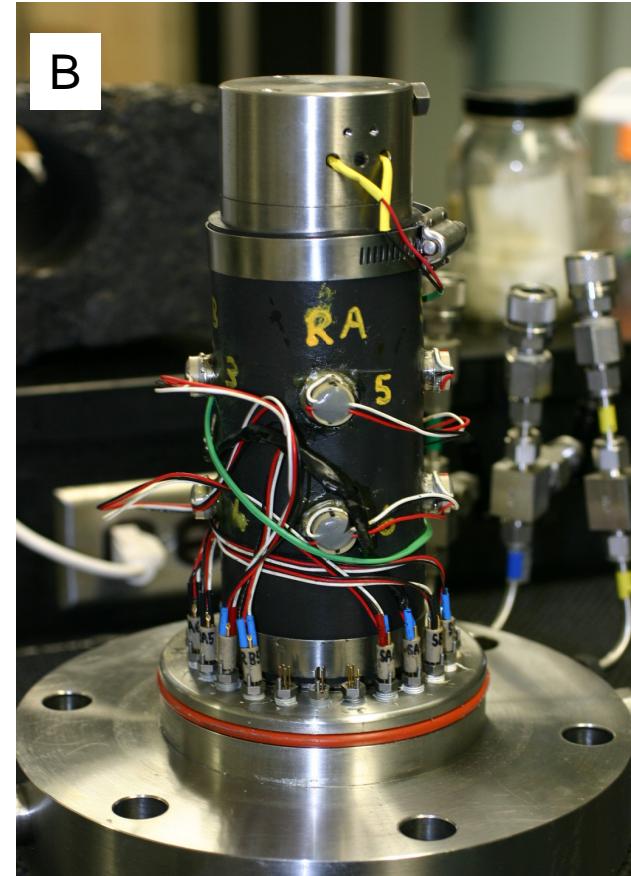
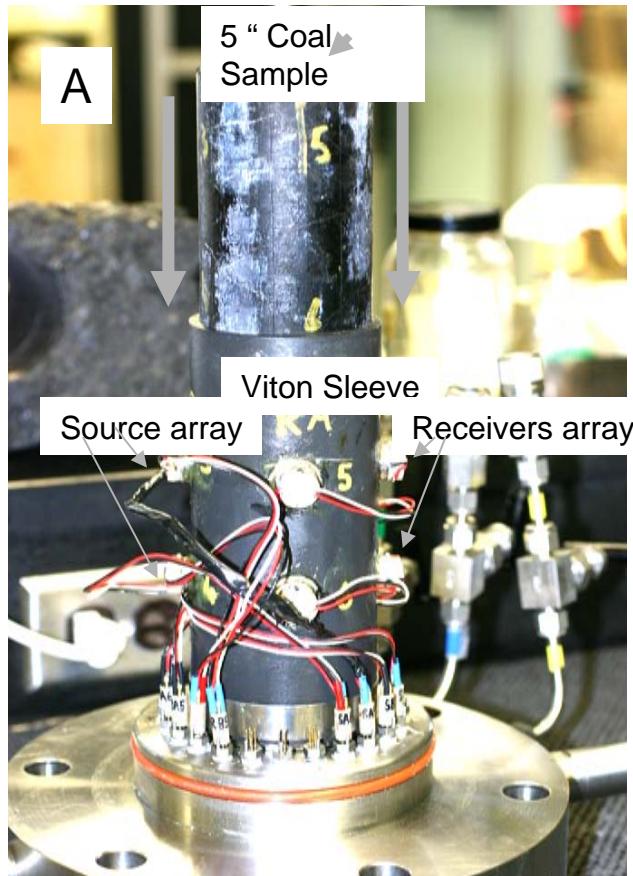
Ultrasonic velocity measurement



Schematic diagram of experimental apparatus



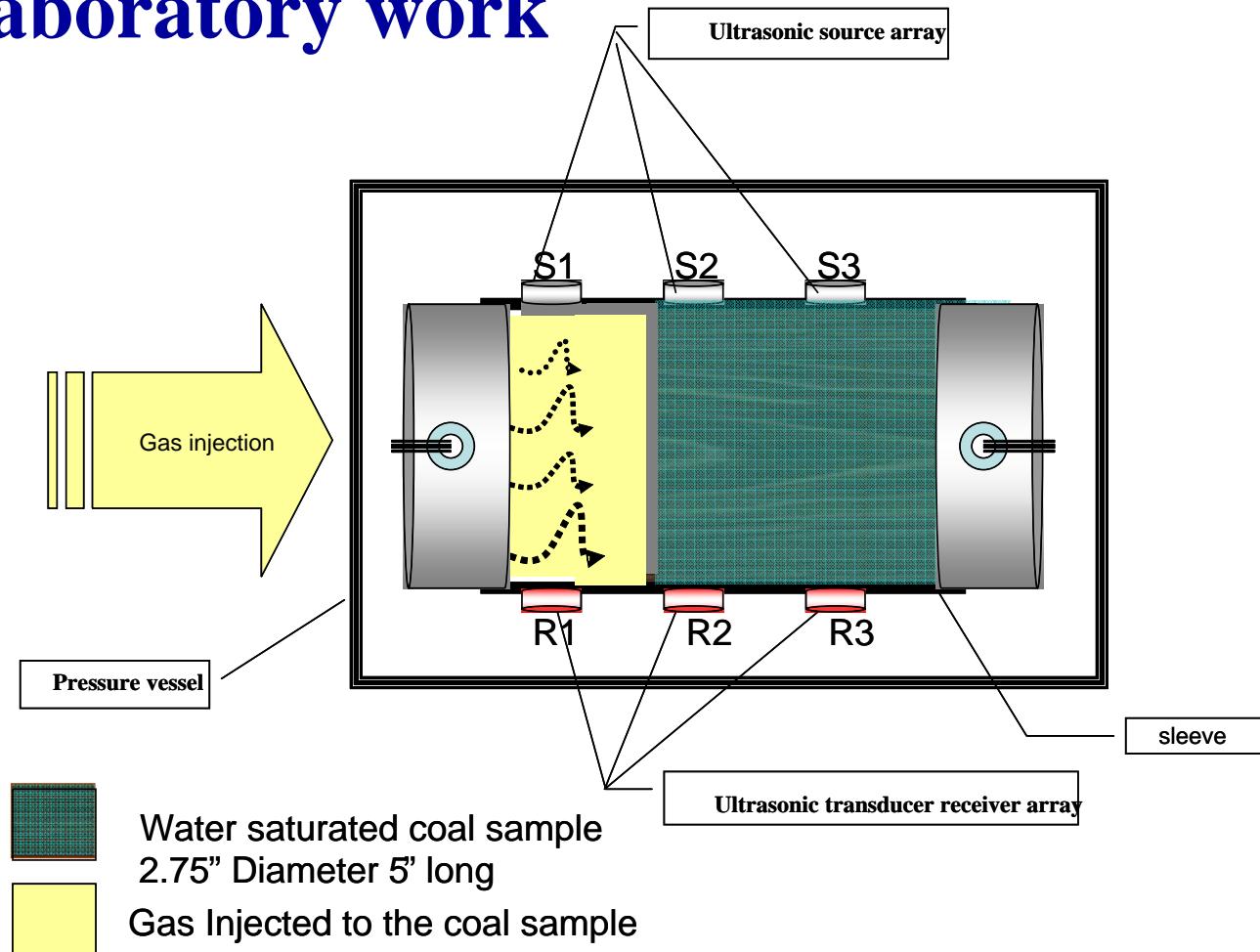
Laboratory work



Sample assemblies for measuring ultrasound velocity



Laboratory work



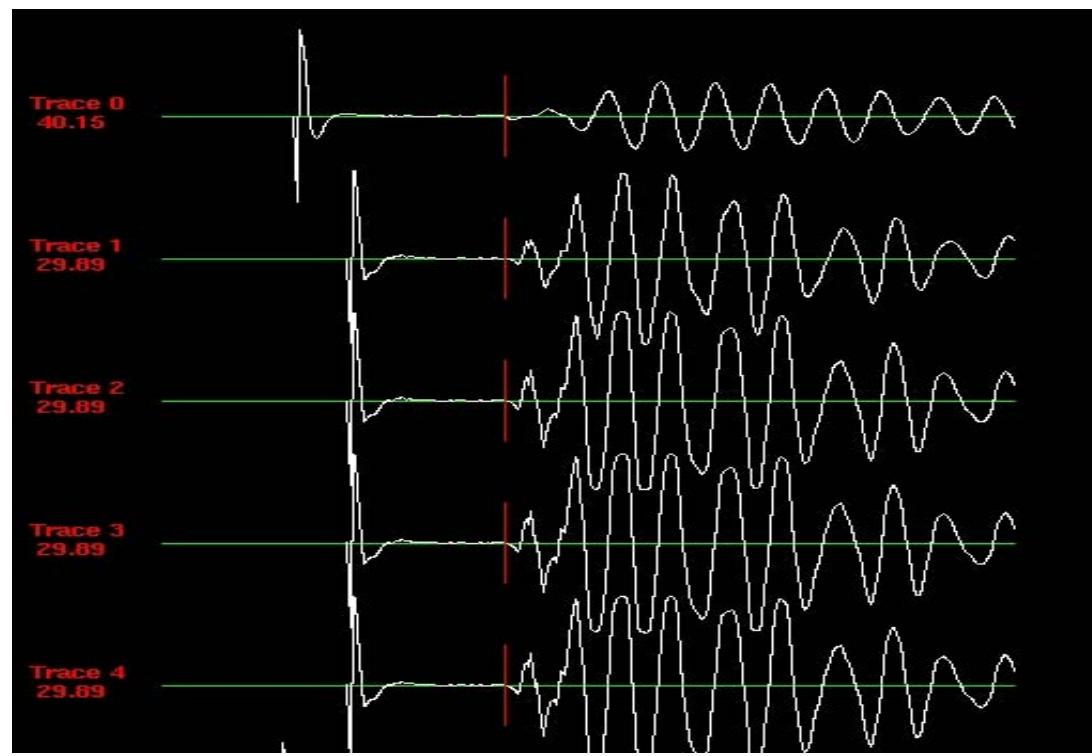
Schematic diagram of experimental apparatus



Illinois Coal Project

Velocity changes resulting from introduction of a gas phase into the water saturated coal

compressional (P) wave velocity



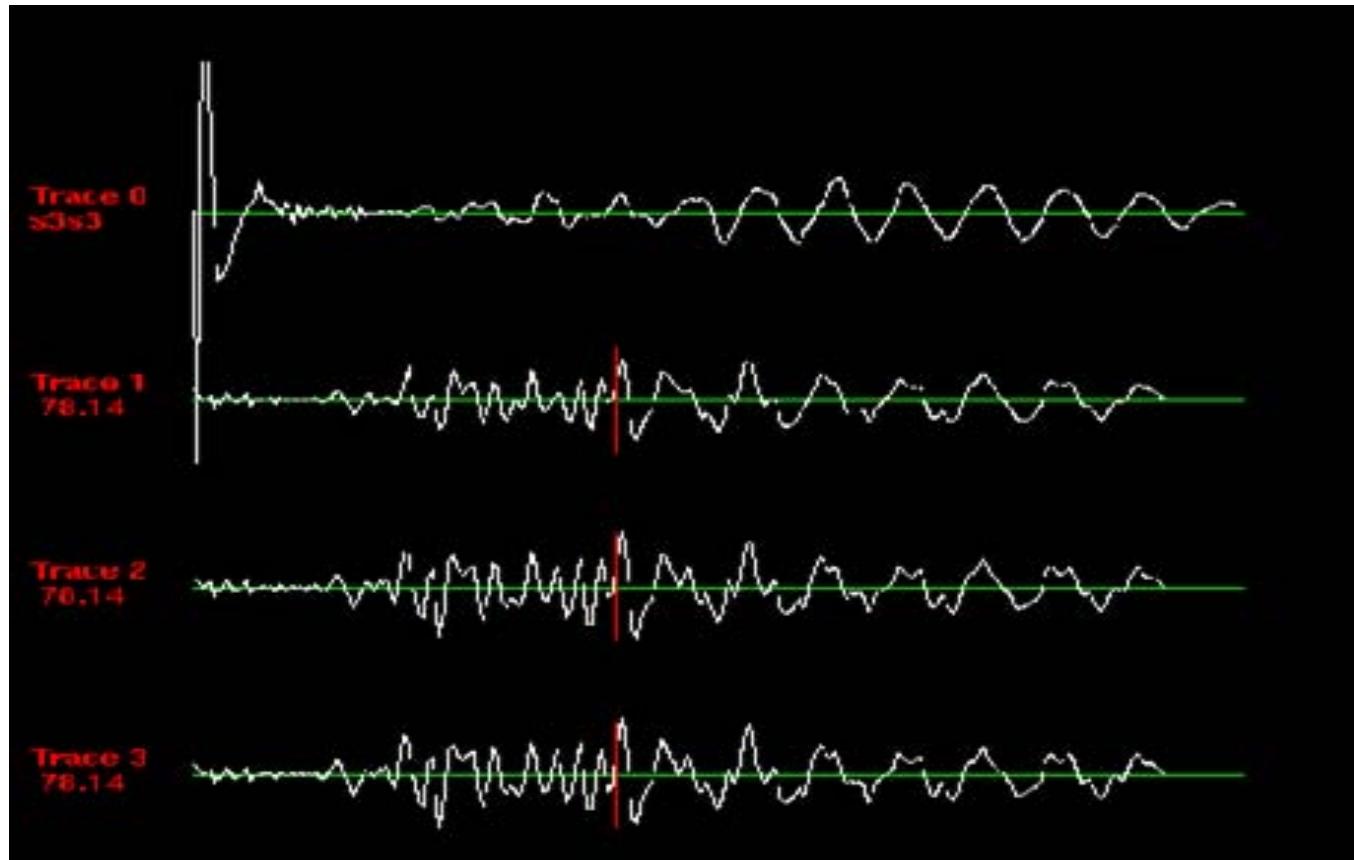
← 40.15
microseconds

→ 29.89
microseconds

34% decrease in P wave velocity.



Illinois Coal Project

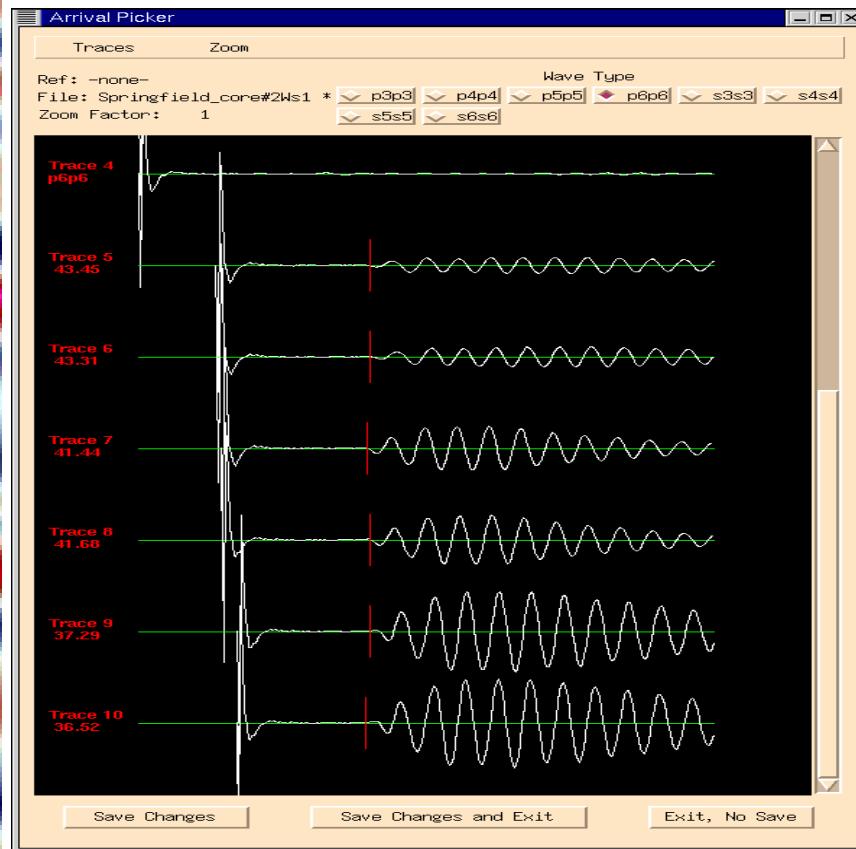


Examples of shear wave arrivals in water saturated coal



Illinois Coal Project

Effects of confining pressure on coal velocity

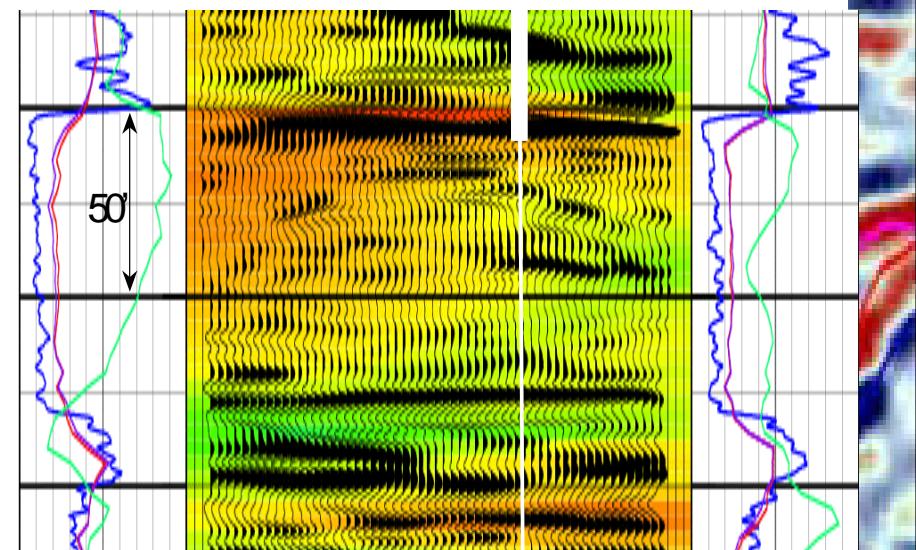


<u>Trace #</u>	<u>Confining pressure</u>
4	1 MPa
5 & 6	43.45ms 2 MPa
7 & 8	3 MPa
9 & 10	36.52ms 4 MPa



Results from lab measurements

Laboratory measurements proved that changes in bulk elastic properties of Illinois coal due to changes in fluid saturation are large enough to render 4-D seismic capable of monitoring the expansion of CBM or CO₂ fronts.



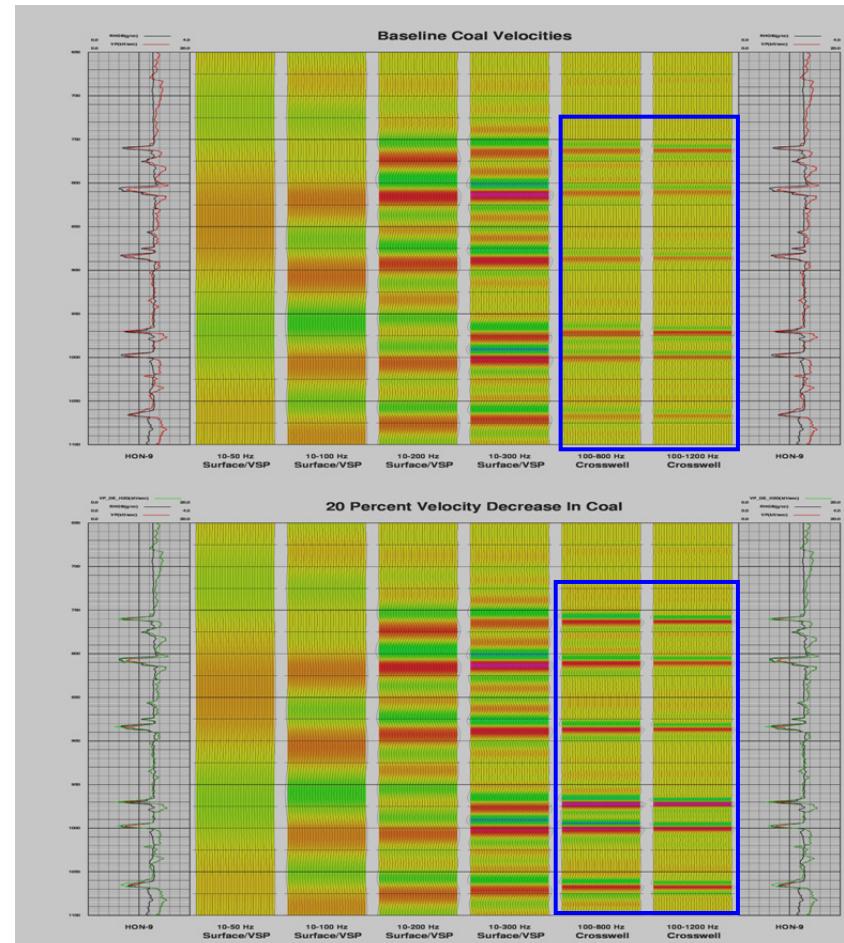
Monitoring of dewatering in Coal Bed Methane production in the Powder River Basin in Wyoming.



Results from Seismic Surveys

VSP, crosswell, and surface seismic surveys work proved that:

- At lower frequencies (surface seismic) coal packages, but not individual seams, can be reliably mapped.
- It is possible to map thin coal seams and to identify small scale discontinuities using higher frequencies (X-well & VSP)
- Seismic modeling indicated that a 20% velocity reduction due to saturation change can be clearly identified at 100 Hz+ frequencies at the ISGS pilot site.



Response of individual coal seams to gas saturation.



Conclusions and Recommendations

- At 10-50 Hz bandwidth the resolution is very low and results from surface seismic surveys are not reliable.
- At 10 -200 Hz bandwidth, high resolution imaging is possible and surface seismic data would be reliable for mapping of the “coal seam packages” as a whole.
- VSP surveys (10-300 Hz bandwidth) noticeably enhance the resolution.



Conclusions and Recommendations

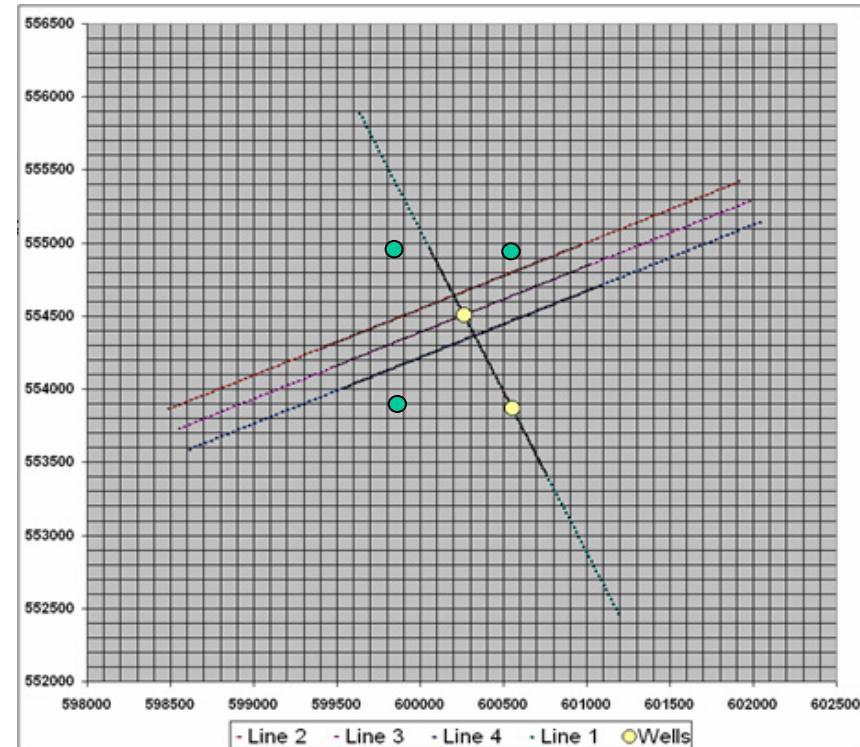
- Laboratory measurements proved that changes in acoustic properties of coal resulting from the addition of a gas phase into the cleat and pore spaces is substantial.
- Monitoring of methane production from coal seams of Illinois appears to be quite practical and can be used as means for determination of the high permeability trends and development of de-watering and production well patterns.



Future work:

**Drill and complete 3 dewatering wells
(ISGS)**

Repeat crosswell and seismic surveys after gas production has been established to map the position of the gas front



- Wells used for crosswell seismic
- Planned dewatering wells



Acknowledgements

- Gas Technology Institute
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- Z-Seis Corporation



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