Measuring Internal Stresses inside Rock Core samples subjected to High External Pressures Prior to Perforation Testing.
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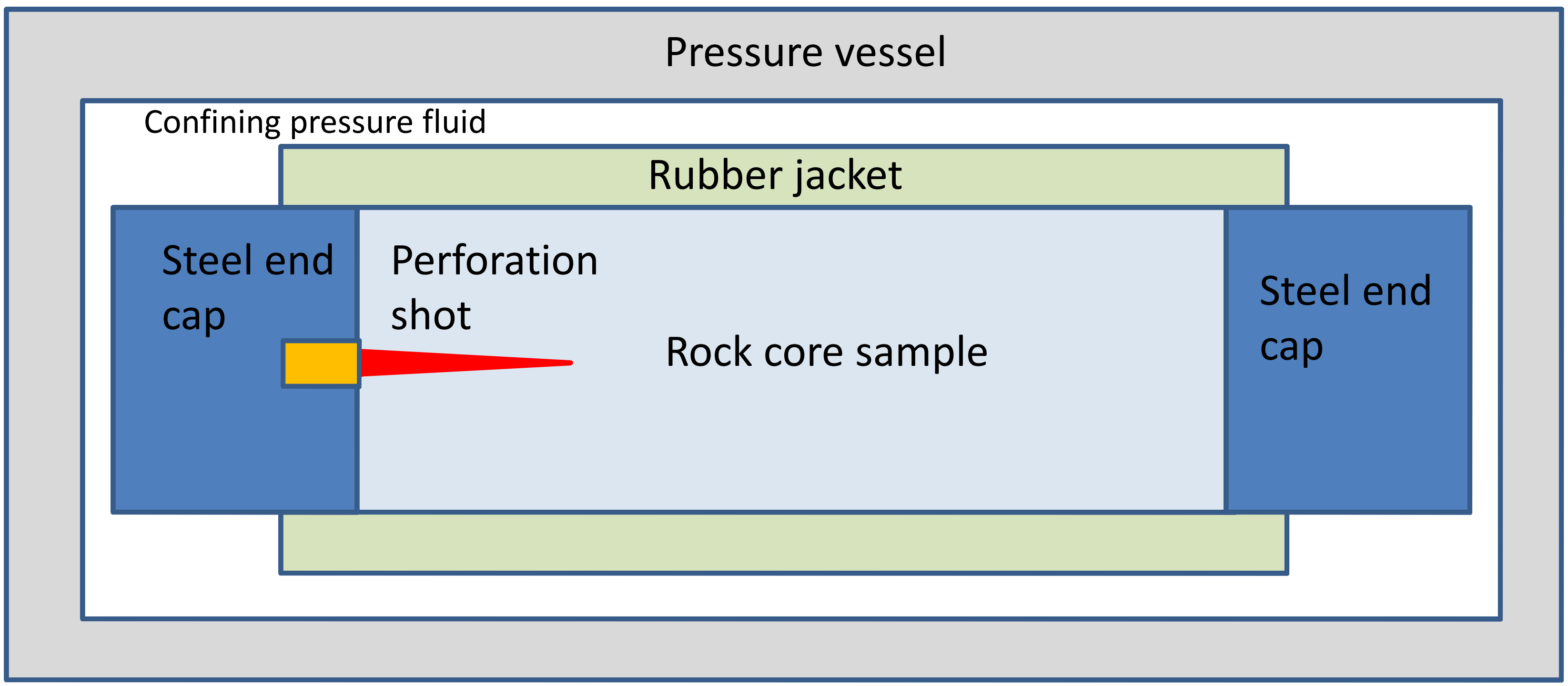
Typically perforation shots are conducted in a pressure cell on a large diameter core sample.   The core is jacketed in an external rubber jacket and steel platens applied to the ends of the sample. External isostatic (equal pressure) is applied to the outside of the rock to a given stress level to simulate subsurface stresses and then a perforation shot is fired into the core.

Basic schematic of a perforation cell



Statement of the problem

The depth of penetration of perforation shots should be pressure and depth dependent. So the observed pattern that, in many cases, the perforation shots are not stress sensitive is curious.

In this study, we investigate if the effect the result of an artifact of the experimental setup and not an inherent feature of the rock core sample itself.

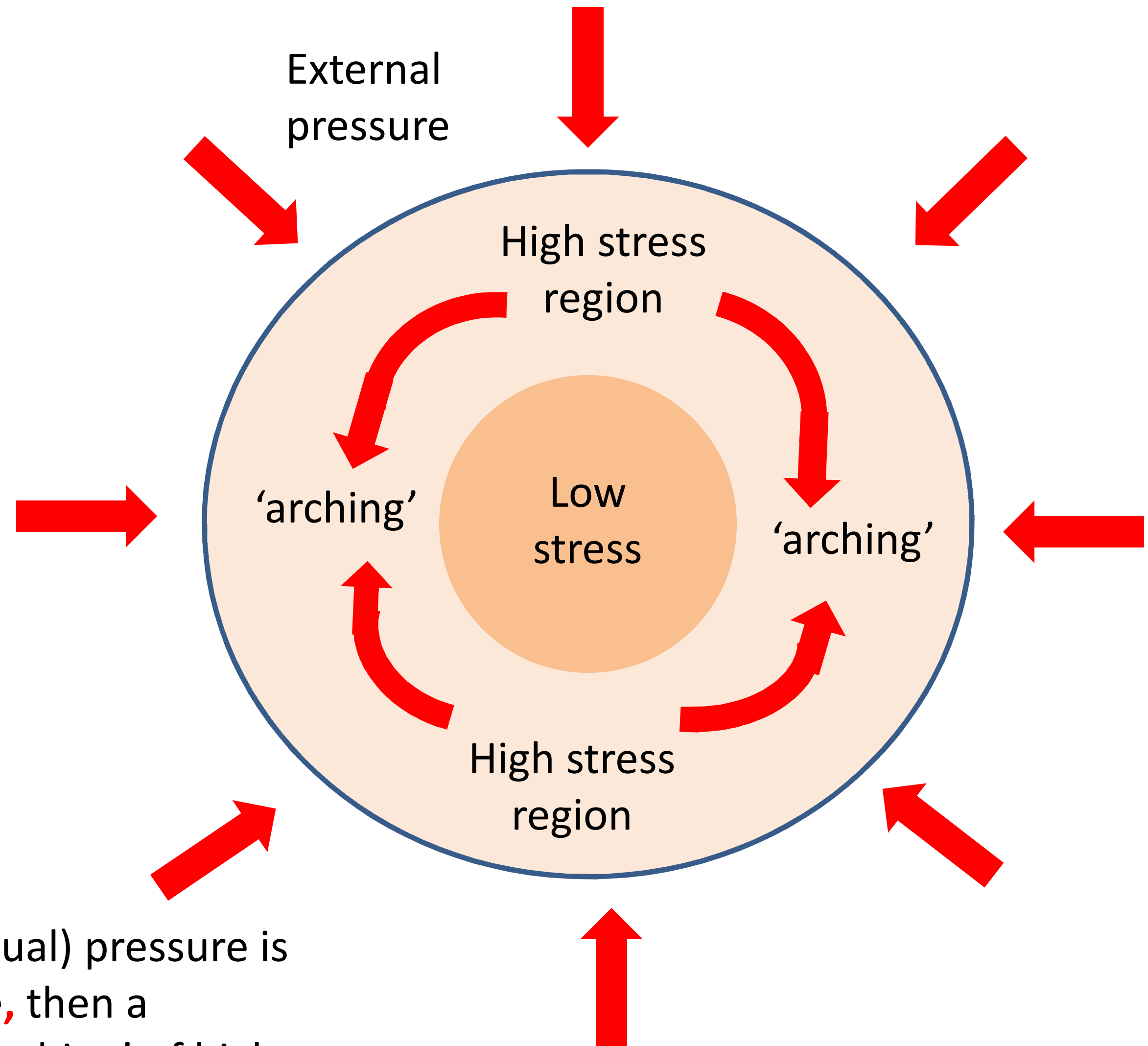
Two possibilities are considered whereby the observed pattern could be developed in perforated core samples.

The first possibility is a ‘stress-arching’ effect whereby we are firing shots into a heterogeneously hydrostatically stressed core sample.

The second possibility is a ‘stress shadowing’ effect whereby we are firing shots into a zone of rock near the end cap that is being influenced by the presence of the steel end cap.

Only the first possibility is investigated in this study.

The concept of **'Stress-arching'** in an isostatically compressed rock core sample

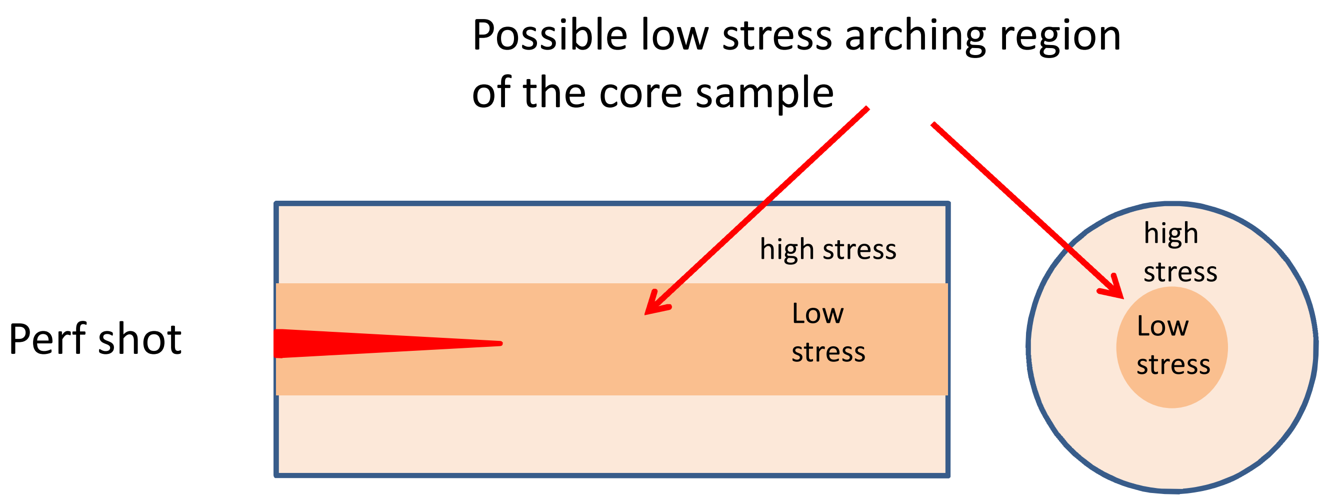


As external isostatic (equal) pressure is applied to the rock core**,** then a circumferential 'stress arching' of high stress outer boundary and an internal low stress central region could **(is thought by some to)** develop.

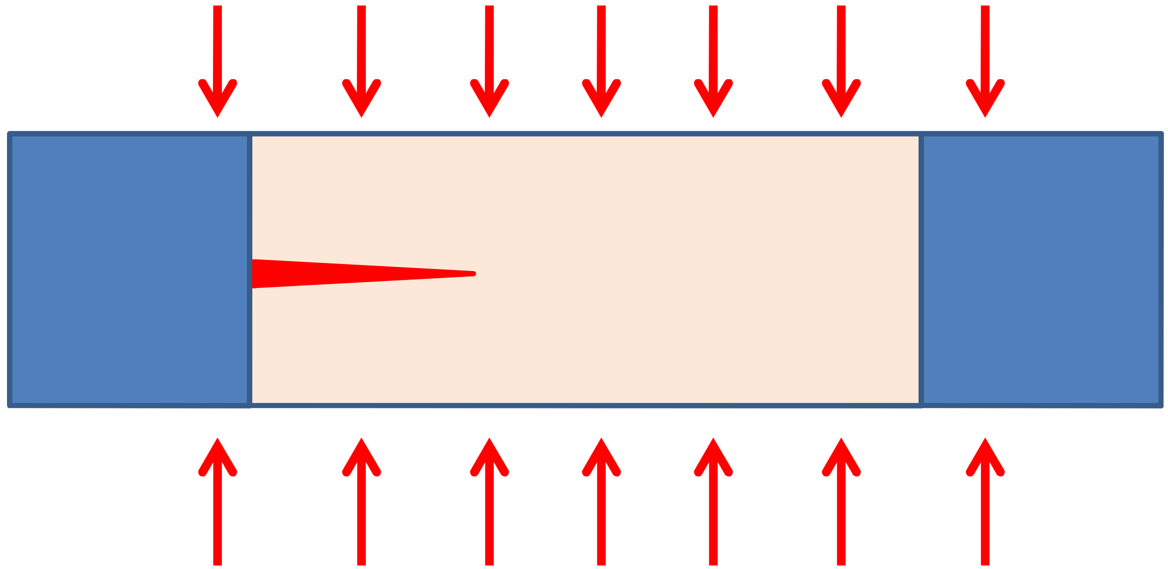
If this is the case then, we are firing the perforation shots into a lower stressed region within the rock core sample. The higher the applied external pressures, then the higher the 'stress difference' becomes.

Such a experimentally induced artifact (if it exists) could explain why we do not observe a minimal external confining presssure effect as pressure is increased on perf shot core samples.

We could be firing the shots into a low stress central region of the core.

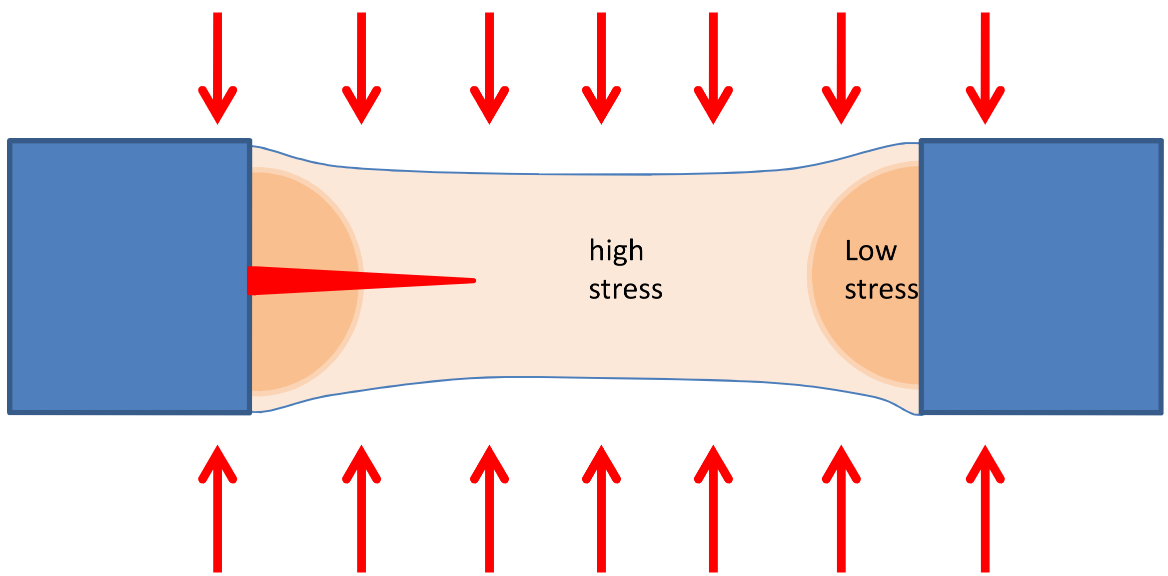


End cap stress shadowing concept



In this concept the central ends of the core are slightly 'protected' from external pressures by the high strength steel caps.

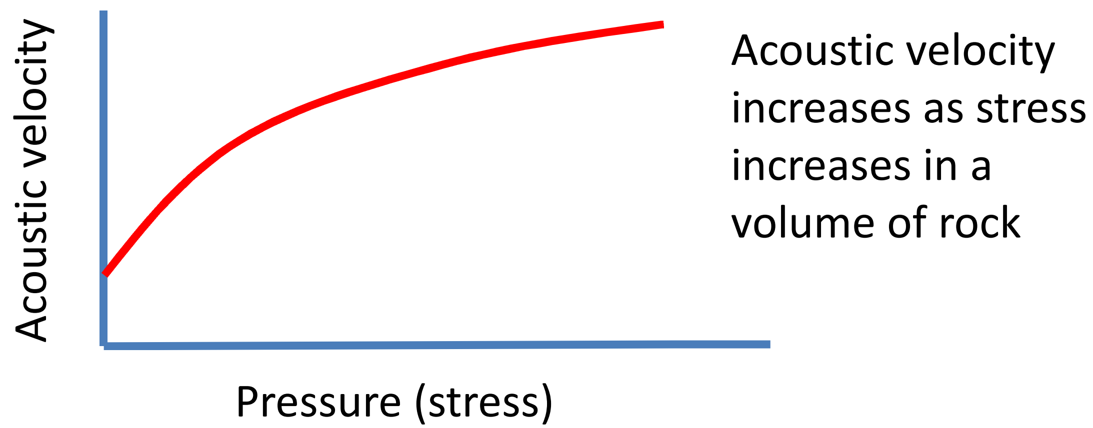
Quite simply, the rock core compresses more than the steel end caps. This leads to heterogeneous stresses in the core.



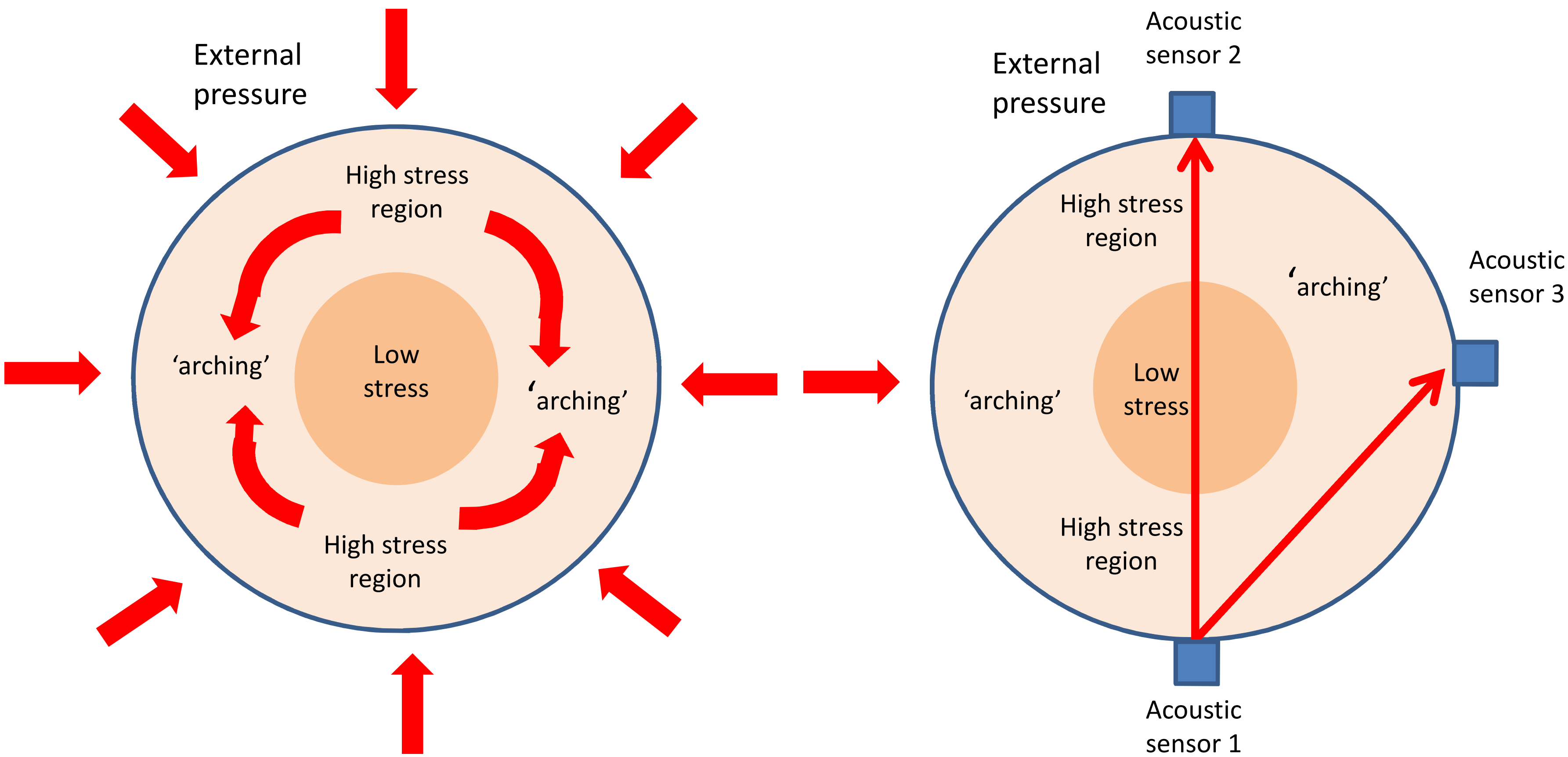
Question: How to observe if internal ‘stress arching’ is occurring in isostatically rock core samples?

Solution: Acoustic wave velocity are stress sensitive in a porous medium. So we could use acoustic wave technology to measure the sonic wave velocity in different sections of the core samples to determine if different zones have varying stress regimes.

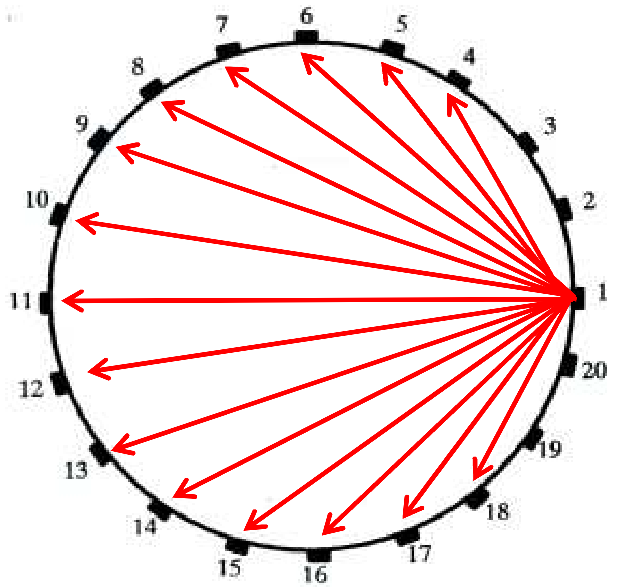
Since acoustic velocities in porous rocks are stress sensitive, as pressure (e.g. stress) is increased in a section of rock, then the ultrasosnic velocity gets faster.

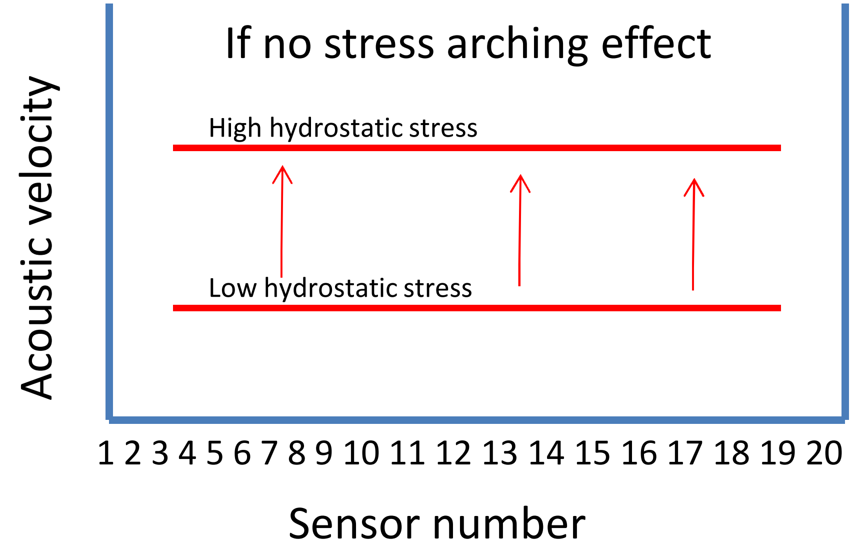


This concept can be used to investigate the 'stress-arching' concept in a volume of rock. By measuring the acoustic velocities in a series of distinct ray paths across the diameter of a core sample, we should be able to detect if different sections of the core are being affected by a heterogeneous distribution of stresses.

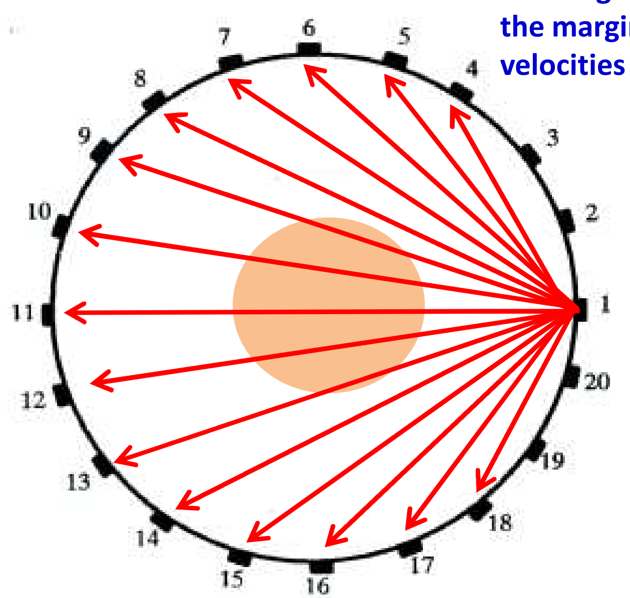


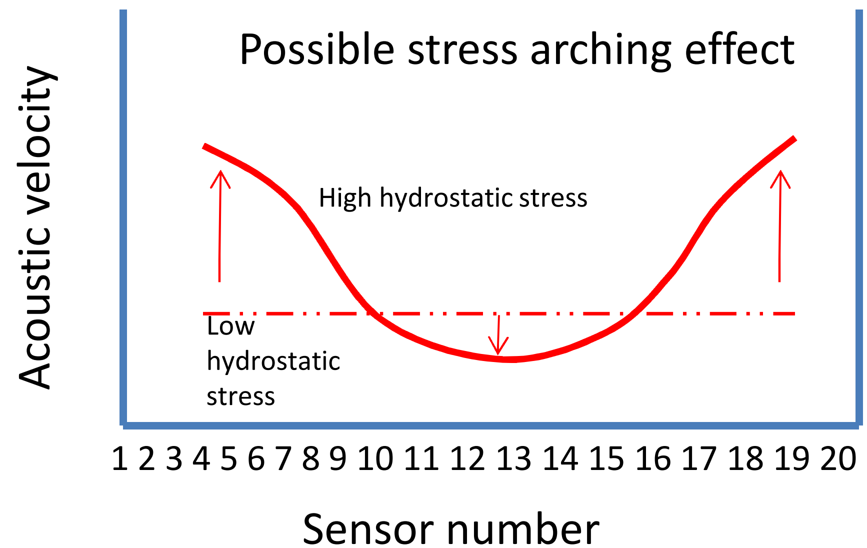
If we pulse an acoustic wave across the diameter (from sensor 1 to 2) of the core, we will see a decrease in acoustic velocity since the wave passes through a low stress region. However, an acoustic wave from sensor 1 to sensor 3 will only pass through a region of high stress.





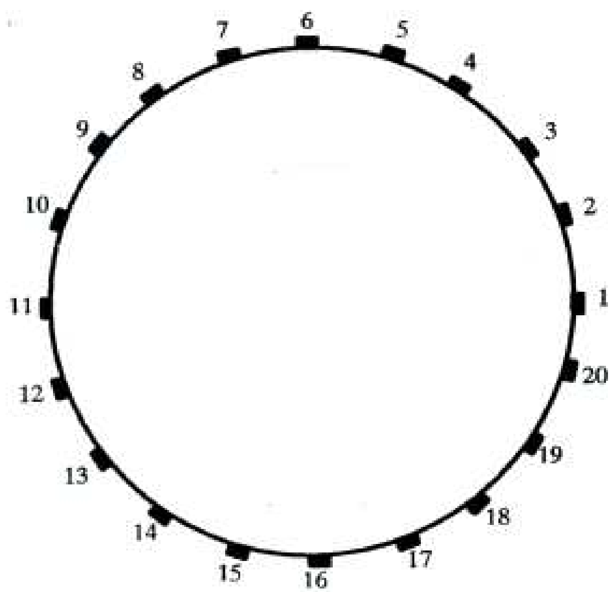
An 'arching effect' would have high velocities on the margins and low velocities in the center





The rock core sample test assembly:

The rock core sample is 5.7 inches in diameter and 5.8 inches long.



A complex array of acoustic sensors was mounted on the rock sample. This presentation shows compressional wave velocity data from the twenty sensors mounted around the diameter of the center of the Carbon Tan rock core.

The Carbon Tan rock core sample was subjected to isostatic (i.e. equal) pressures of 500, 1000, 2000, 4000, and 6000 psi. The pressures were raised in a ‘step and hold’ manner.

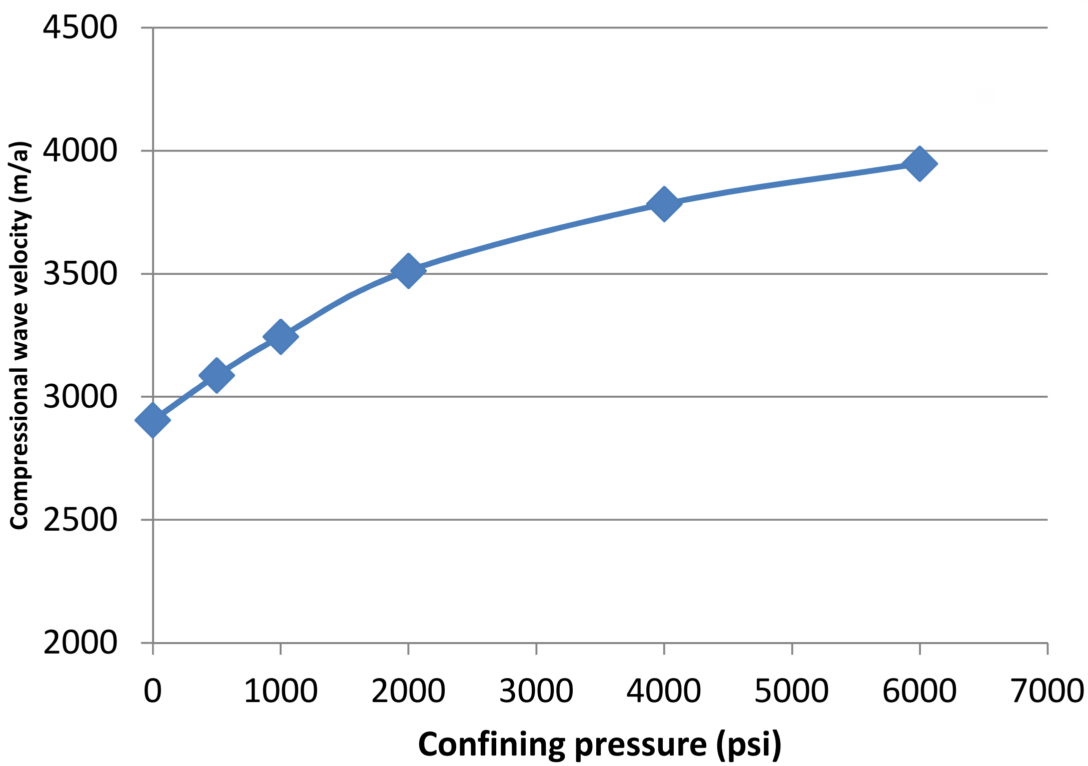
At each pressure step, acoustic wave velocities along several hundred ray paths were recorded.

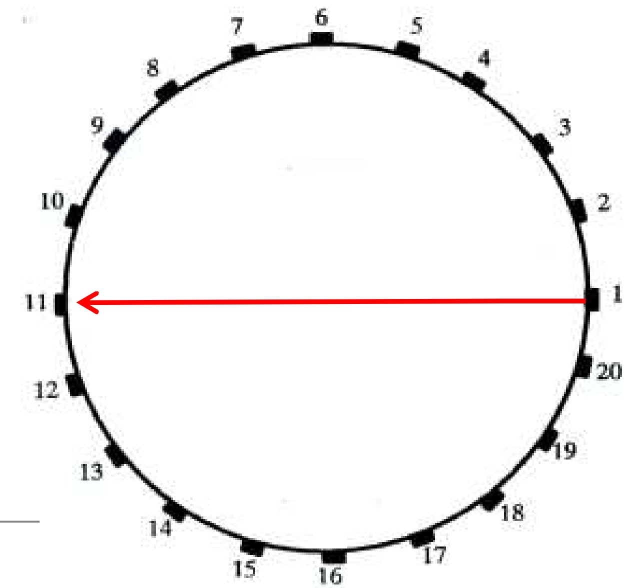
The data sets show the change in velocity referenced to the 500 psi starting condition.

The core sample was placed in a triaxial cell

The Data:

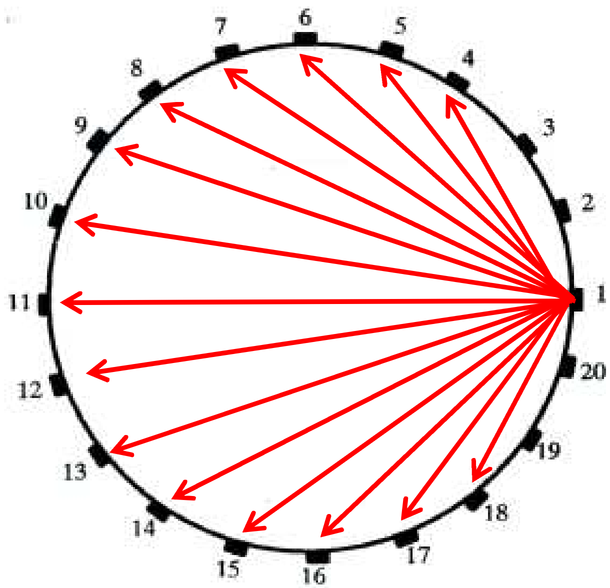
Acoustic velocities in the Carbon Tan sample do show a stress sensitivity. As confining pressure is increased the compressional wave velocity increases.

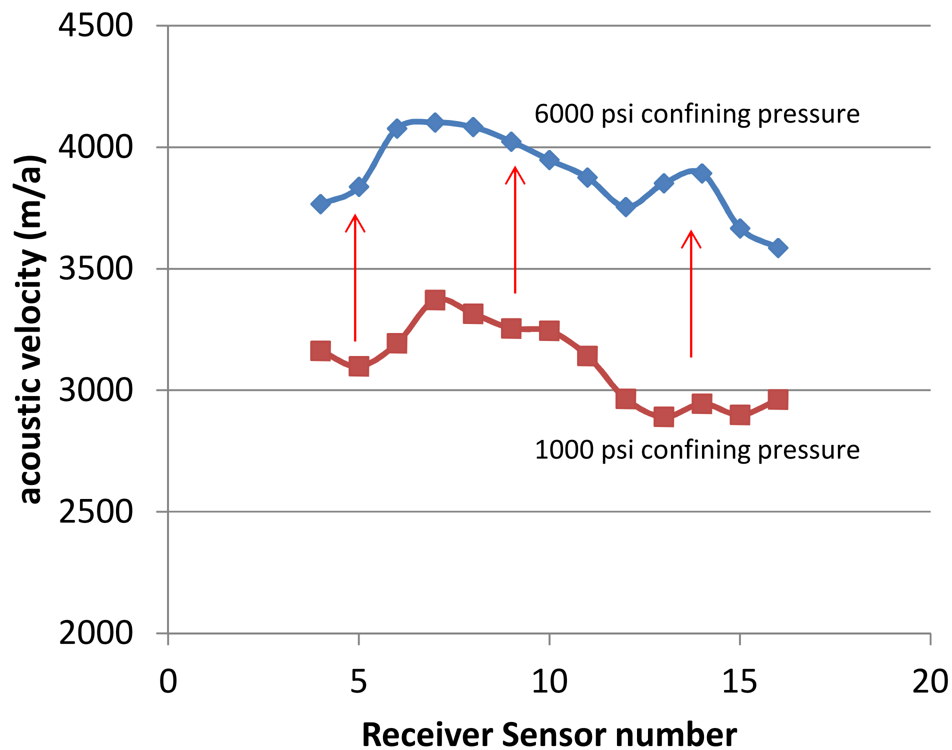




The plotted data are from sensor 1 to sensor 11. This is the pulsed acoustic ray path directly across the diameter of the sample.

Acoustic velocities
pulsed from sensor 1





A plot of acoustic compressional wave velocities in a ray path fanbeam through the diameter of the Carbon tan sample. The acoustic velocities are from 1000 psi confining pressure and 6000 psi confining pressure. The geometry of the pattern of acoustic velocities observed at 1000 psi seems to be very similar to that observed at 6000. Acoustic ray paths on the margins do not evidence large shifts in velocities as would be expected with an arching effect.

Conclusion: The preliminary set of acoustic velocities measured along a wide azimuth of acoustic ray paths does not support that an ‘arching effect’ is occurring. However, additional testing will be needed to confirm this observation.

More work needs to be done to see if the ‘stress shadow’ effect created by the presence of steel platens is created during hydrostatic compaction.   This tests will be conducted in the near future.