Petrophysical Properties of a Deformation Band Fault Zones in the Entrada Sandstone, Utah*

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Abstract

Deformation band networks can inhibit fluid flow in permeable reservoir sandstones. Understanding the petrophysical qualities and developing geophysical methods to detect deformation bands is important to the petroleum industry, especially regarding reservoir characterization and modeling. This study analyzed the directionally dependent ultrasonic compressional and shear wave velocity of deformation bands and host rock at the core sample and meter scales. The meter scale was used as a proxy for sonic logging data collection, which is typically at a similar scale of investigation, and addresses how well we can upscale velocity data from cores to the sonic logging scale. In situ high frequency velocity studies of variable facies within the Slickrock Member of the Entrada Sandstone and cores with deformation bands provides insight into whether and how well variably dense deformation band networks can be detected in the subsurface in log and seismic data. Combining the measured velocities of different facies within the outcrop, a connection between deformation band character and width of damage zone was made between facies and velocity signature. The tested fluvial units contained deformation bands that appeared at 10% of the frequency and only extended 50% of the distance away from the fault compared to the Aeolian facies. Fluvial units had measured unconfined outcrop velocities of 1000-1100 m/s, whereas the Aeolian units' velocities were clustered around 800 m/s. A link between facies velocity and damage zone width and character can help determine the sealing or leaking nature of a damage zone surrounding a fault through a volume assessment of individual facies and their combined impact on fluid flow.

Reference Cited

Davatzes, N., and A. Aydin, 2005, Distribution and nature of fault architecture in a layered sandstone and shale sequence; an example from the Moab Fault, Utah, *in* R. Sorkhabi, and Y. Tsjui, (eds.), Faults, fluid flow, and petroleum traps: AAPG Memoir 85, p. 153-180.

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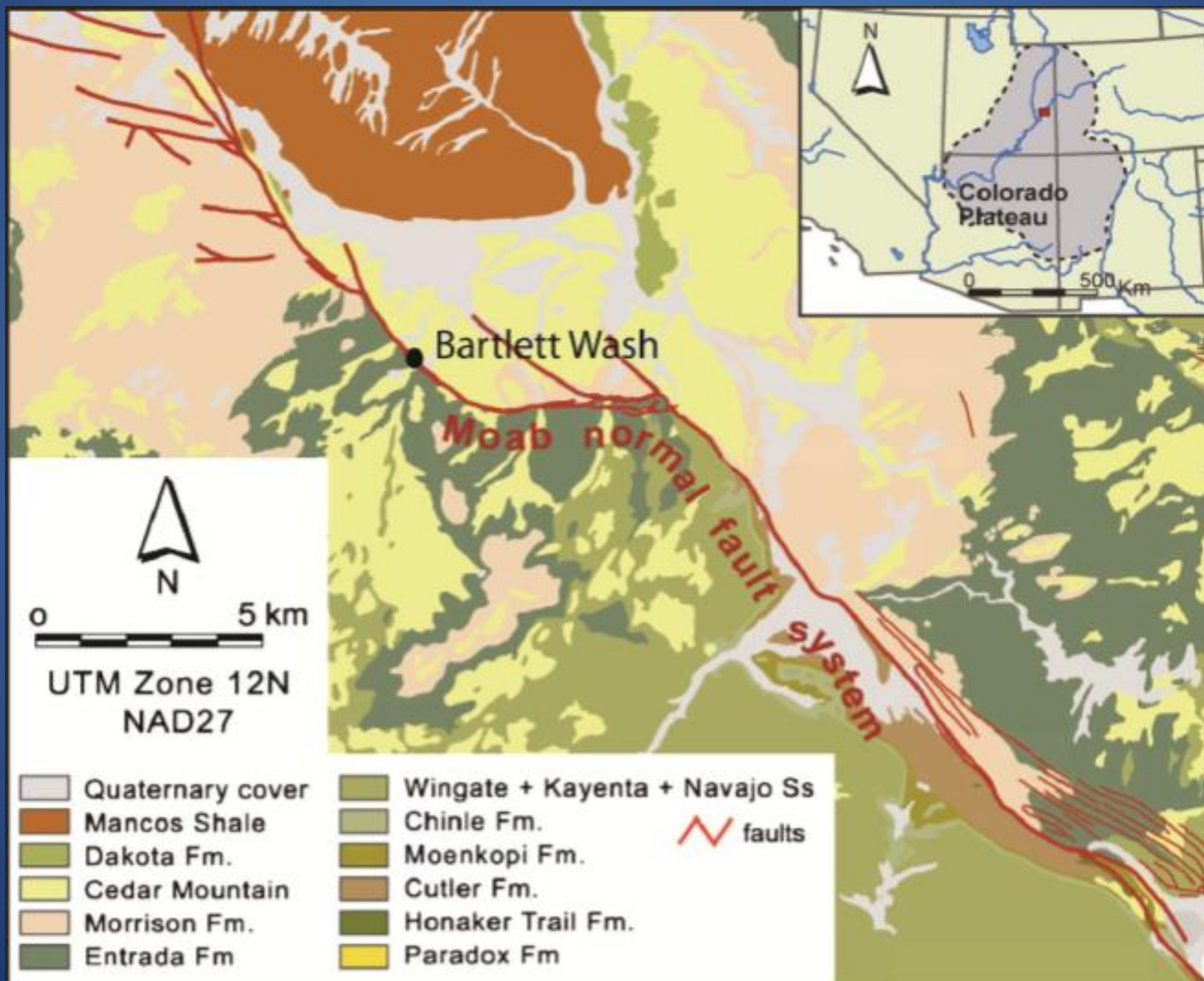
Outline

- Field location and geology
- Introduction to deformation bands and velocity
- Laboratory and Field Techniques
- Velocity Measurements and Observations
- Current Conclusions

Field Location/Geology Overview



Davatzes and Aydin (2005)

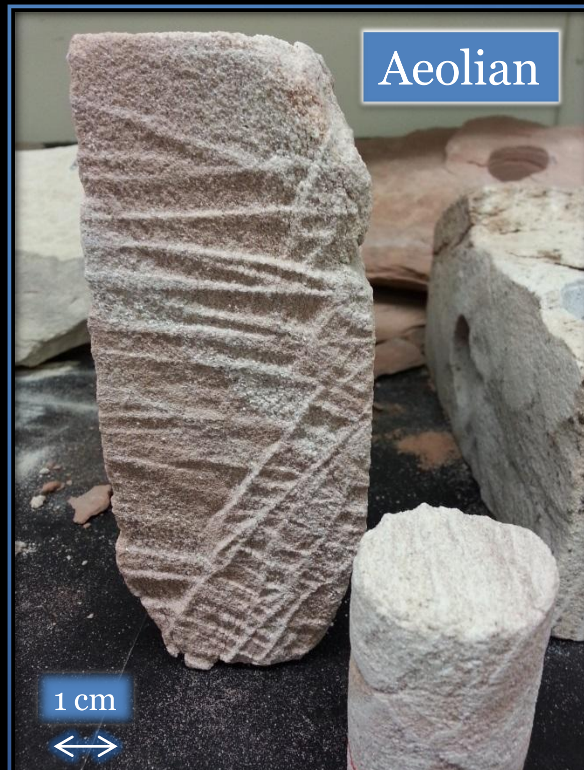
Field Location/Geology Overview

Deformation Bands

Deformation bands are zones of local compaction, shearing, or dilation in porous media

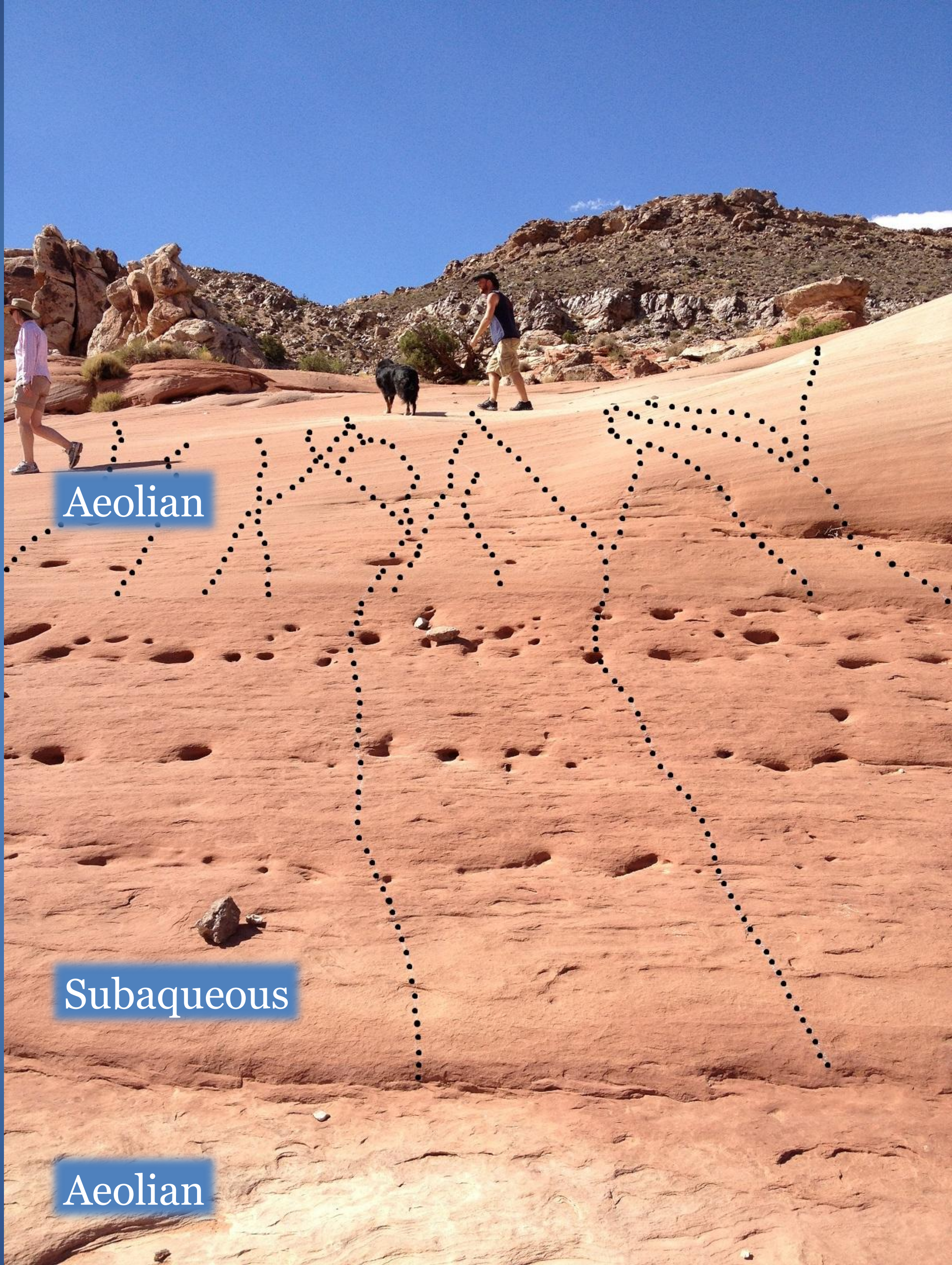
Typified by a reduction of porosity through:

- Grain realignment
- Cataclasis
- Preferential Cementation
- Diagenesis



Deformation Bands

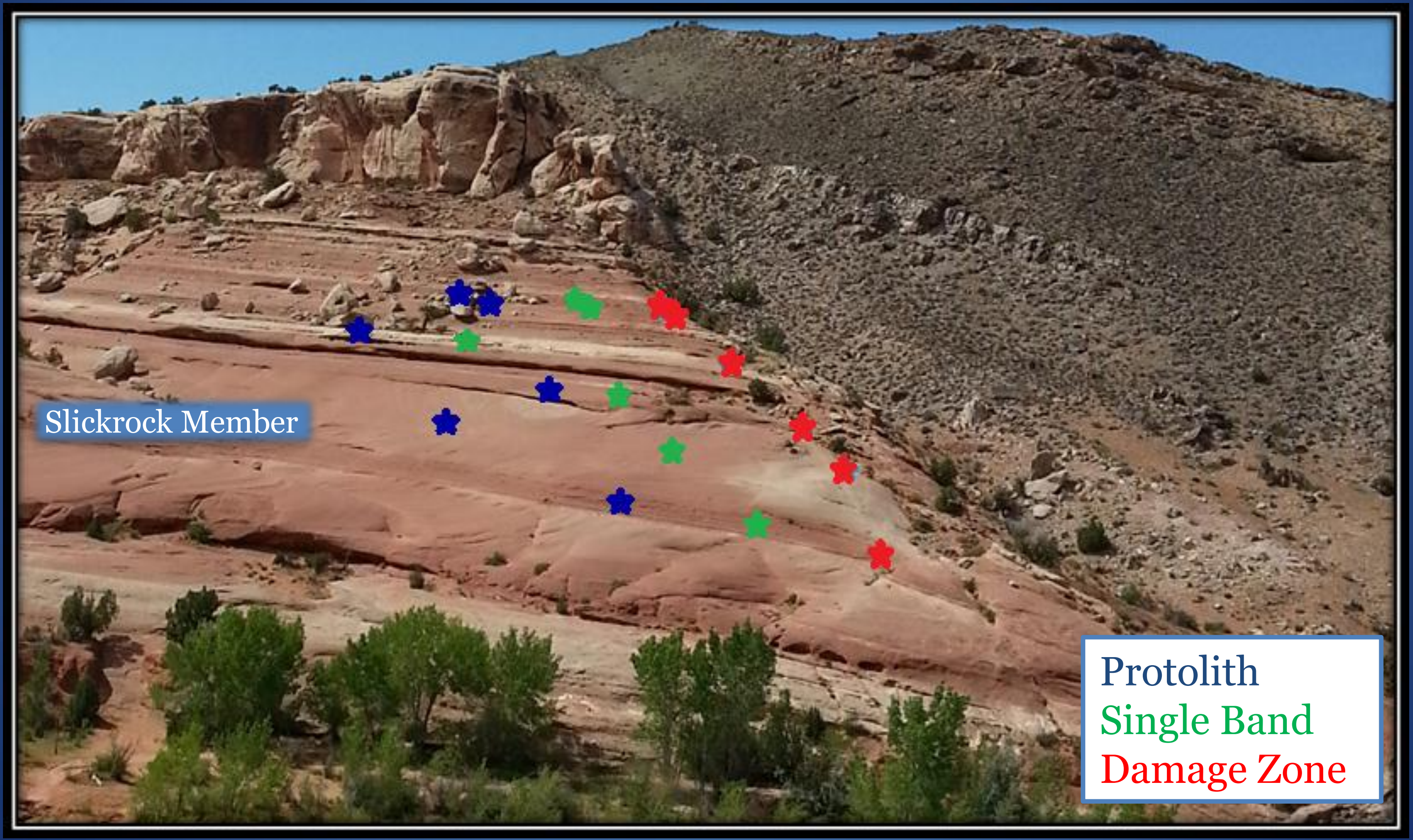
- Commonly found in damage zones near faults
- A single band can extend laterally for hundreds of meters
- Networks of bands can create a permeability barrier
- Can play a key role in determining whether or not a fault is sealing or leaking
- Deformation bands cannot easily be detected in the subsurface



Deformation Bands and Velocity

- The petrophysical characteristics of deformation bands could allow them to be fast paths for P and S-wave energy
- Previous laboratory experiments have shown positive correlations
- Hand samples were collected for laboratory tests and outcrop measurements were made within the same units

Velocity Tests Locations

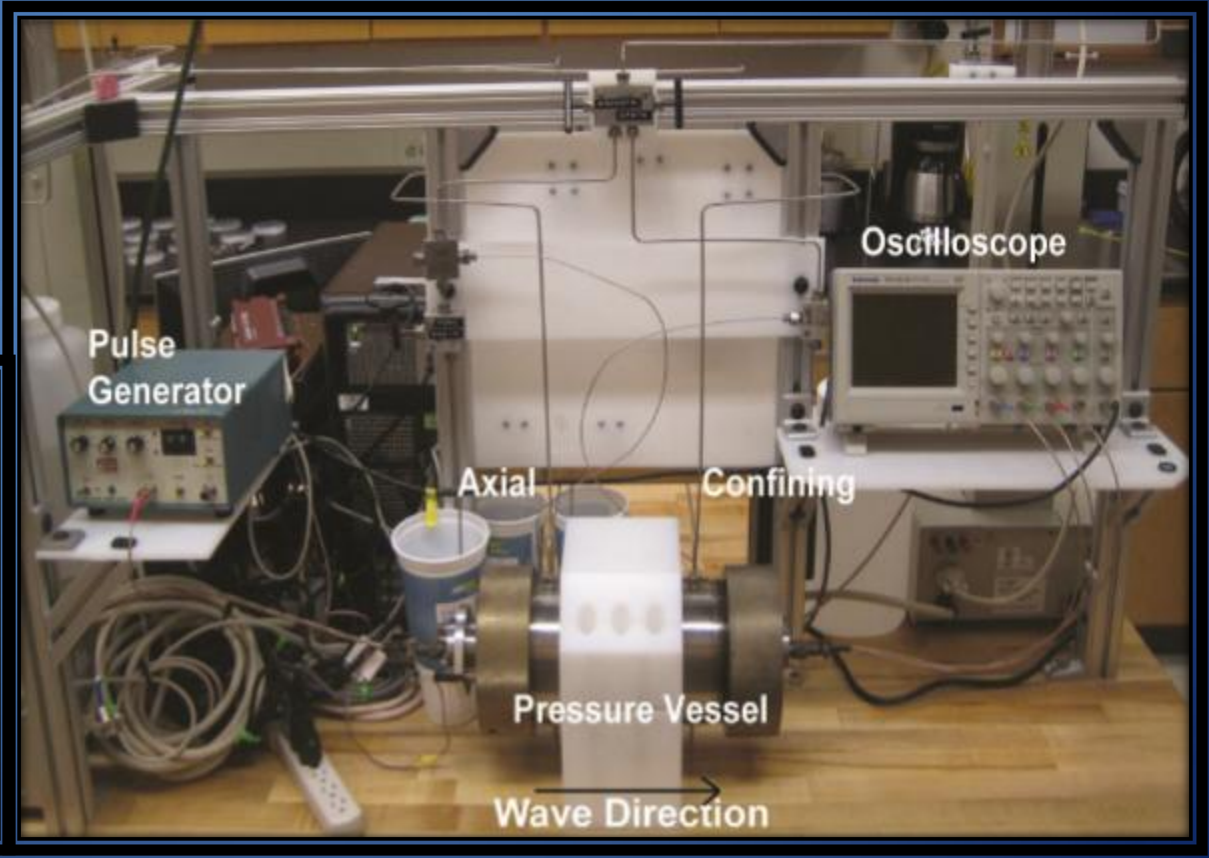


Six units were targeted for velocity analysis based on variations in lithology

Laboratory Velocity Tests

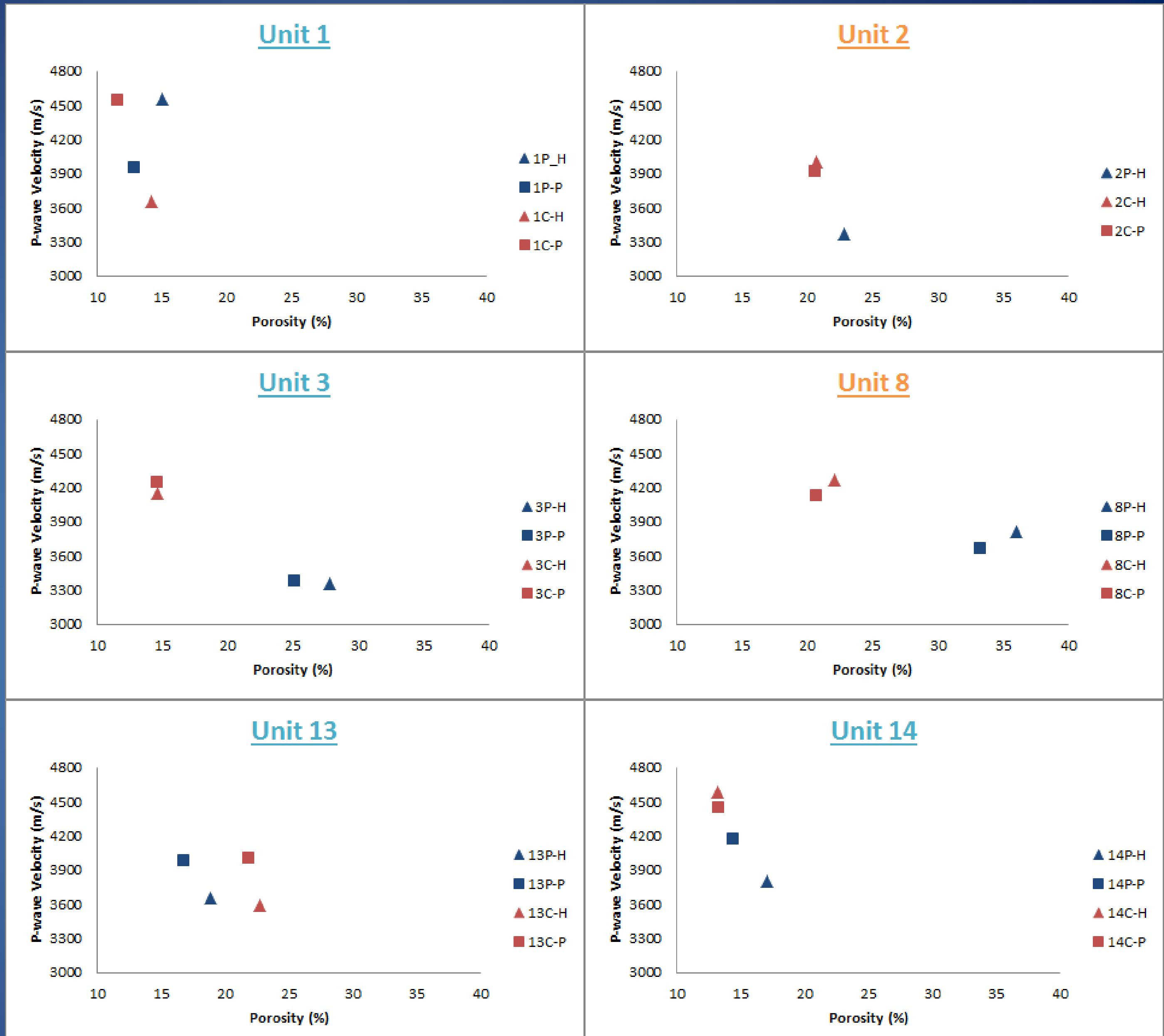
Samples were pressurized to 70 MPa

- Laboratory samples are on the centimeter scale
- Very high frequency waveforms provide high degree of accuracy



Lab Velocity Results

- Expected inverse relationship between velocity and porosity
- Deformation bands produce higher velocities
- Both facies types exhibit similar velocity characteristics



Subaqueous Unit
Aeolian Unit

Horizontal to bedding
Perpendicular to bedding

Protolith
Damage Zone

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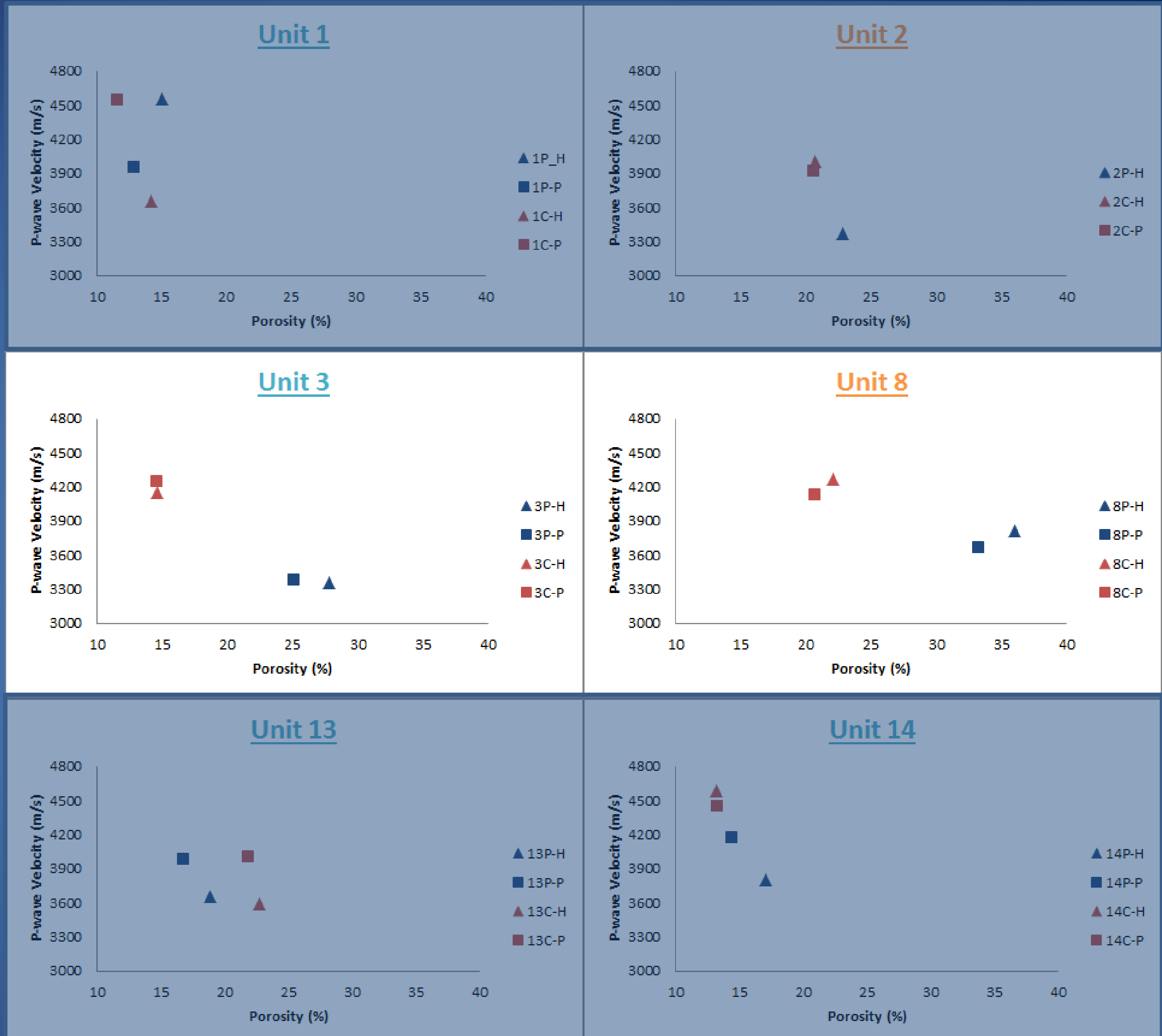


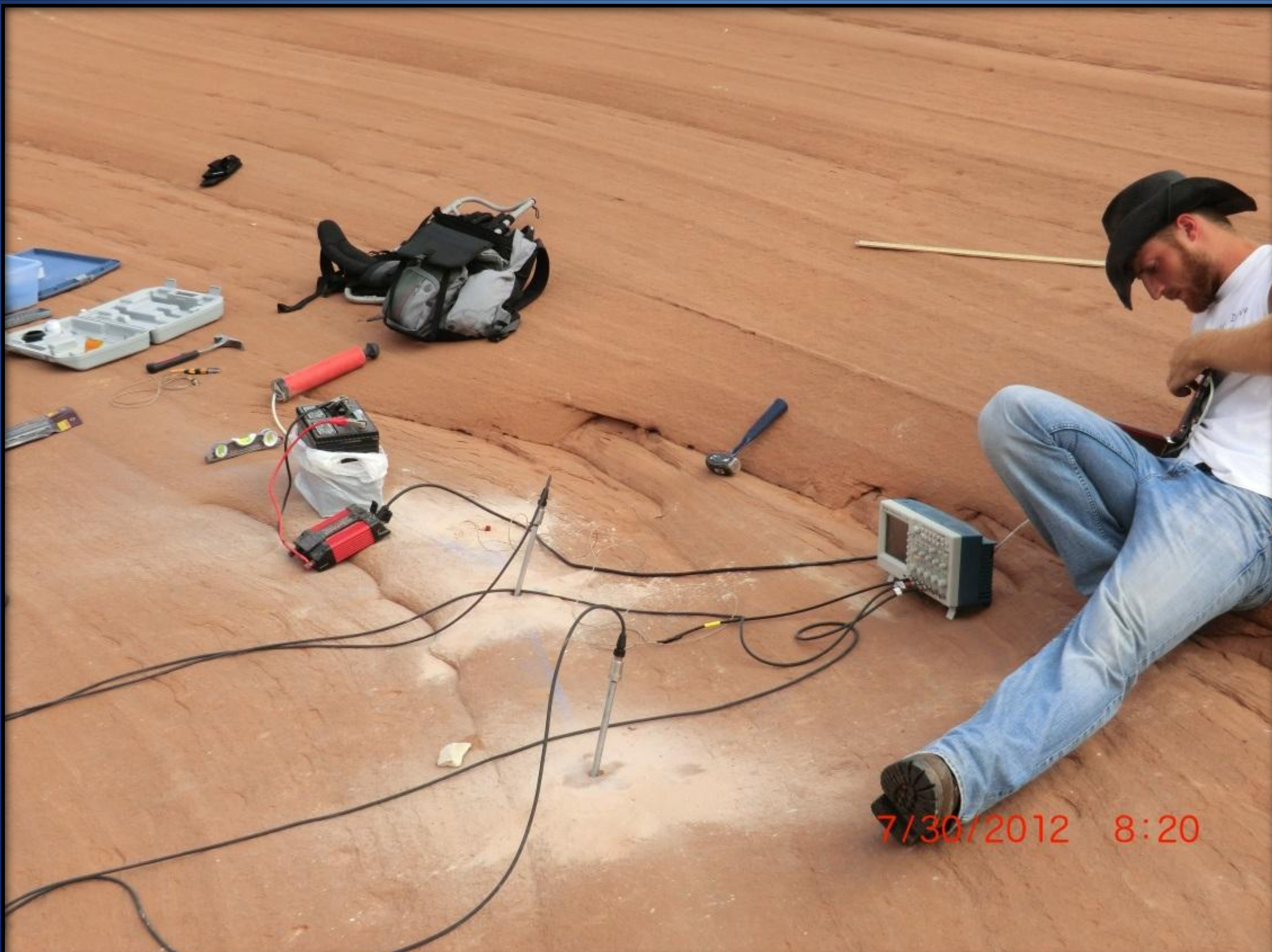
Subaqueous Unit
Aeolian Unit

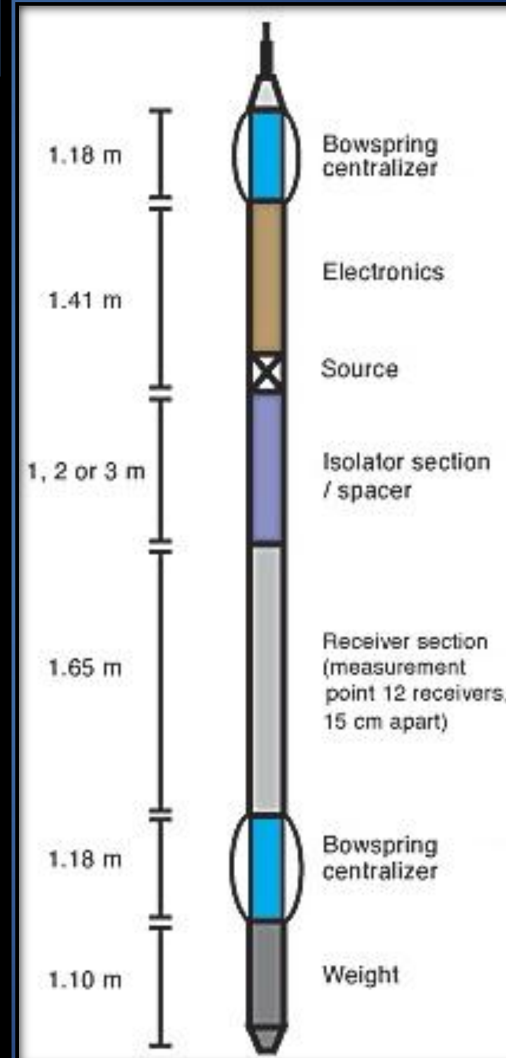
Horizontal to bedding
Perpendicular to bedding

Protolith
Damage Zone

Outcrop Velocity Tests

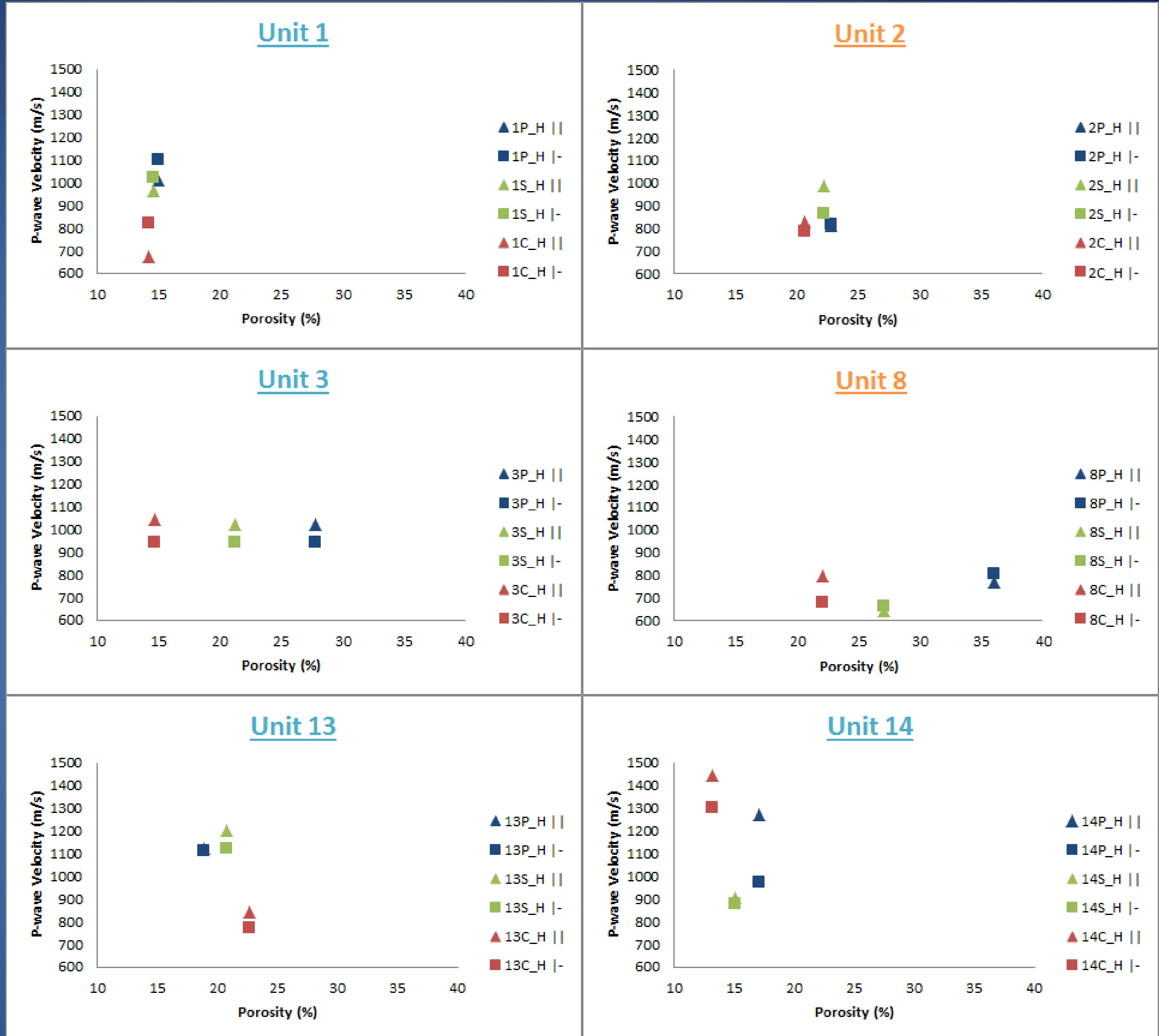
Tests were designed to be an analog to common sonic logging tools, which operate at similar scales and frequency





Outcrop Velocity Results

- Lack of differentiation between protolith, single band tests, and tests within dense zones of bands
- Overall velocities much lower than lab measurements
- Both facies types exhibit similar velocity characteristics



Subaqueous Unit
Aeolian Unit

▲ Horizontal to bedding
■ Perpendicular to bedding

Protolith
Damage Zone

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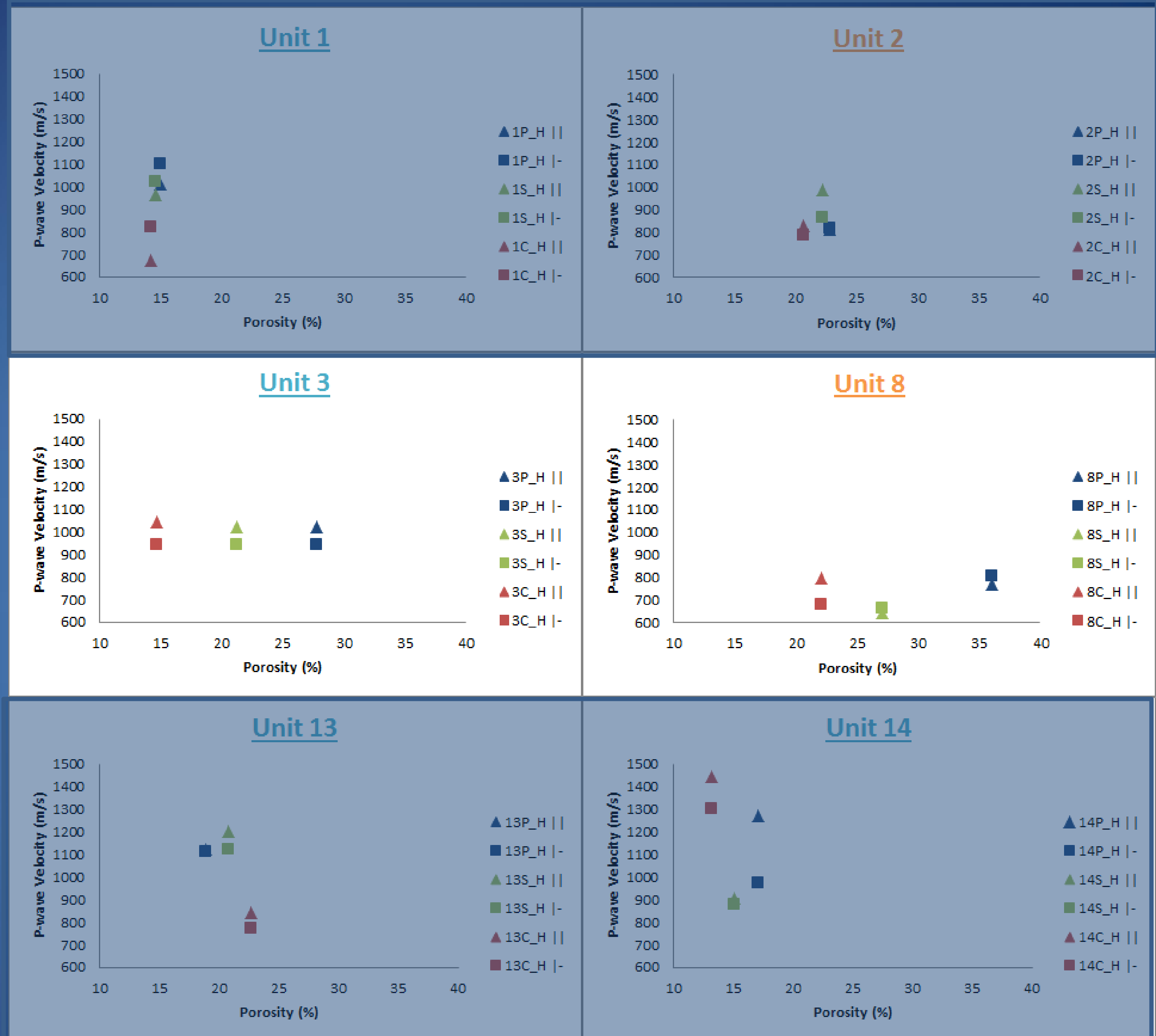


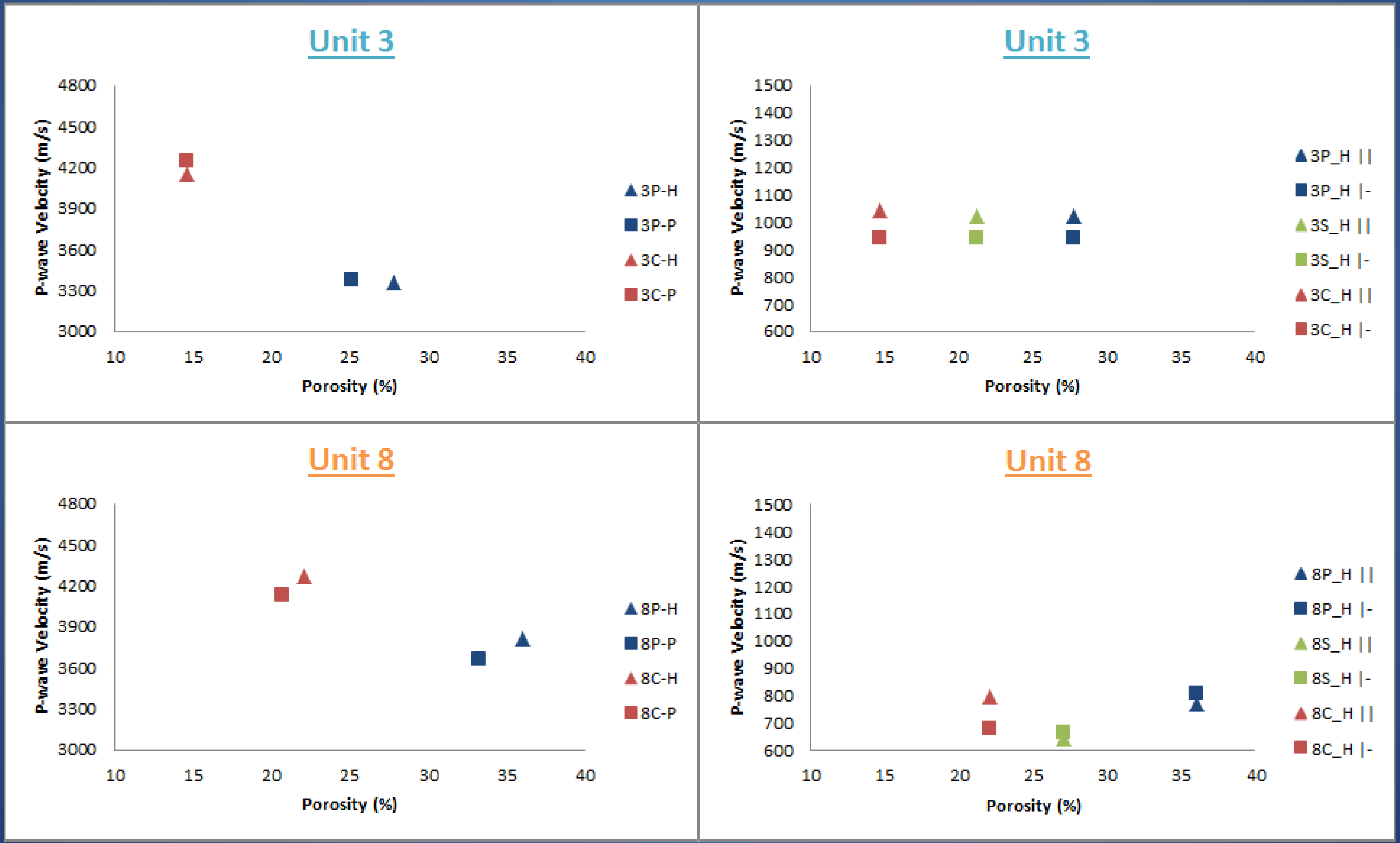
Subaqueous Unit
Aeolian Unit

Horizontal to bedding
Perpendicular to bedding

Protolith
Damage Zone

Comparative Results

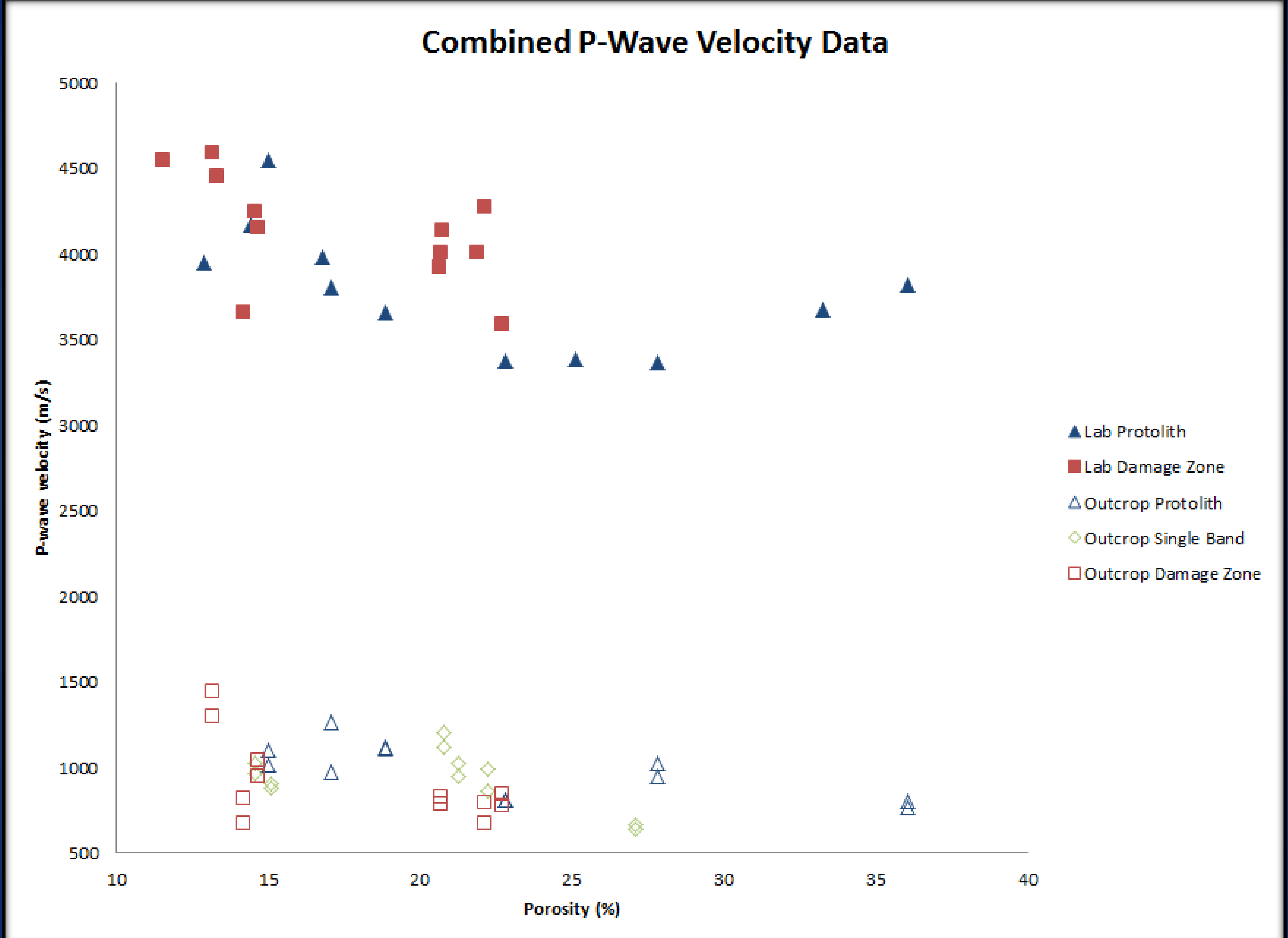
Laboratory | Outcrop



Subaqueous Unit
Aeolian Unit

▲ Horizontal to bedding
■ Perpendicular to bedding

Protolith
Damage Zone


Combined P-Wave Velocity Data
P-wave velocity (m/s)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
10
15
20
25
30
35
40
Porosity (%)
Lab Protolith
Lab Damage Zone
Outcrop Protolith
Outcrop Single Band
Outcrop Damage Zone

Current Conclusions

- Outcrop velocity tests do not mimic laboratory measurements
- Outcrop velocities do not differentiate between protolith and damage zone
- Lack of confining pressure may reduce bulk rigidity of damage zone material due to the presence of microcracks
- May not act as a proxy to well logging analysis due to lack of confining pressure
- Results do not rule out the potential ability to find deformation bands using sonic tools

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Microcracks