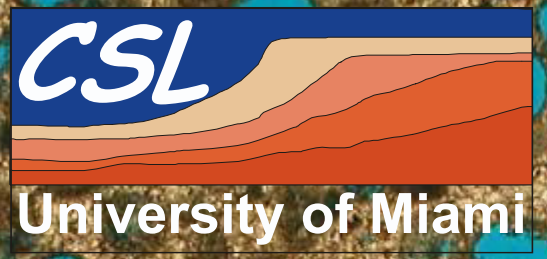

Effect of Spherical Pore Shapes on Acoustic Properties in Carbonates

Gregor Baechle[1], Layaan Al-Kharusi[1], Gregor Eberli[1], Austin Boyd[2] and Alan Byrnes[3]

[1]Comparative Sedimentology Laboratory
[2]Schlumberger Doll Research, Boston
[3]Kansas Geological Survey

Outline

- **Porosity & Pore Type Effects**
  - Dominant oomoldic pore type
  - Minor inter-crystalline pore type
- **Fluid & Pressure Effects**
  - 3-30 MPa differential pressure
  - 7 different pore fluids

Key Points – Part 1

- Large p-wave velocity scatter (2500 m/s) at given porosity
- Our results question two major assumptions in respect to moldic, spherical pores:
  - Moldic pores are always associated with strong rock-frame
  - Amount of spherical porosity is related to velocity variations at a given porosity

→ **Not dominant pore type, but minor inter-crystalline pore type in rock frame causes slow velocity at given porosity**

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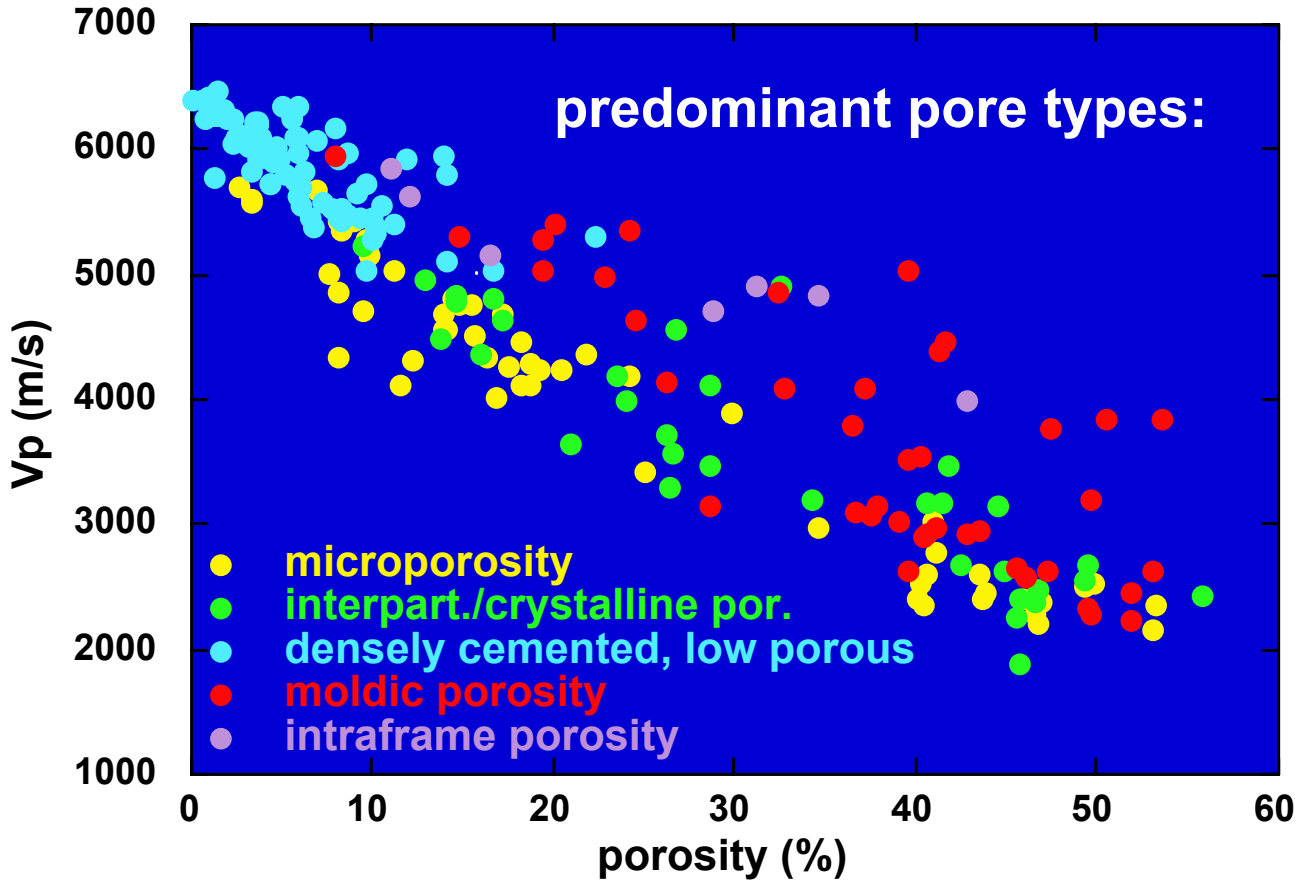
Conceptual Pore Type Model



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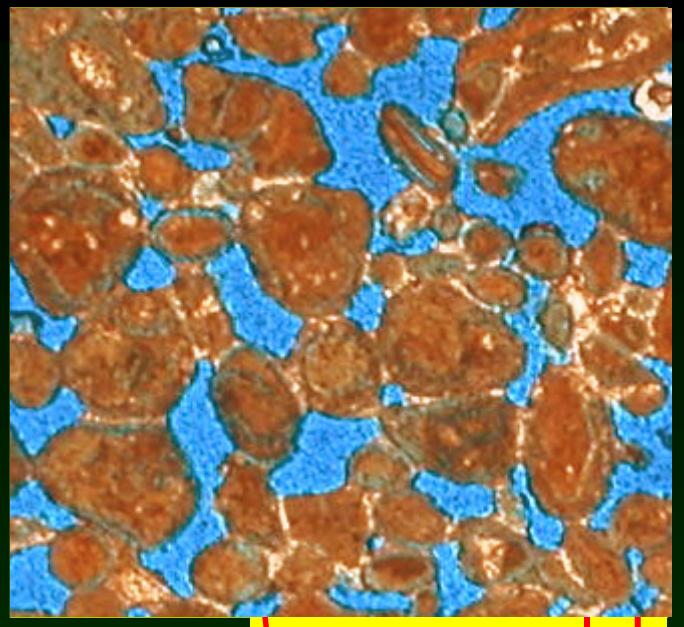
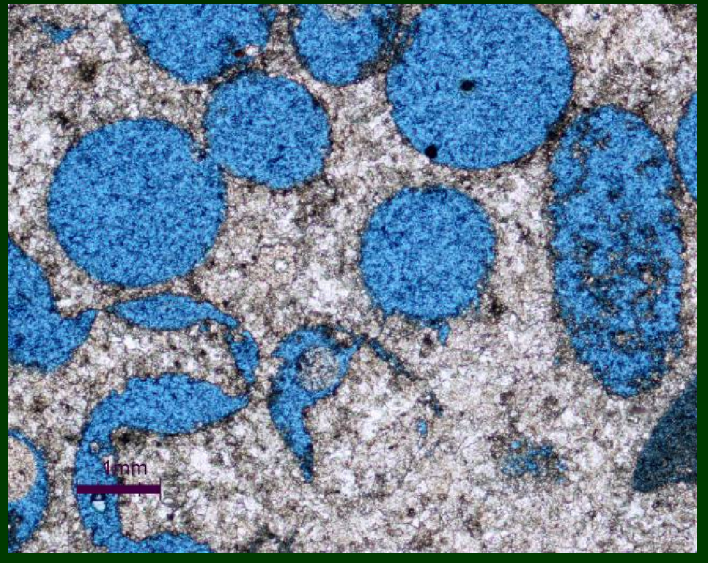
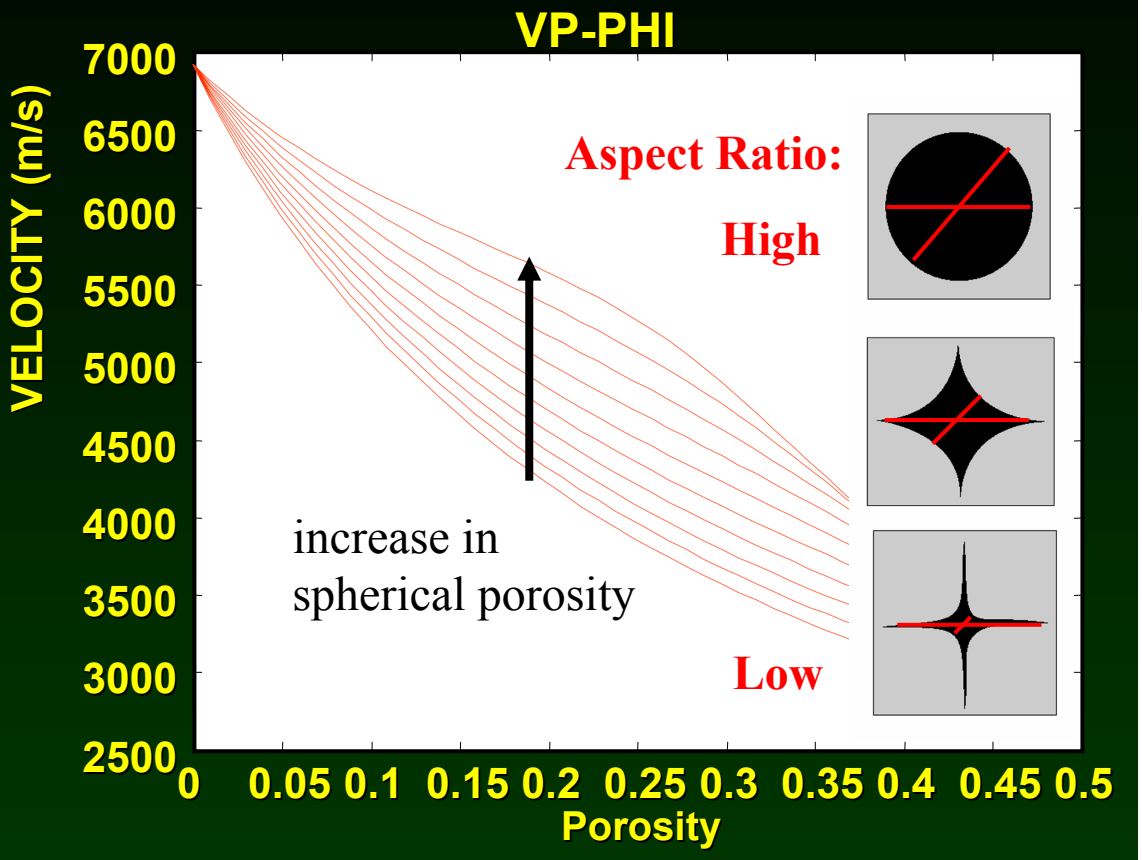


Pore Space (1)
Solid Frame (2)
Contact Area (3)



Saleh and Castagna, 2004, Geophysics,
(drawing modified by Ralf Weger)



oomoldic pore type ~ strong cemented frame
spherical pores shapes ~ incompressibility

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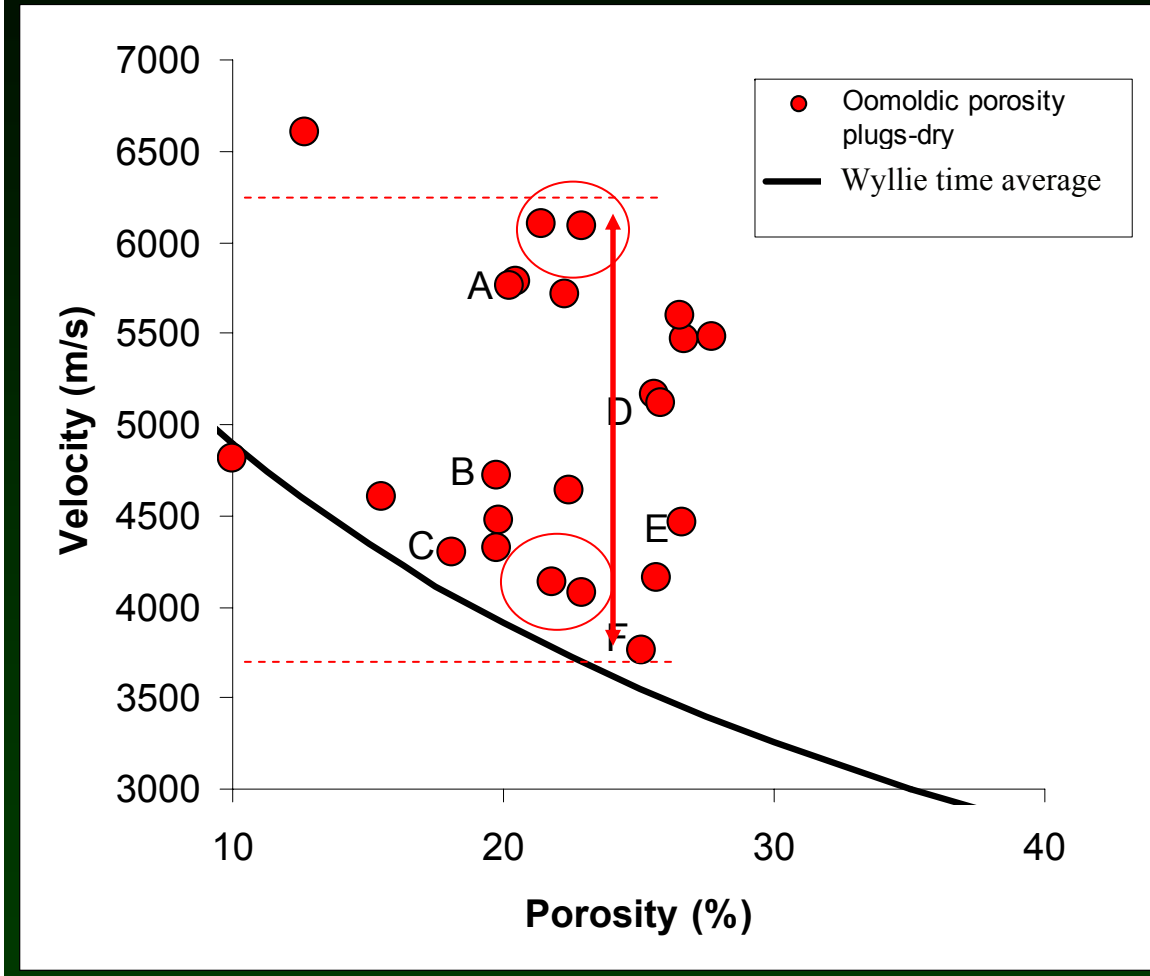
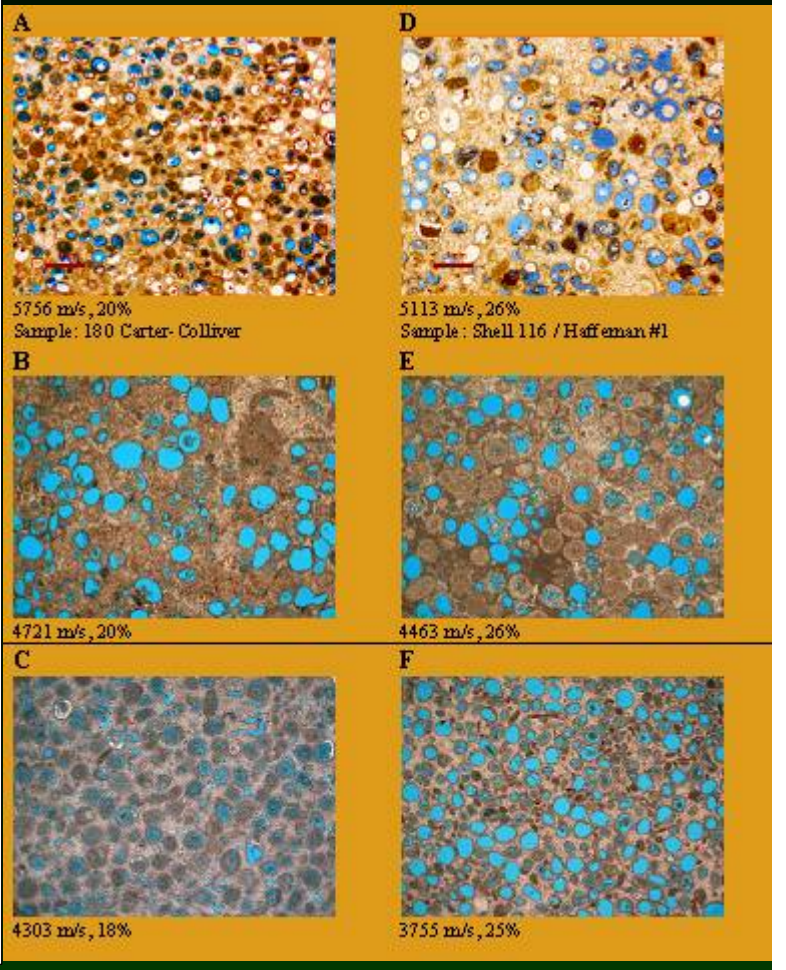
Large Scatter in Vp-Porosity Plot





30MPa; dry conditions

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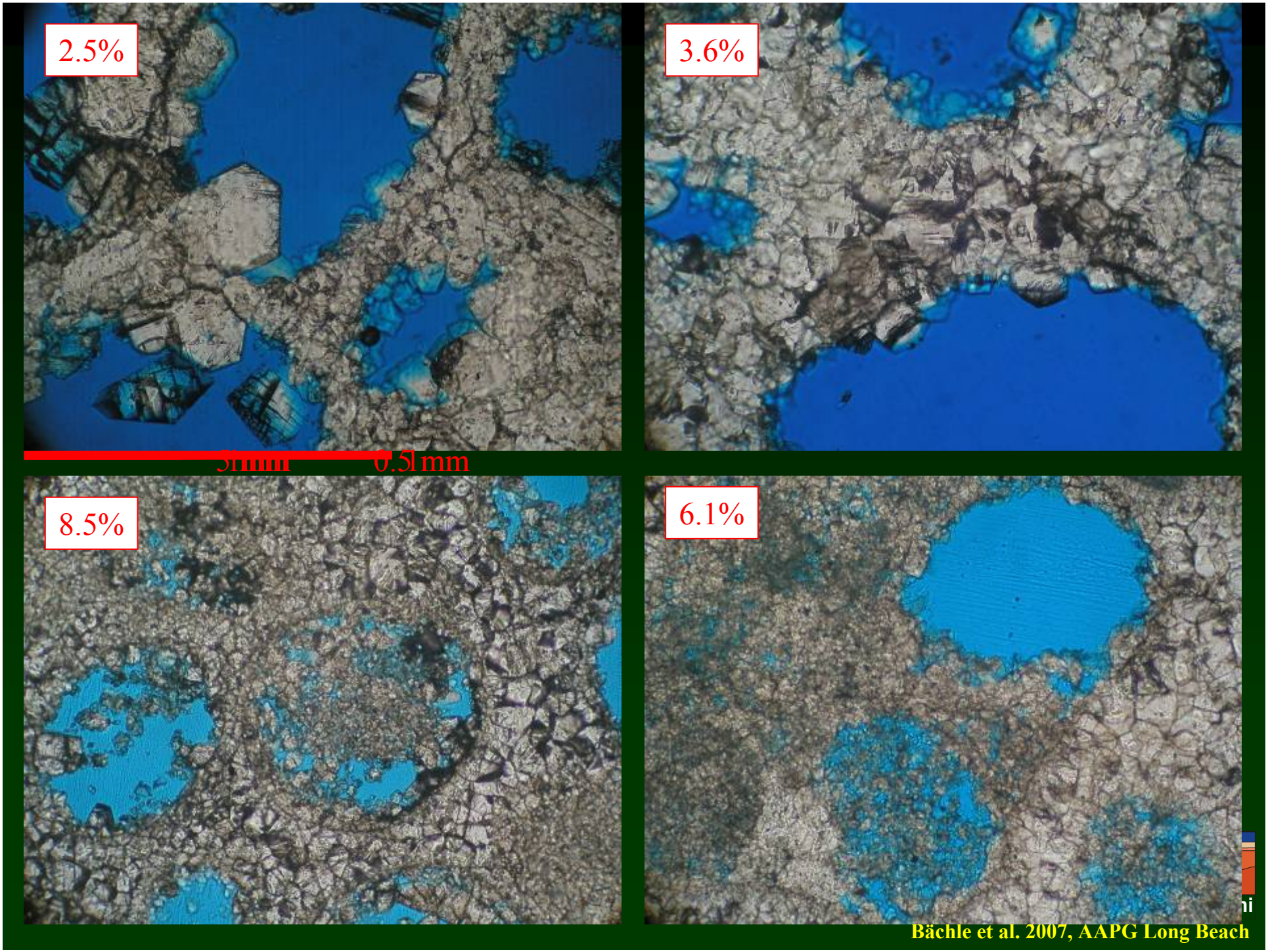

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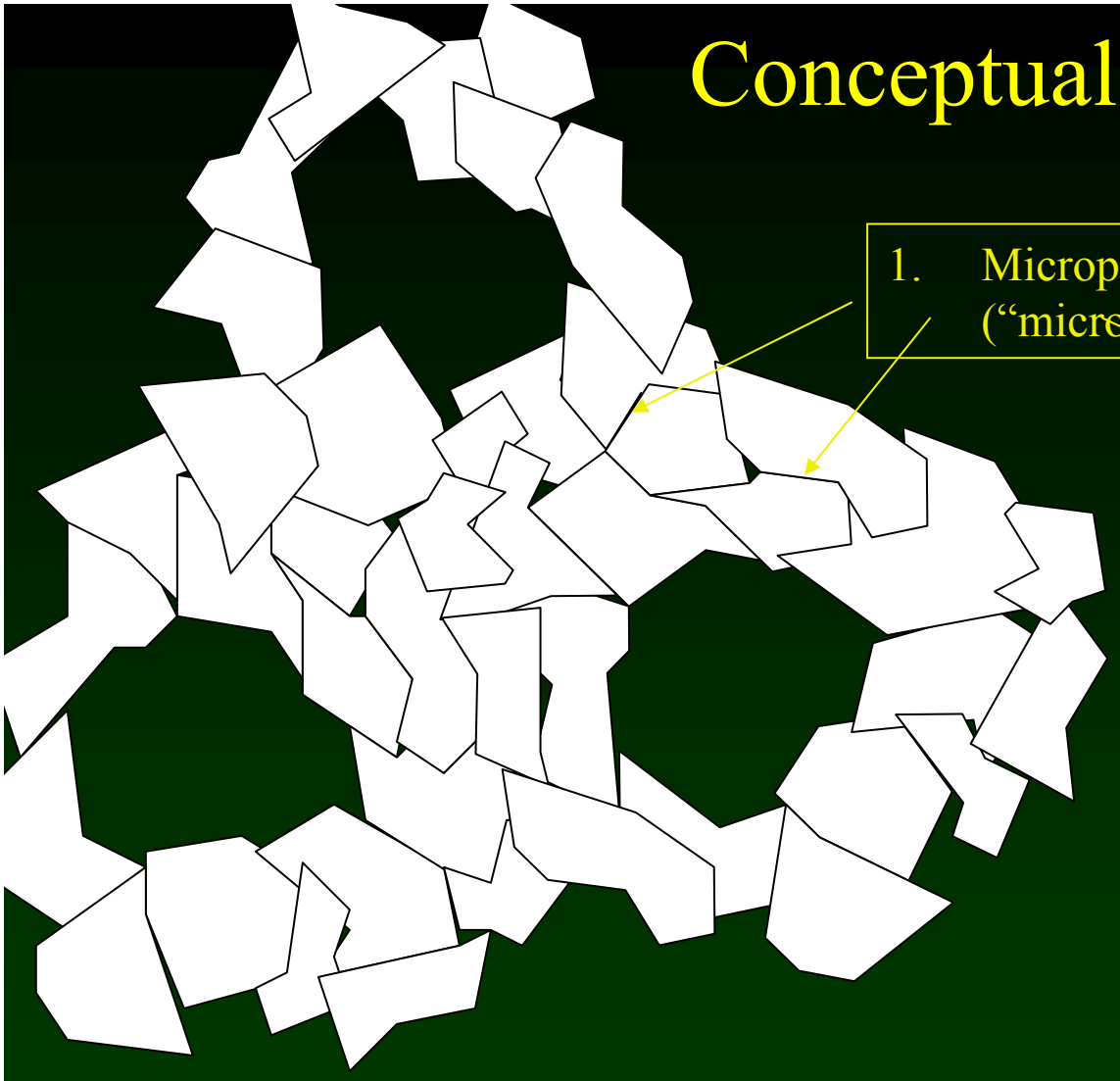
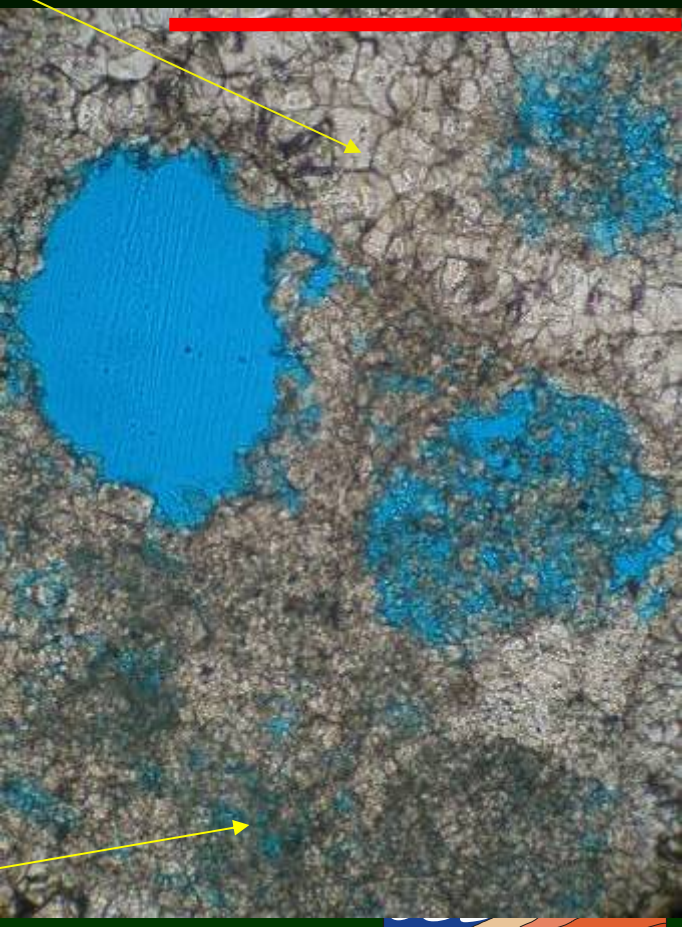
Conceptual Model



1. Micropores between mosaic cement ("microcrack porosity")



2. Micropores in fine grained cement

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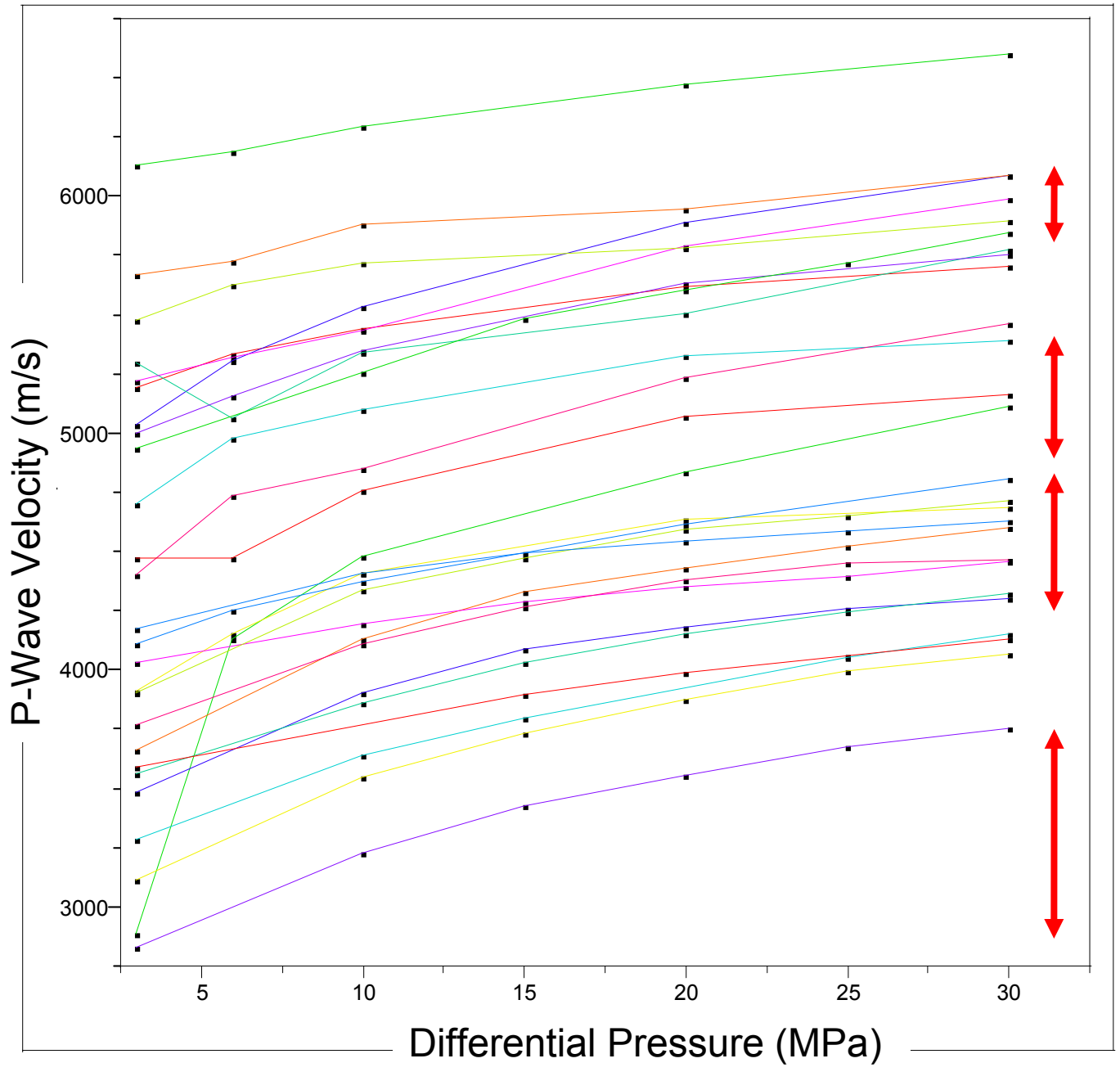

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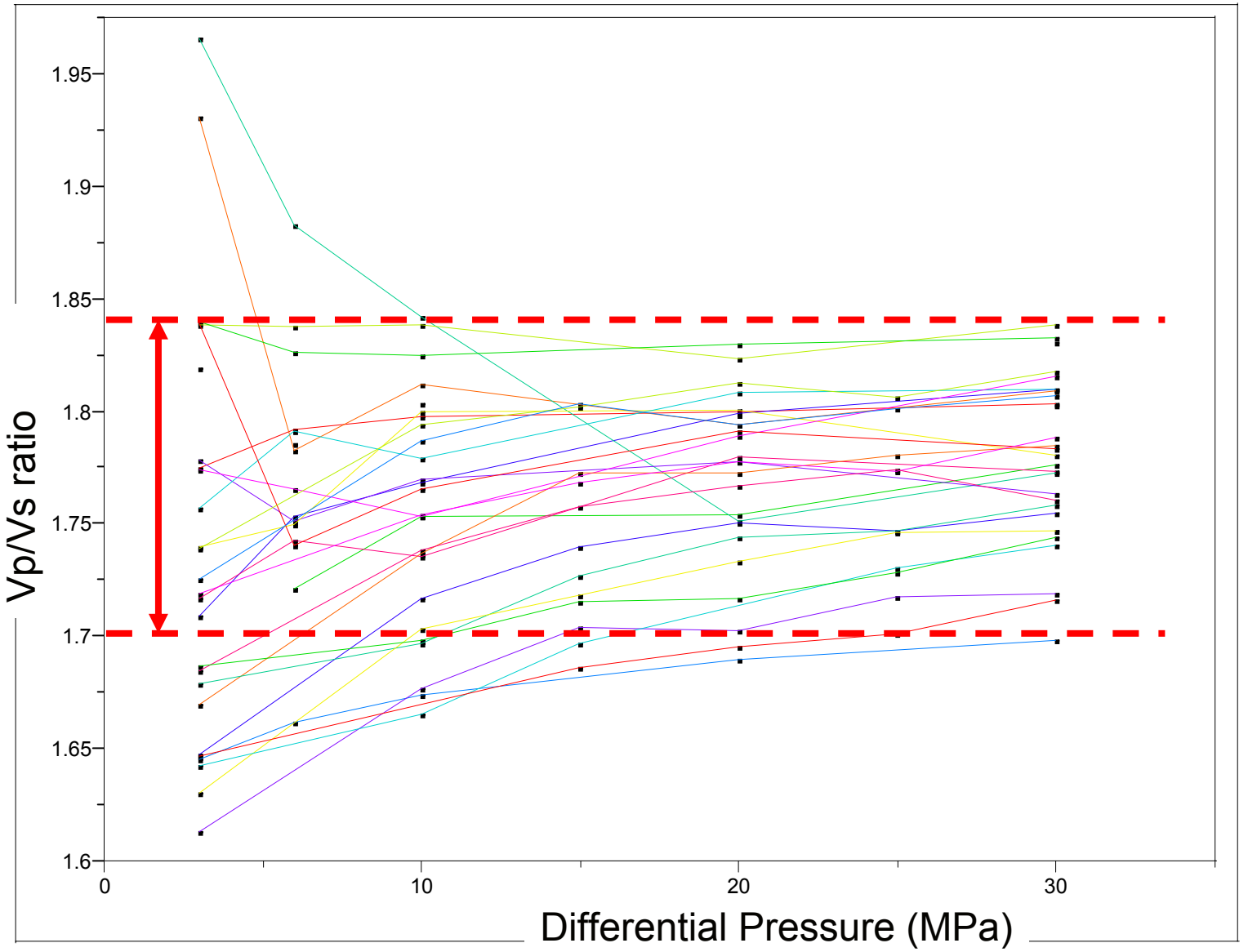

Increasing Vp/Vs with pressure

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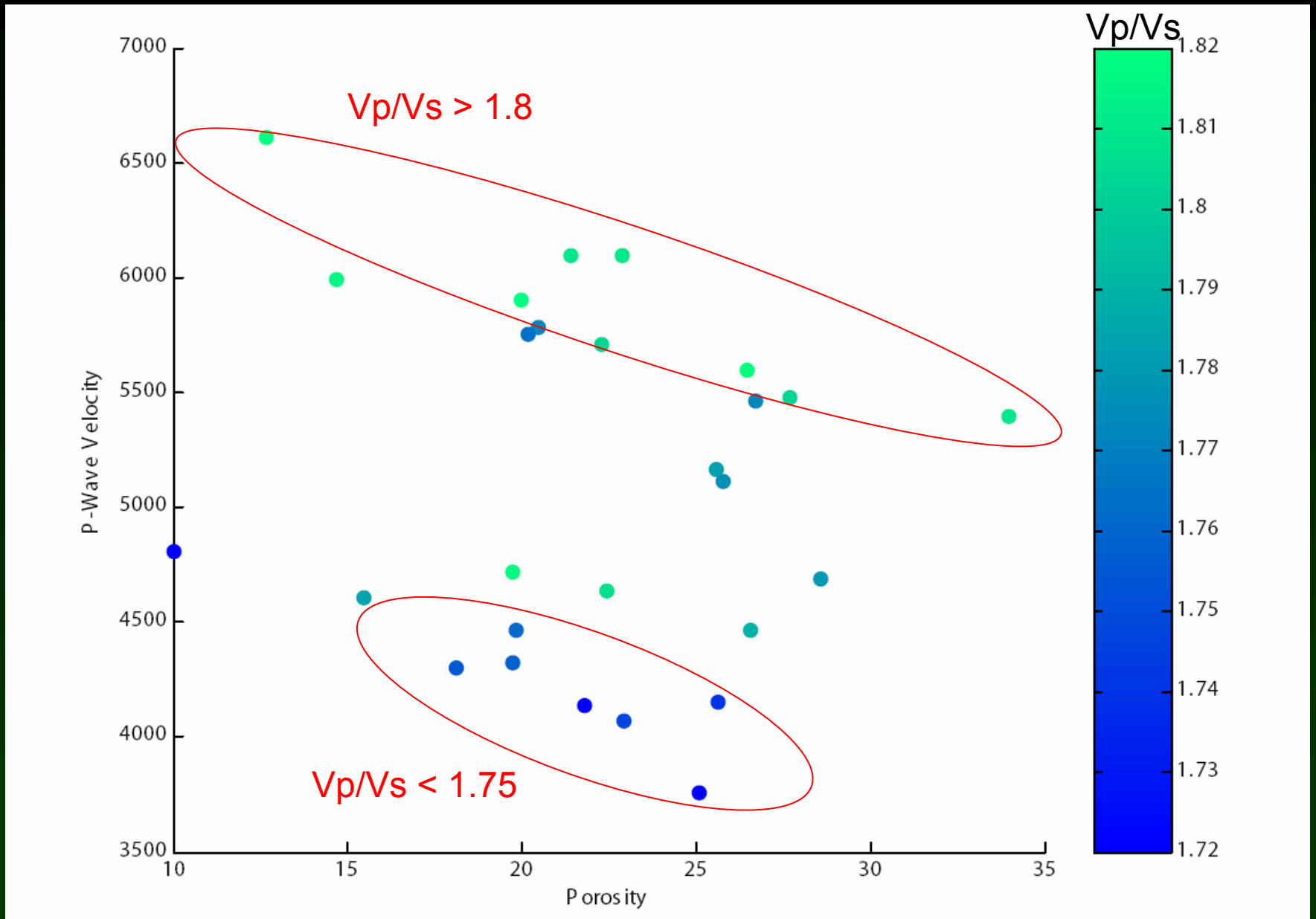

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→ **Not dominant pore type, but minor inter-crystalline pore type in rock frame causes slow velocity at given porosity**

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Key Points (Part 2)

- P-wave velocity of rocks with oomoldic porosity changes significantly with different pore fluids
- Bulk modulus shows linear relationship with changes in fluid modulus
- Fluid saturation effects on bulk modulus is function of porosity & pore types

Dry gas (K=0)

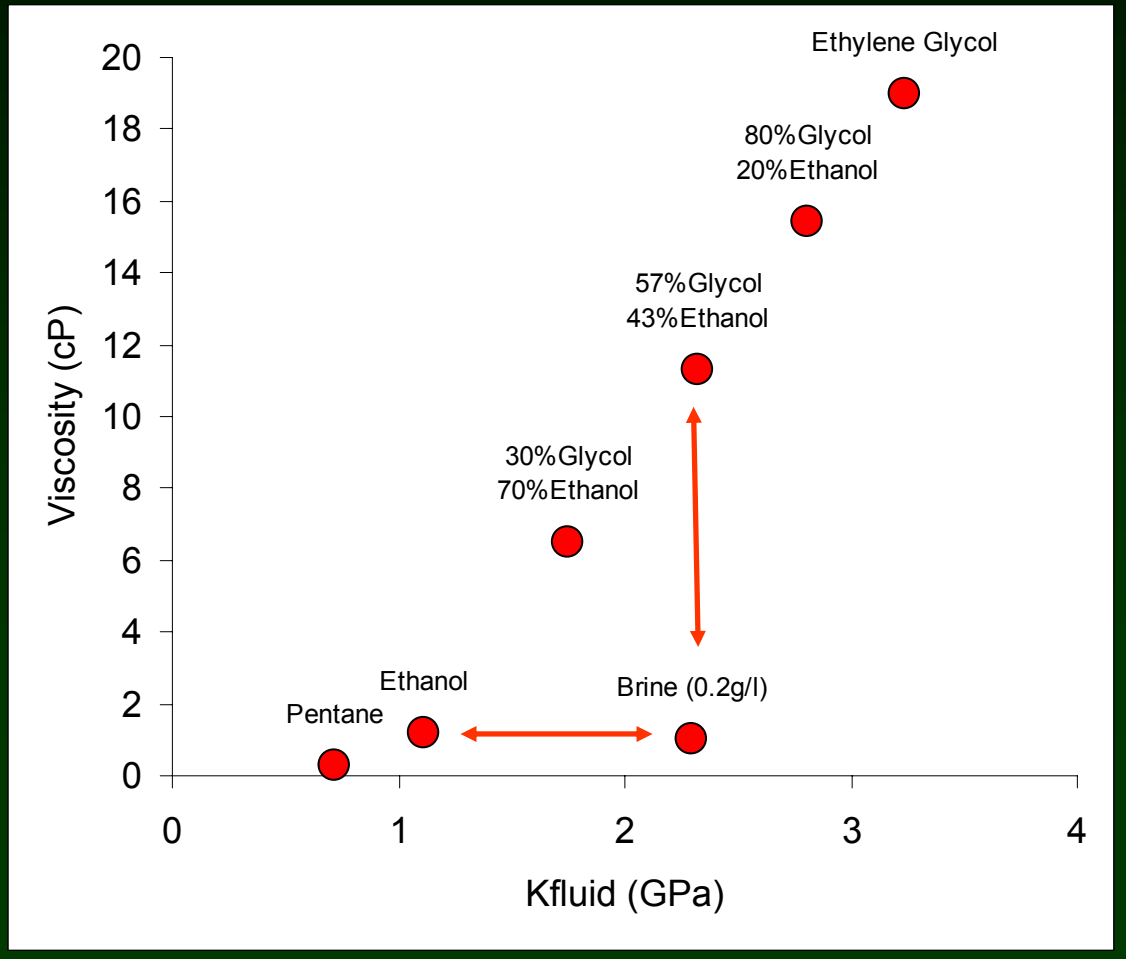
Wet gas

Live oil

Formation water

Heavy oil

Kfluid



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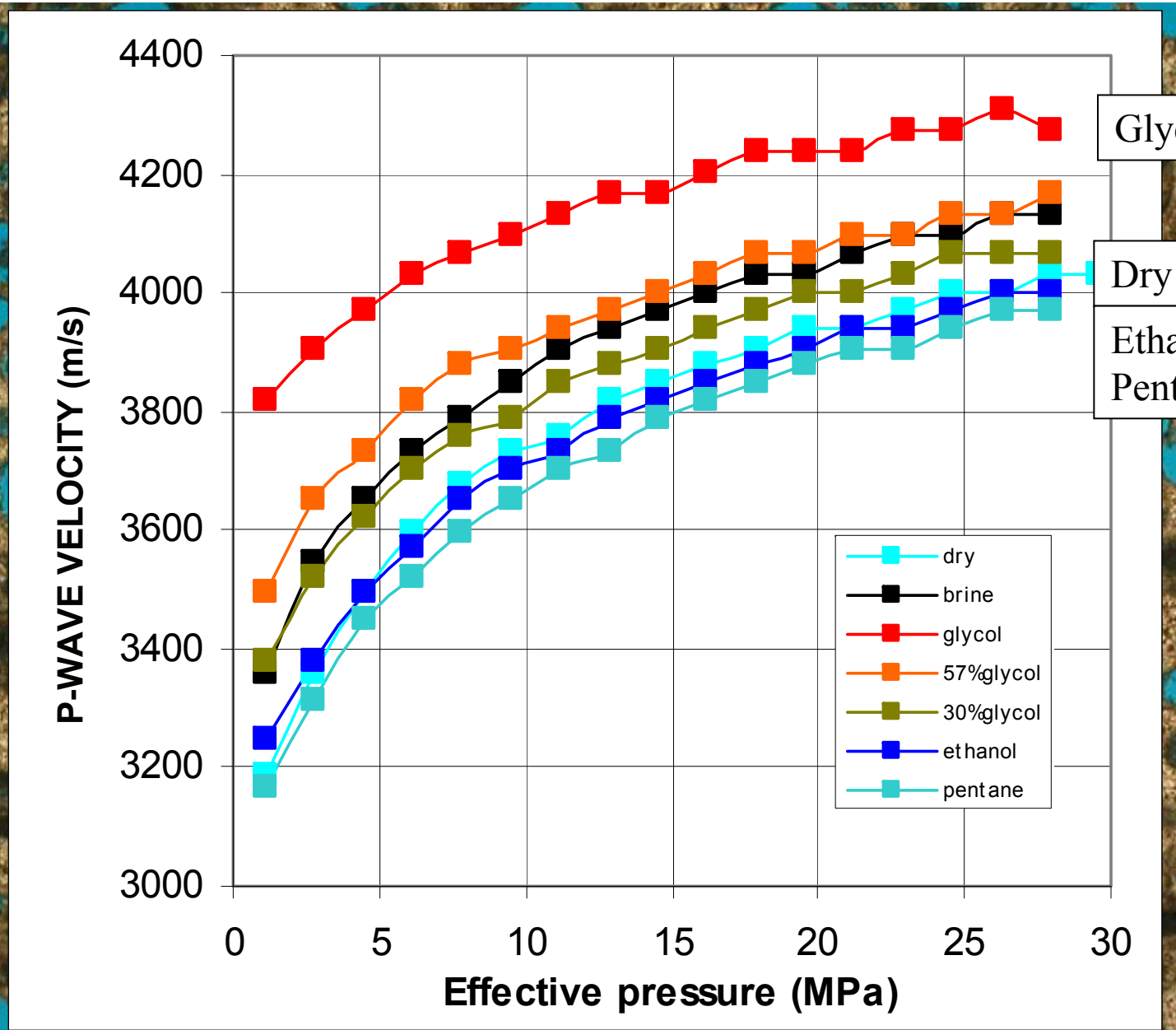
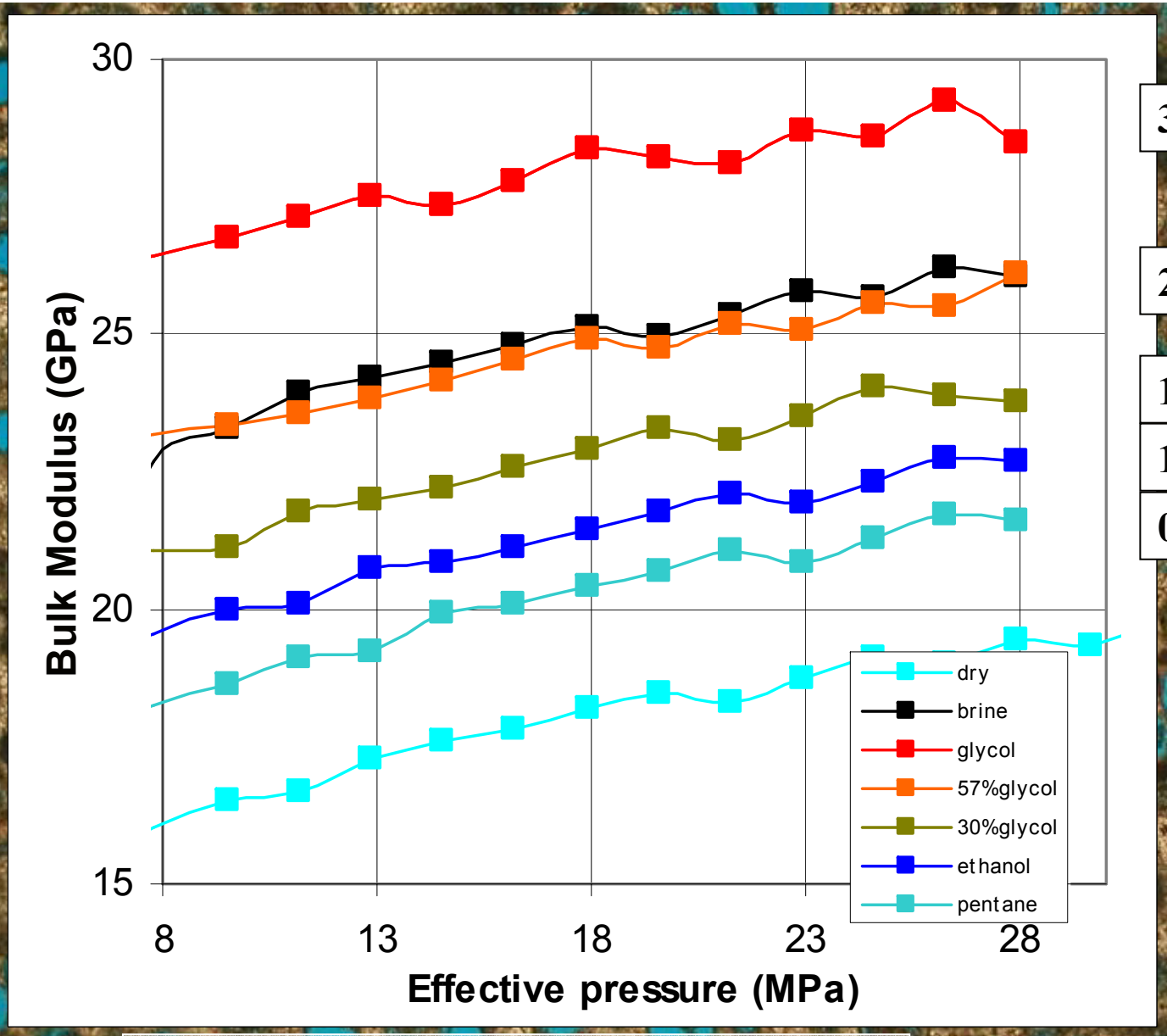


- $Vp_{brine} \neq Vp_{57\%\ Glycol}$ at low pressure (but similar K_{fluid})
- Density Effect: $Vp_{Ethanol}$ and $Vp_{Pentane} < Vp_{Dry}$



3.23 GPa

2.3 GPa

1.75GPa

1.1 GPa

0.7 GPa

Bulk modulus increases with Kfluid

Bulk modulus less sensitive to pressure changes than to saturation changes

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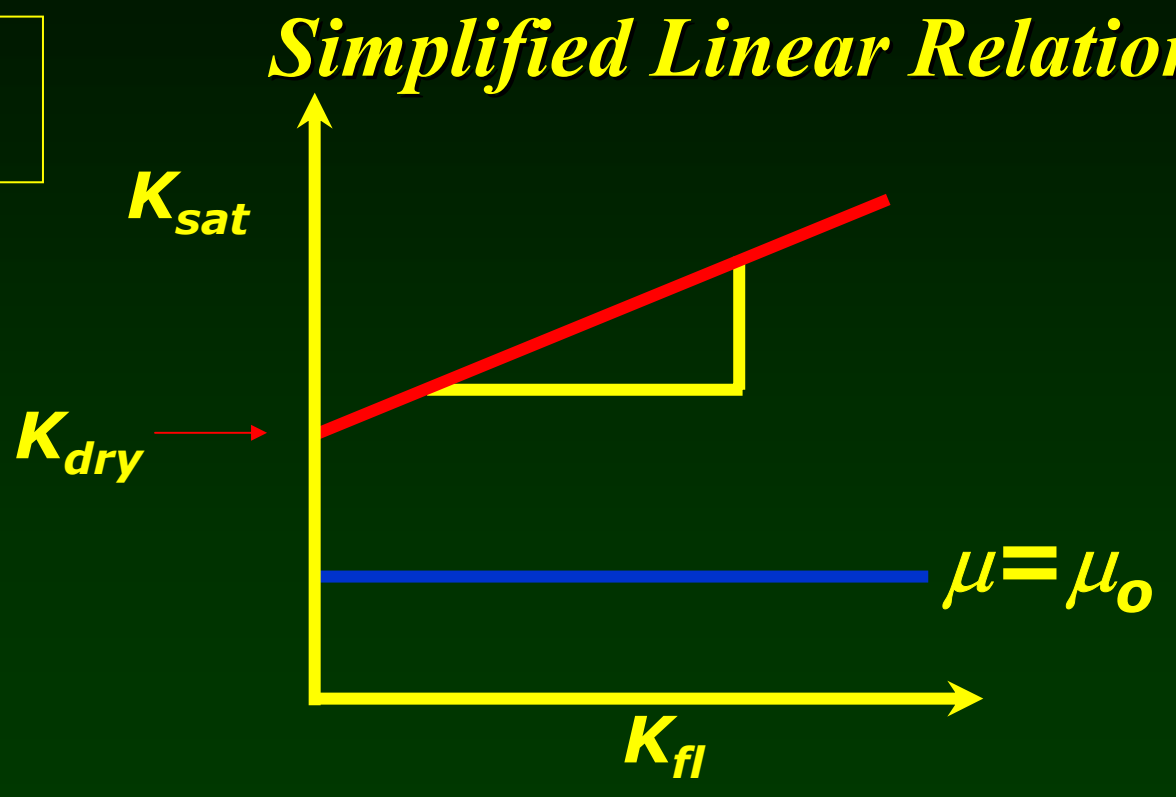
Simplified Gassmann Equation*

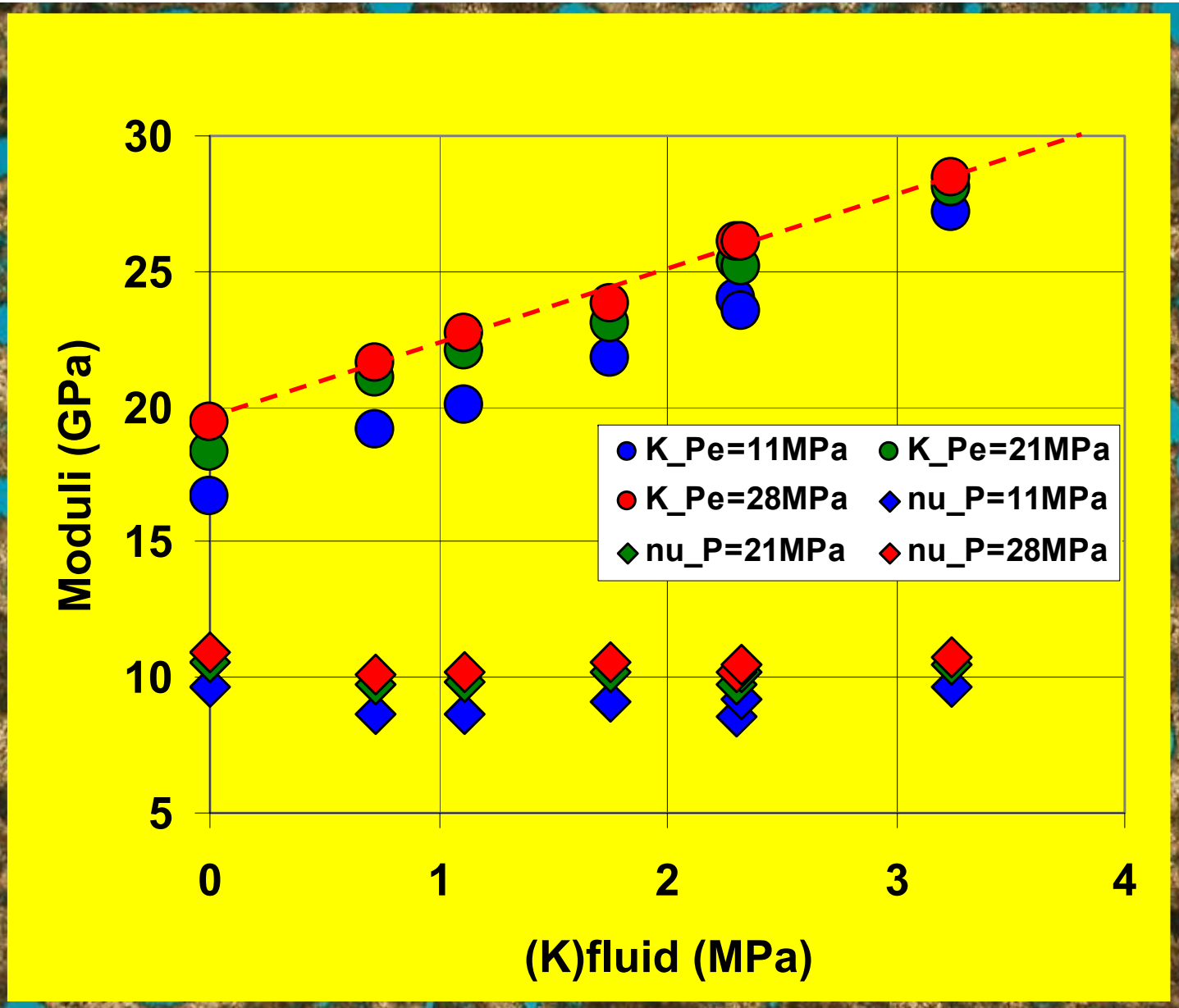
***Mavko et al., 1995; Han and Batzle, 2004; Rasolofosaon and Zinszner, 2004**

Assumption:

Kgrain >> Kfluid

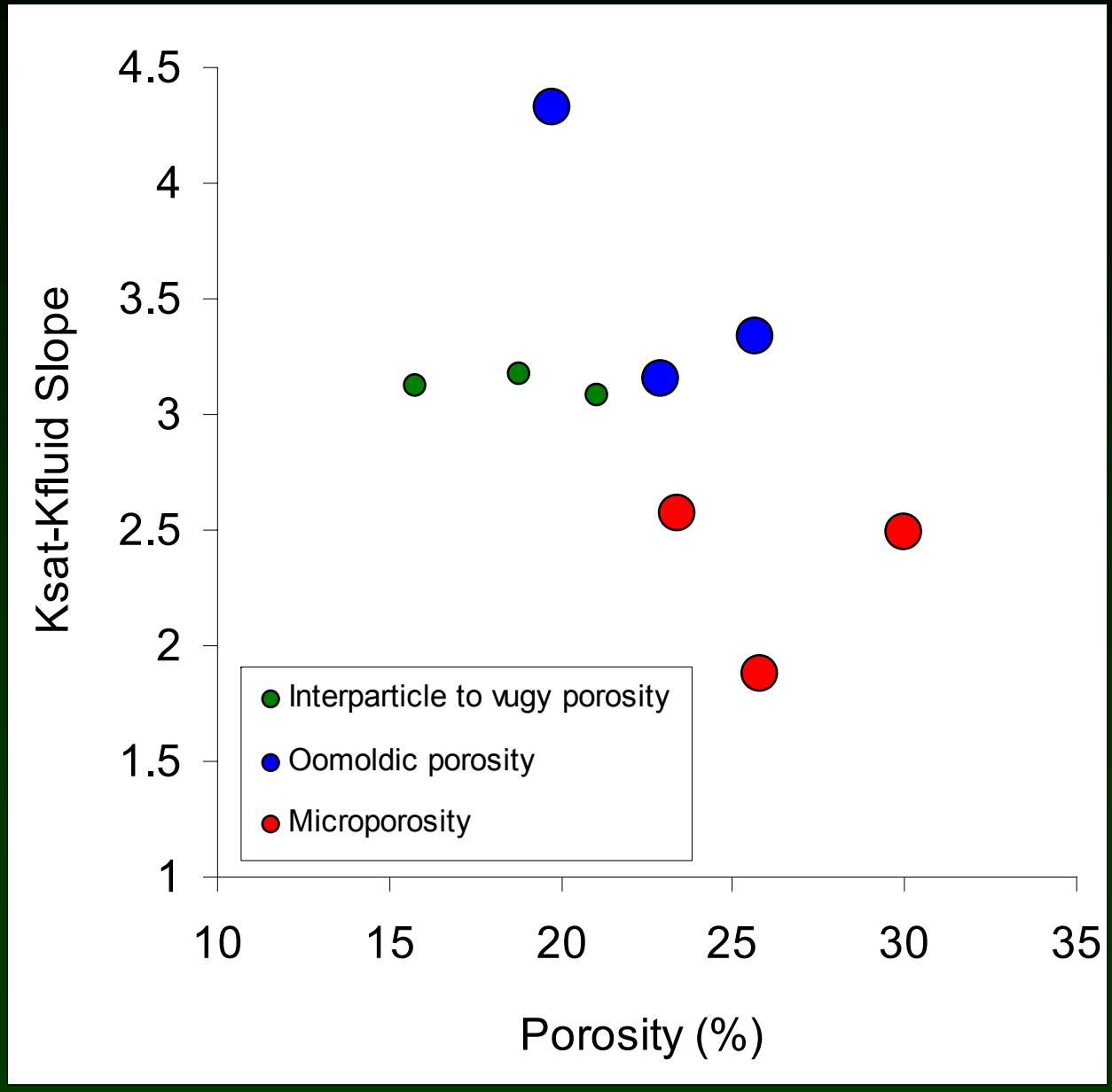


Steeper slope ~ larger increase of sonic velocity with fluid substitution



Slope Function of Pore Type & Porosity

Slope is the combined effect of porosity and pore type



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Conclusions & Implications

- **Large velocity scatter (2500 m/s) at given porosity observed in rocks dominated by oomoldic porosity**
- **Minor inter-crystalline microporosity causes slow velocity at given porosity**

- **The rock frame affects velocity at high frequencies and not the dominant pore shape or pore type!**
- **Ground truth of theoretical models is necessary to obtain meaningful acoustic characterization of carbonates rock/pore types**

Acknowledgement

Industrial Associates Consortium For Research and Training in Modern and Ancient Carbonates

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