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Effect of carbonate dissolution on reservoir rock integrity.

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Outline

- Objective
- Why the study?
- Experimental protocol
- Results
- Conclusion

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Objective

How is the rock integrity affected by acid exposure during CO_2 storage

- Establish experimental protocol for simulating subsurface processes.
- Assess the alteration of rock integrity.

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Why this study?

- New to the industry
  - IFP (Institut Français du Pétrole) has done similar studies
- Important for CCS projects in terms of license to operate
- Workflow:

Reservoir simulation + geochemical modeling: how much carbonate is dissolved (not part of present study).

↓

Determine dependence of rock stiffness and strength on amount of carbonate dissolved.

↓

Use geomechanical model to assess reservoir and caprock integrity (not part of present study).

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Experimental protocol

- Injecting an acidic solution results in channeling

Established protocol:

1. Retarded acid → saturate before reaction
2. Activate by heating
3. Flush with water
4. Measure stiffness
5. Repeat x number of times

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Performed experiments

- Material: Euville Limestone (98% Calcite, 2% Clay)

Sample ID	# of treatments (RAT)	Objective
1	3	Core analysis, CT – scanning, Mercury injection
2	6	
3	6	Determine failure envelope for treated rock.
4	6	
5	6	
6	0	Determine failure envelope for untreated rock.
7	0	
8	0	

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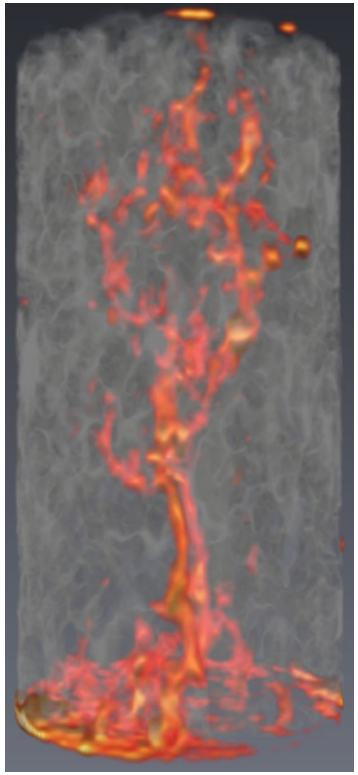
Results – Core analysis

Sample ID	Porosity [%]		Permeability [mD]	
	Pre	Post	Pre	Post
1	16.5	16.9	190	2750
2	16.9	19.9	266	2798

3 RAT →



← 6 RAT

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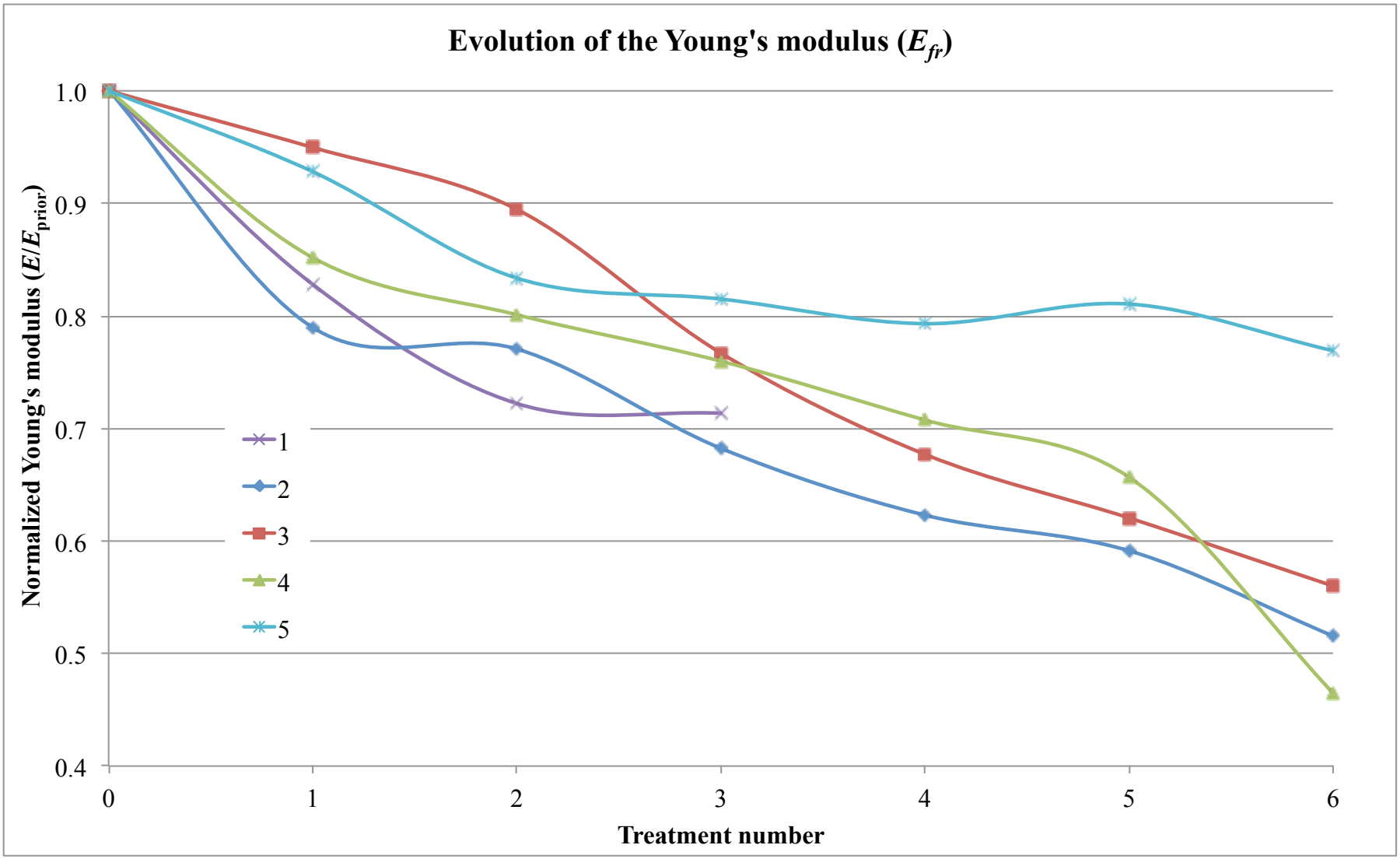
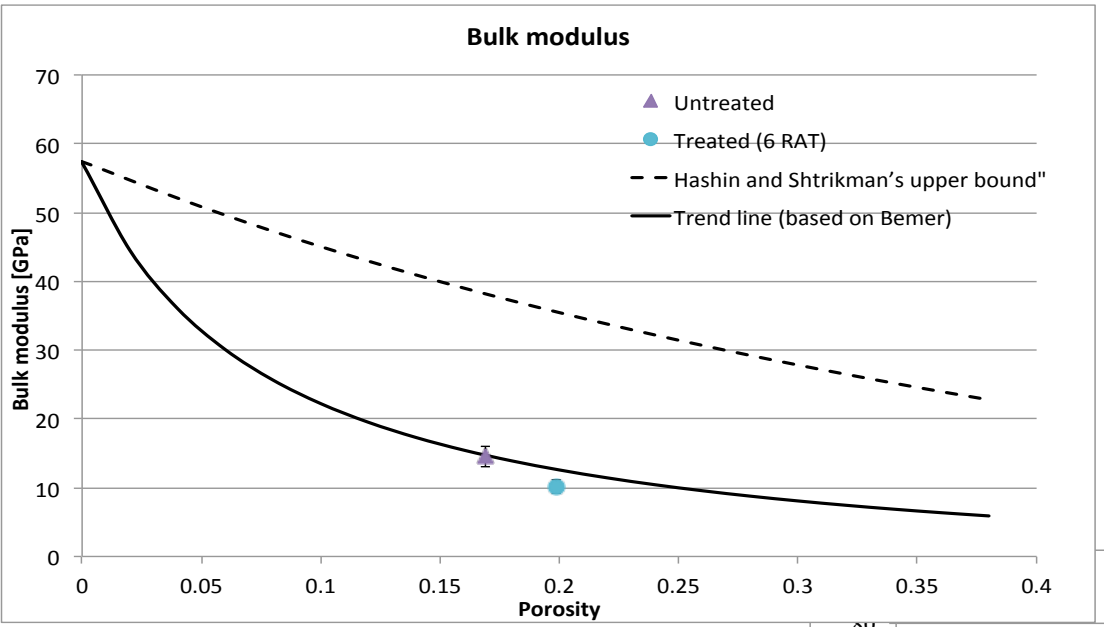
Stiffness evolution



Stiffness – porosity models

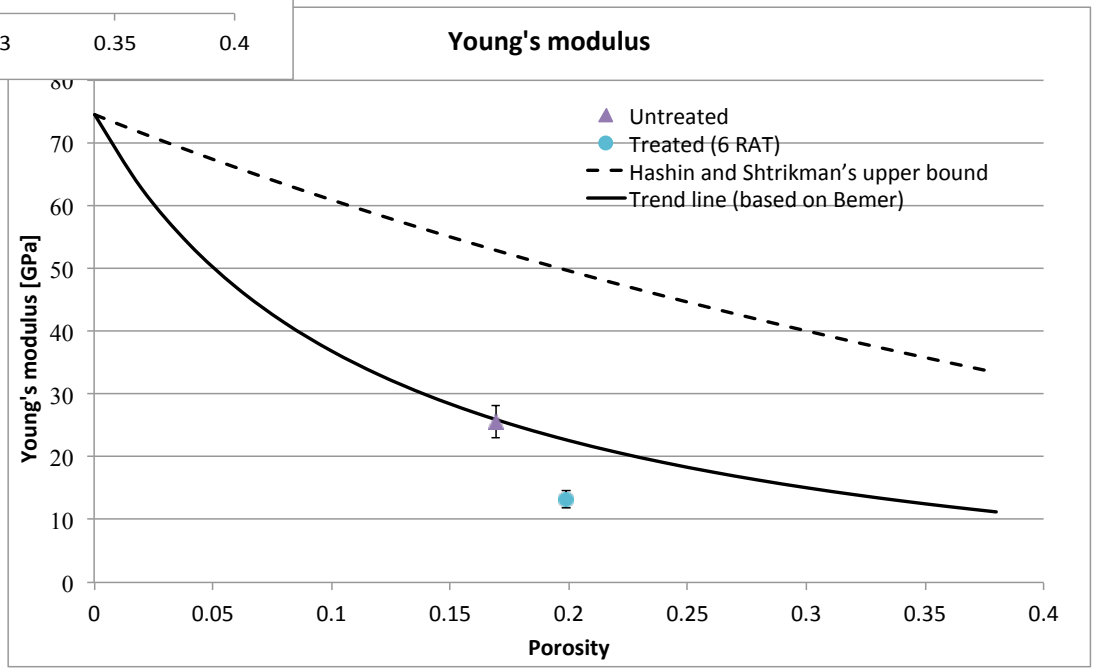


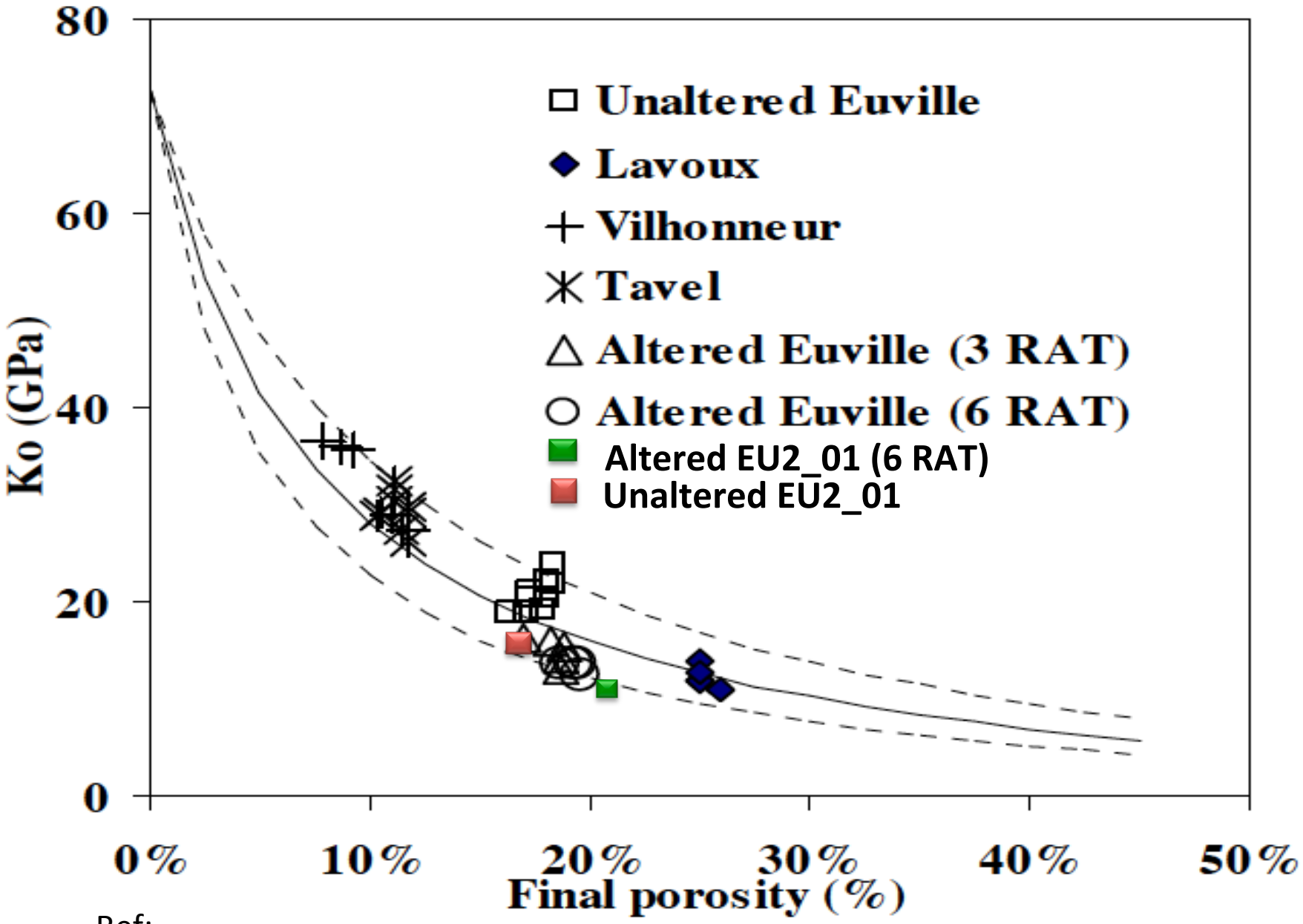
Model derived by IFP,
based on rock consisting of:

- A grain phase
- A cement phase
- A pore fluid phase

$$K_{fr} = \frac{(1-\varphi)K_s}{1-\varphi+\varphi\frac{K_s}{K_c}}$$

$$G_{fr} = \frac{(1-\varphi)G_s}{1-\varphi+\varphi\frac{G_s}{G_c}}$$

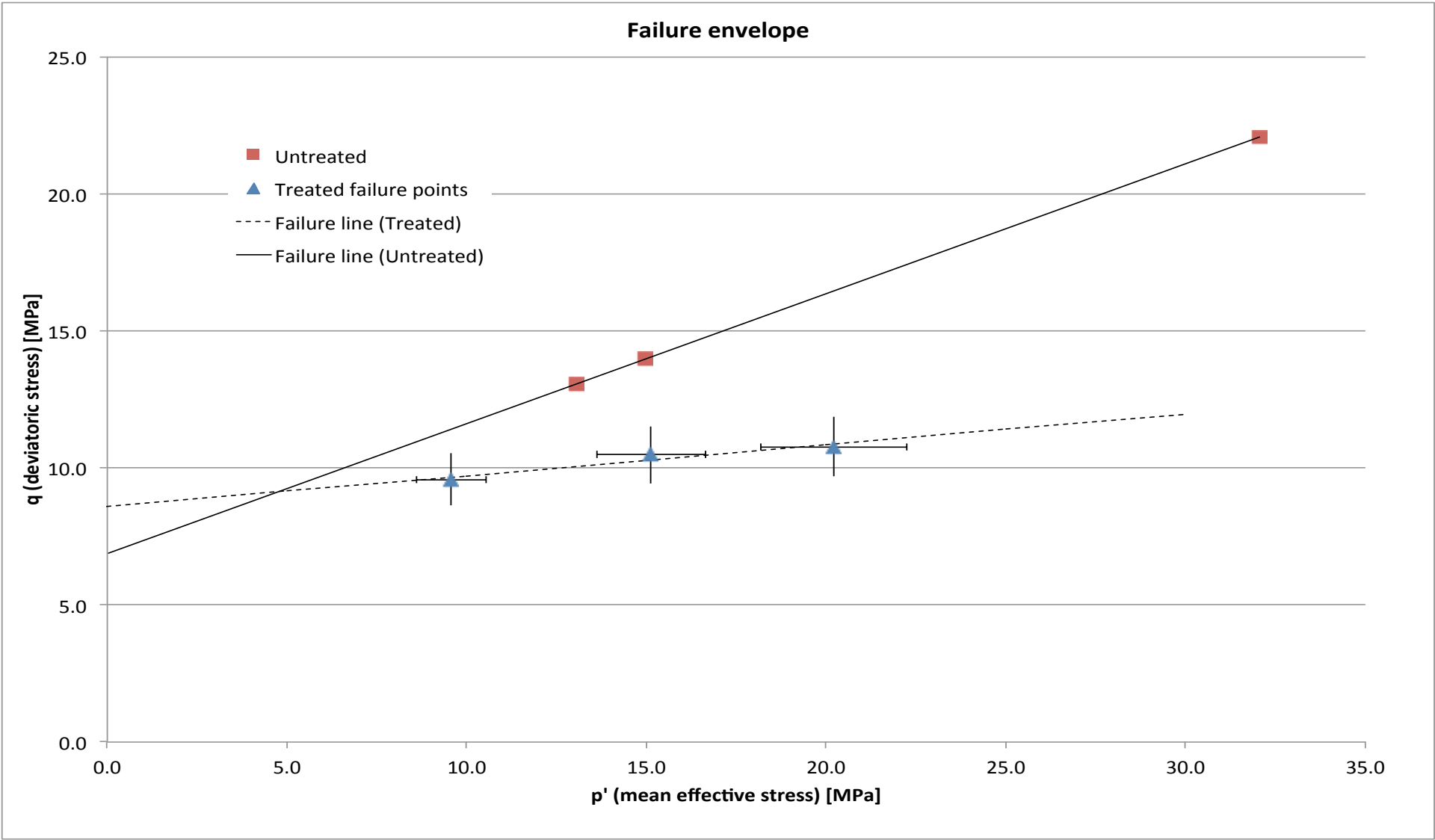




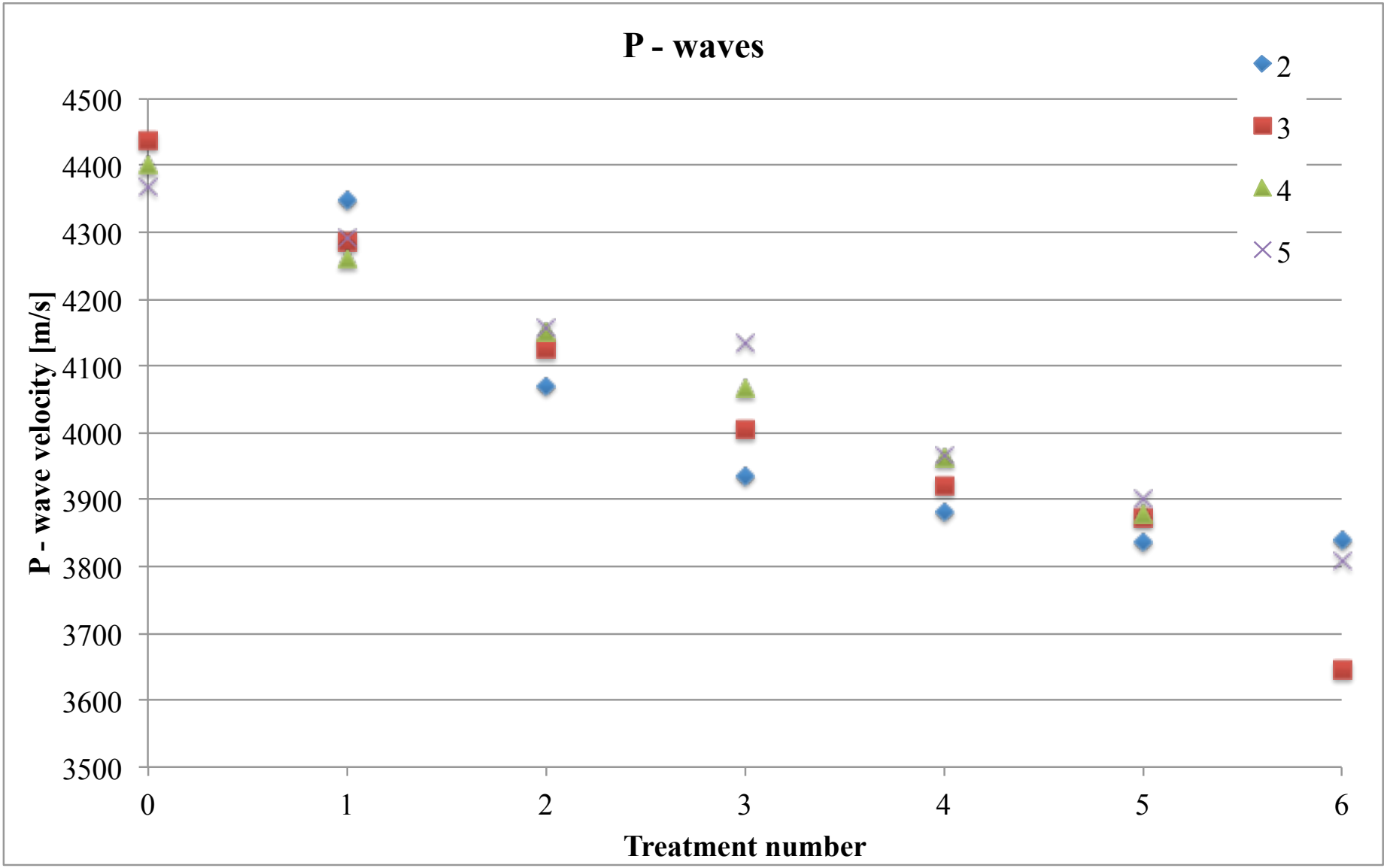
Ref:

Nguyen, M.T., Bemer, E. and Dormieux, L. (IFP) (2011), '*Micromechanical modeling of carbonate geomechanical properties evolution during acid gas injection*', 45th US Rock Mechanics/Geomechanics Symposium June 26th – 29th, 2011, San Francisco, CA.

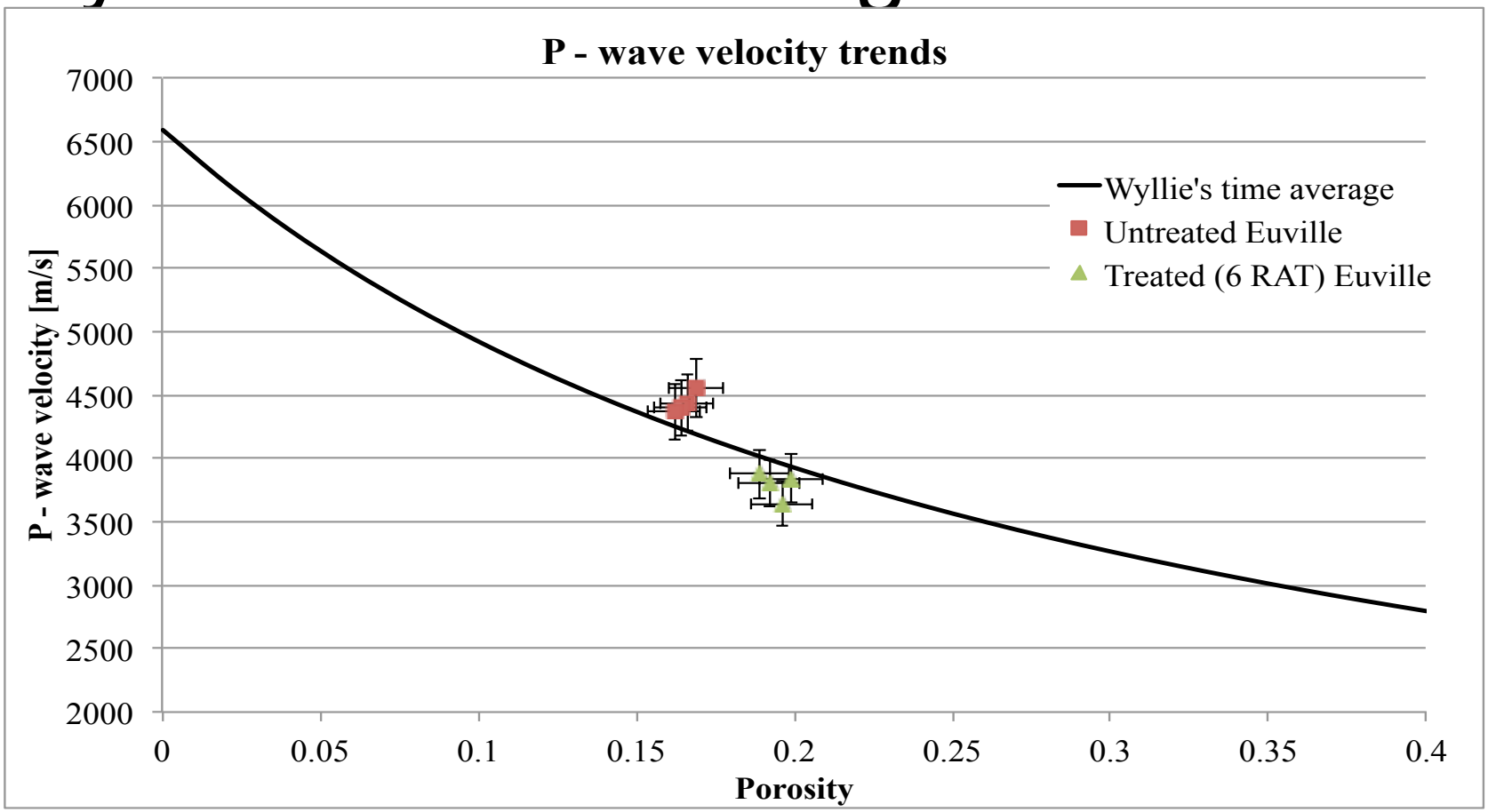
Strength alteration



Velocity evolution



Velocity – Porosity model
Wyllies's Time Average



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Velocity – Porosity models

IFP approach (1 & 2)

$$K_{fr} = \frac{(1-\varphi)K_s}{1-\varphi+\varphi\frac{K_s}{K_c}}$$

$$G_{fr} = \frac{(1-\varphi)G_s}{1-\varphi+\varphi\frac{G_s}{G_c}}$$

Critical porosity model (3 & 4)

$$K_{fr} = K_s\left(1-\frac{\varphi}{\varphi_c}\right)$$

$$G_{fr} = G_s\left(1-\frac{\varphi}{\varphi_c}\right)$$

Gassmann theory

$$K = K_{fr} + \frac{K_f}{\varphi}\frac{\left(1-\frac{K_{fr}}{K_s}\right)^2}{1+\frac{K_f}{\varphi K_s}\left(1-\varphi-\frac{K_{fr}}{K_s}\right)}$$

Biot's theory

$$V_p = \sqrt{\frac{K+\frac{4}{3}G_{fr}}{\varphi\rho_f+(1-\varphi)\rho_s}}$$

$$V_s = \sqrt{\frac{G_{fr}}{\varphi\rho_f+(1-\varphi)\rho_s}}$$

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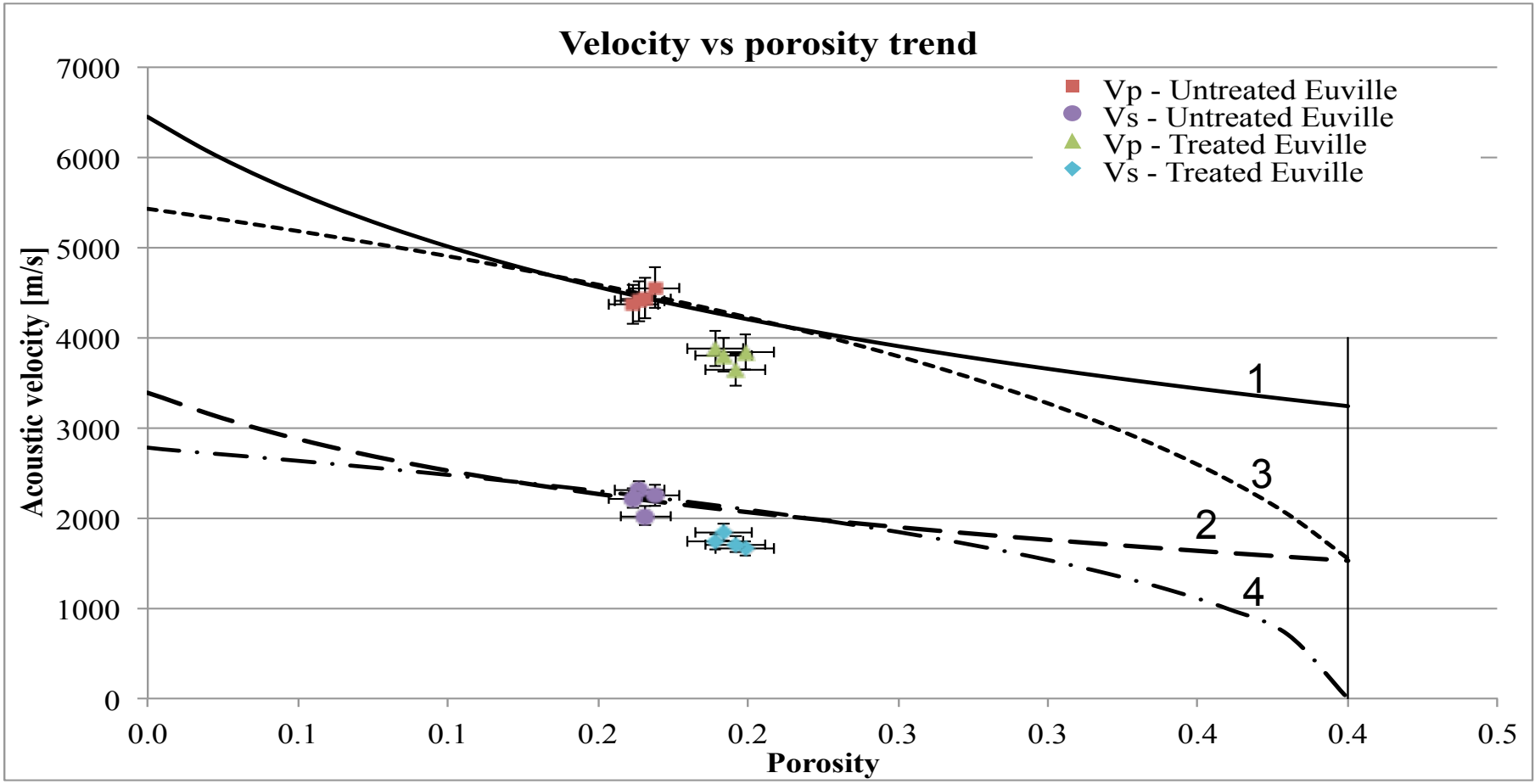
Biot's theory: velocity – porosity



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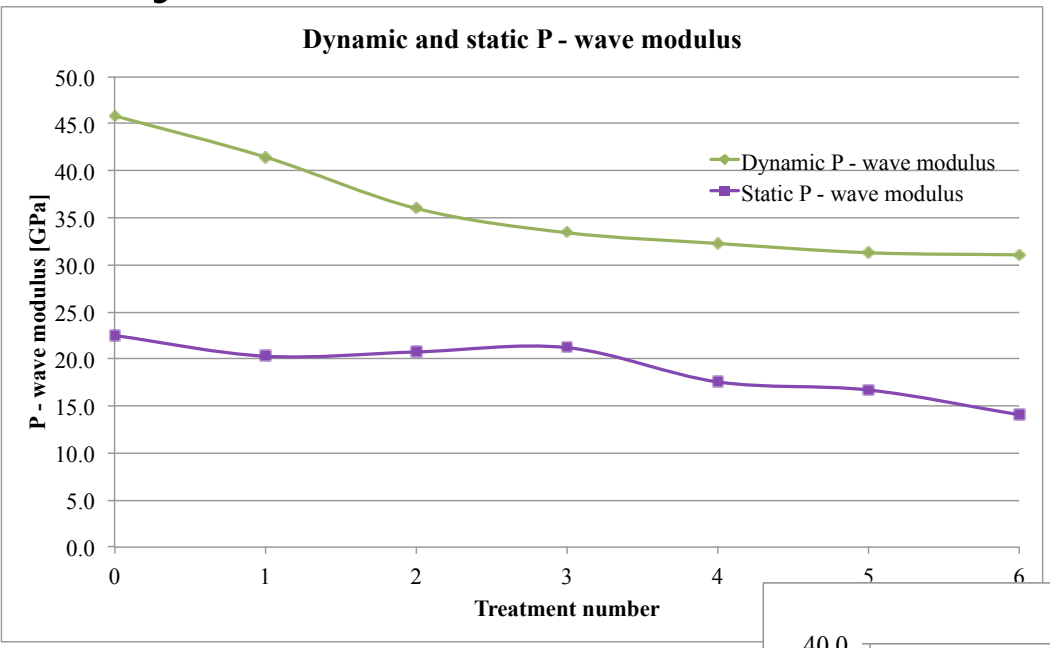
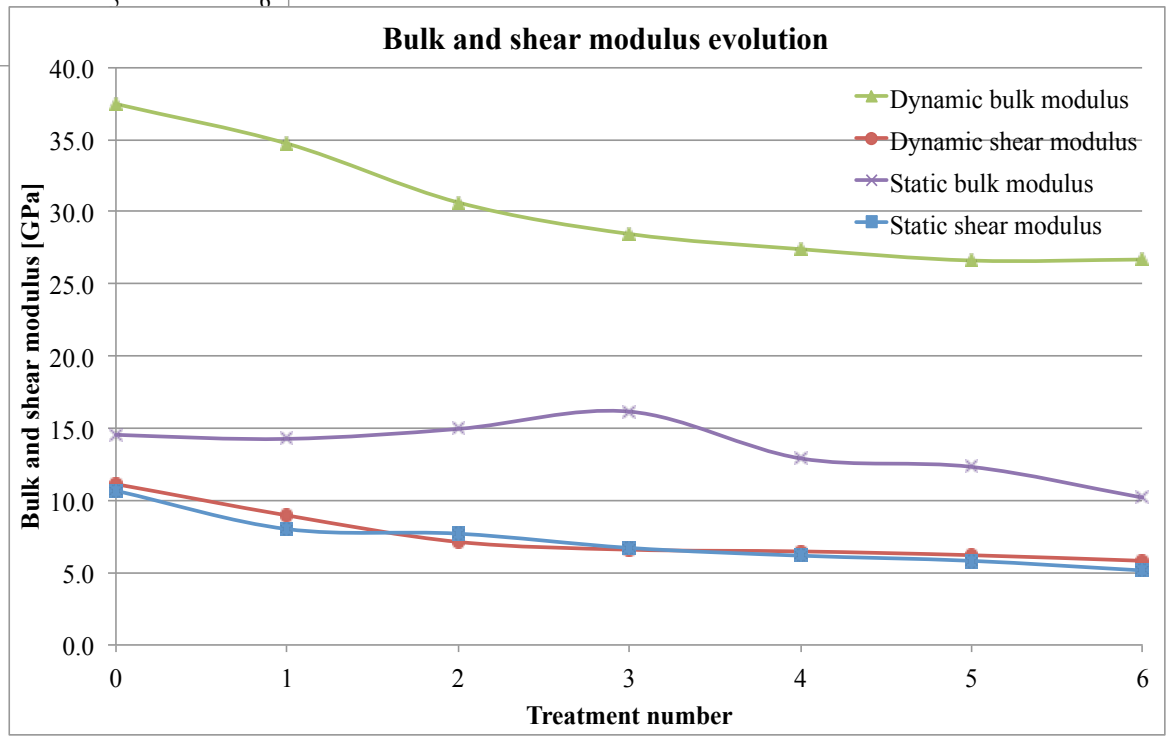
Dynamic vs. static moduli



- Similar trends between static and dynamic moduli.
- Similar shear modulus.



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Conclusion

- Homogeneous dissolution due to acid exposure:
  - Reduce the stiffness. Other effects, in addition to porosity increase, could be seen.
  - Reduced strength the rock.
  - Lower the acoustic velocities, where other effects also seems to effect the properties.
- For the future, more detailed studies are recommended.

Q & A

Acknowledgements

Co. authors

Rune Holt

Other co workers at Shell, Rijswijk, especially Holger Ott

For further reading, referring to master thesis of Kristian Eide:

CO_2 Sequestration: The effect of carbonate dissolution on reservoir rock integrity

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