SPE International
Hungarian Section

How to maximize the value of mature HC fields?

Workshop

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Society of Petroleum Engineers

Application of cost efficient lightweight cement slurries in mature environments

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Agenda

Theoretical Background

- Frac gradient in depleted zones
- Requirements for lead cements
- Decreasing cement density

Microspheres in cementing

- Types of microspheres
- Aluminium silicate microsphere
- Engineered borosilicate microsphere

Case studies & application summary

- Aluminiumsicilate microsphere
- Engineered borosilicate microsphere
- Application summary

Frac gradient in depleted zones

- **One dimensional compaction model**

$$\sigma_{OB} = \sigma_Z + P_f$$

Overburden stress to be supported by the rock and the formation fluid

- **Eaton's equation**

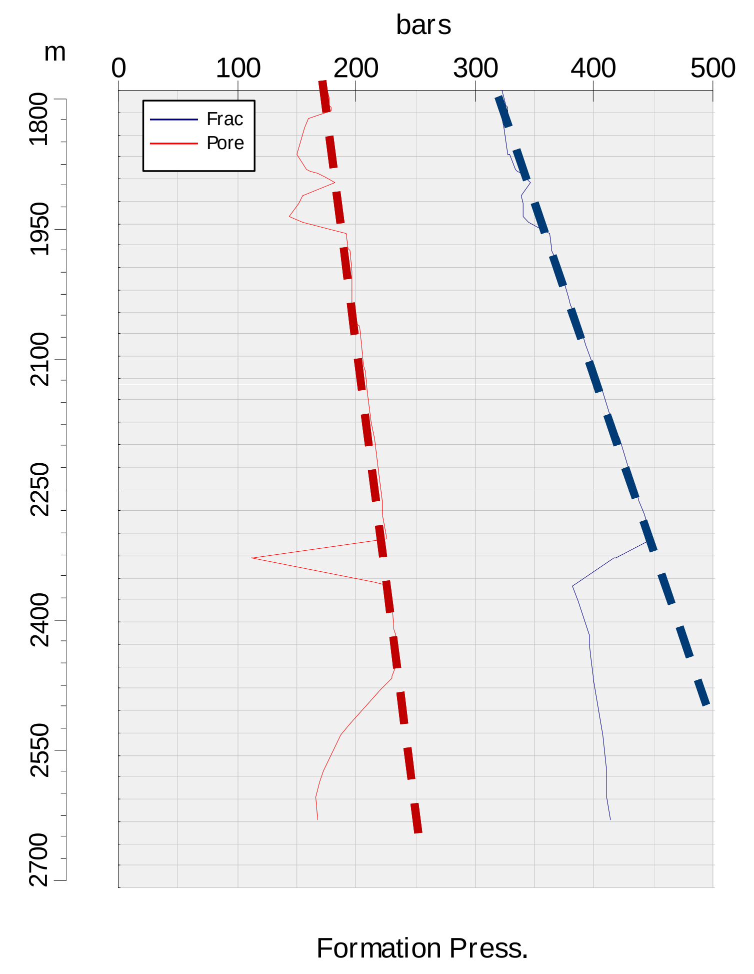
$$P_{frac} = \frac{\nu}{1-\nu}\left(\sigma_{OB} - P_f\right) + P_f$$

… just to tie in the Young modulus

Frac gradient in depleted zones

- Trends mapped in Pannonian Basin (Lányi-Mucsányi-Szabó)
- Critical importance for layered reservoirs in brown fields

Pore and frac pressures in Algyő



Frac gradient in depleted zones

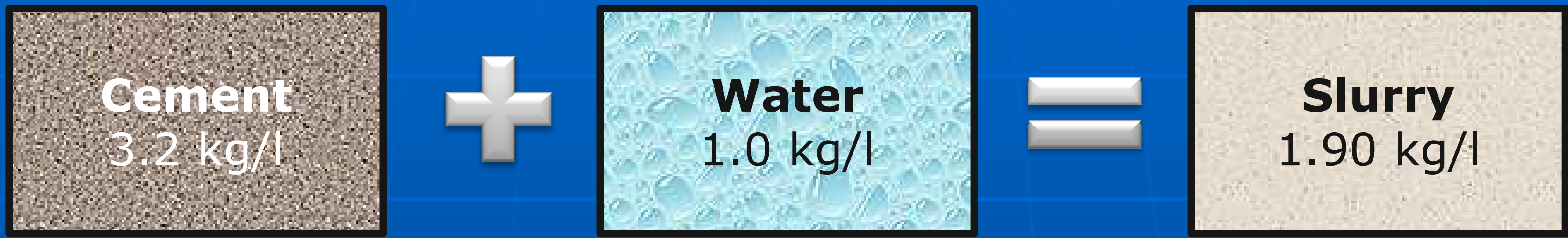
- Lower frac gradient will require lower ECD (Equivalent Circulating Density)
- Primary factor in ECD: slurry density

Depleted reservoirs and mature fields require low density cement slurries

Requirements for lead cements

- Minimize formation damage
  avoid losses into formation (**low density**)
  minimize fluid invasion (good fluid loss)
- Provide acceptable zonal isolation
  cement to required TOC (**low density**)
  maximize isolation (low permeability)
  achieve good cement bond (mud removal)
- Balanced economical performance
  reserve premium solution for production zone (keep costs reasonable)

Decreasing cement density



Have to add something to decrease density…

Option 1 – Liquid
- more water!!!
- and some bentonite for stability

Option 2 – Gas
- add nitrogen
- and something to stabilize foam)

Option 3 – Solid
- add something lightweight (flyash, microshperes)
- …but pay attention on stability

Decreasing cement density

	Option 1 Bentonitic	Option 2 Foamed	Option 3 Solids
Permeability	Increased	Increased	Same
Fluid loss	Increased	Same	Same
Compressive strength	Decreased	Decreased	Minor decrease
Slurry cost	Low	Medium	Medium
Additional costs	n/a	possible	n/a
Stability/Mixability	Very good	Low to Medium	Medium

Decreasing cement density

Option 2 – Nitrogen addition

- Decreased density
- Increased permeability (porosity)
- Reasonable fluid loss
- Reasonable compressive strength (function of density)
- Reasonable slurry cost, but might come with related extra costs
- **Very careful testing required** (stability)

Decreasing cement density

Option 3 – Solids addition

- Decreased density
- Maintained permeability (porosity)
- Good fluid loss (high solids content)
- Reasonable compressive strength (function of density)
- Reasonable slurry cost
- Careful testing required (stability and mixability)

Decreasing cement density

Option 1 – Liquid addition

- Decreased density
- Increased permeability (porosity)
- Increased fluid loss (more fluid)
- Decreased compressive strength (function of density)
- Good stability with bentonite (or others)
- Very low slurry cost

Decreasing cement density

Option 3 – Solids addition
What kind of solids preferred?

- Low gravity solids (floaters)
- Silicates for optimum synergy with Portland cement
- Hollow microspheres

Types of microspheres

Different glasses

- Aluminium silicates
- Borosilicates
- Ferrosilicates

Different strength

- Mechanical resistance
- Pressure resistance

Different size

- Coarse particles
- Medium particles

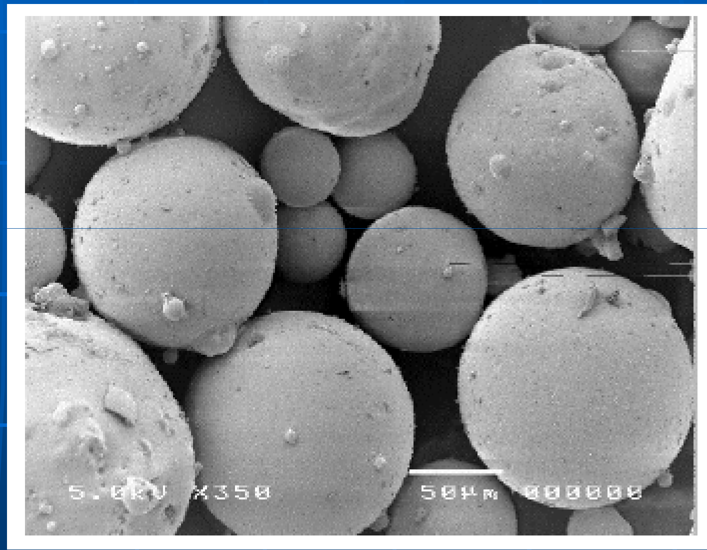
Different wettability

- Uncoated
- Coated (antistatic)
- Coated (wettability)

Types of microspheres

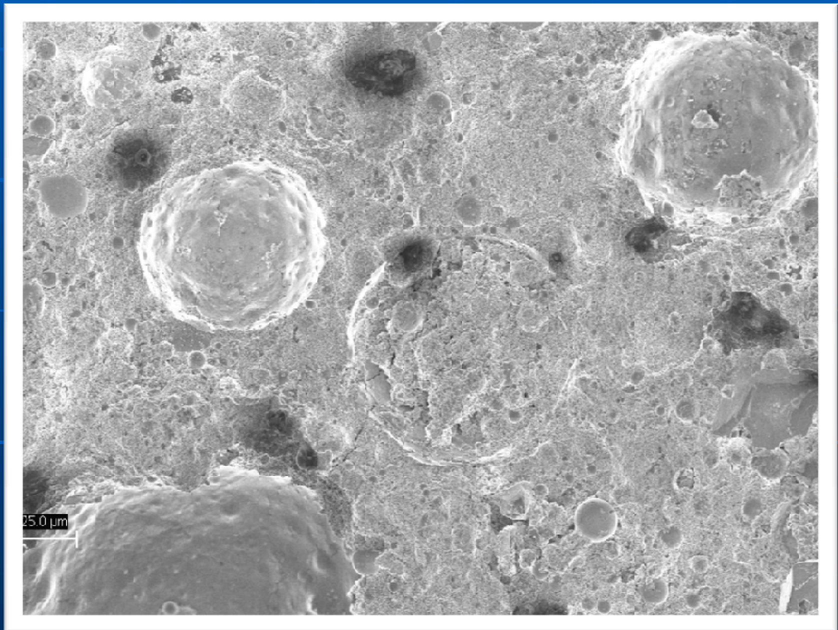
Basic microspheres: Class F flyash

- Aluminium silicate (industrial pozzolan)
- No coating applied
- Varying particle size
- Varying density
- Varying strength

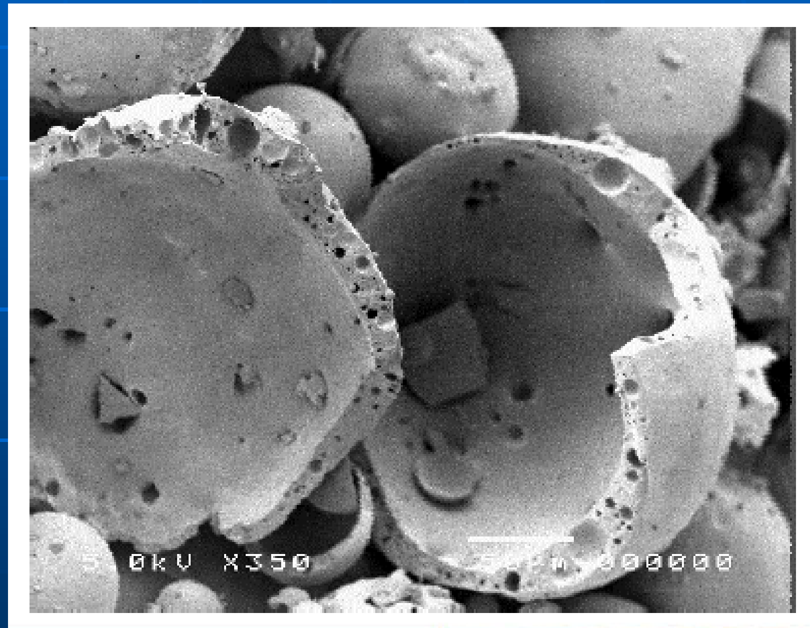


Types of microspheres

Basic microspheres: Class F flyash



Pozzolan + Portlandite = CSH-gel



Unpredicatble pressure resistance

Types of microspheres

Premium microsphere: Engineered borosilicate particles

- Borosilicate glass
- Antistatic coating
- Pressure resistance can be selected
- Narrow density window
- Narrow particle size window

Types of microspheres

Premium microsphere: Engineered borosilicate particles

- Pressure resistance selected based on specific requirements
- Good stability can be achieved (particle size and density)
- Limited reactivity of borosilicate
- Wettability of coating

Case study: UGS project

Design

- Depleted zones in multilayered reservoir
- ECD limited to 1.70 kg/l
- 1.40 kg/l bimodal lead slurry
  Class F Flyash microspheres
  fibrous lost circulation material
- 1.60 kg/l tail slurry
  gas migration control additive
  engineered Young's modulus cement

Case study: UGS Project

Design

Lead slurry (1.40 kg/l, porosity: 52%)

Compressive strength (at surface!):

625 psi in 16 hrs

1345 psi in 24 hrs

API static fluid loss: 78 ml (at 63 degC)

Execution

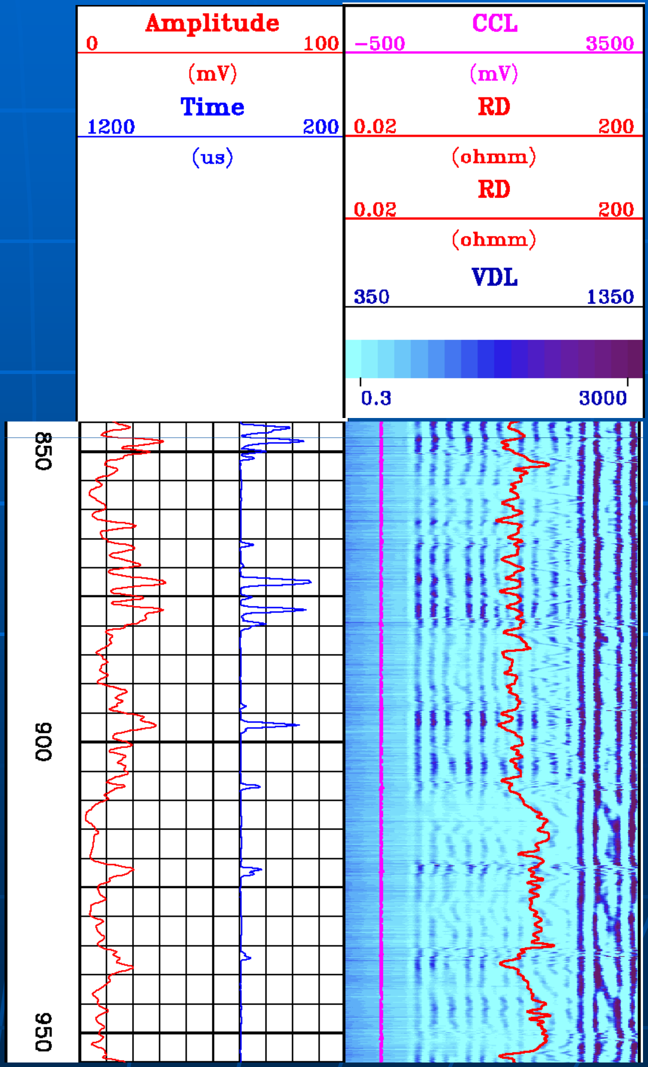
Cement to surface on 43 of wells

Pressure resistance not as per requirements

Case study: UGS Project

Evaluation

- Good cement bond across open hole
- Top of cement as required (surface)
- Microannulus in casing-to-casing due to shrinkage (pozzolanic reaction)



Case study: Well reentry

Design

- Multiple depleted zones across OH section
- ECD limited to 1.70 kg/l
- 1.40 kg/l bimodal lead slurry
  engineered borosilicate microspheres
  fibrous lost circulation material
- 1.92 kg/l tail slurry
  gas migration control additive
  Class G cement system with added silica

Case study: Well reentry

Design

Lead slurry (1.40 kg/l, porosity: 50%)

Compressive strength (at 40 degC):

500 psi	in 7.5 hrs
1770 psi	in 12 hrs

API static fluid loss: 82 ml (at 95 degC)

Execution

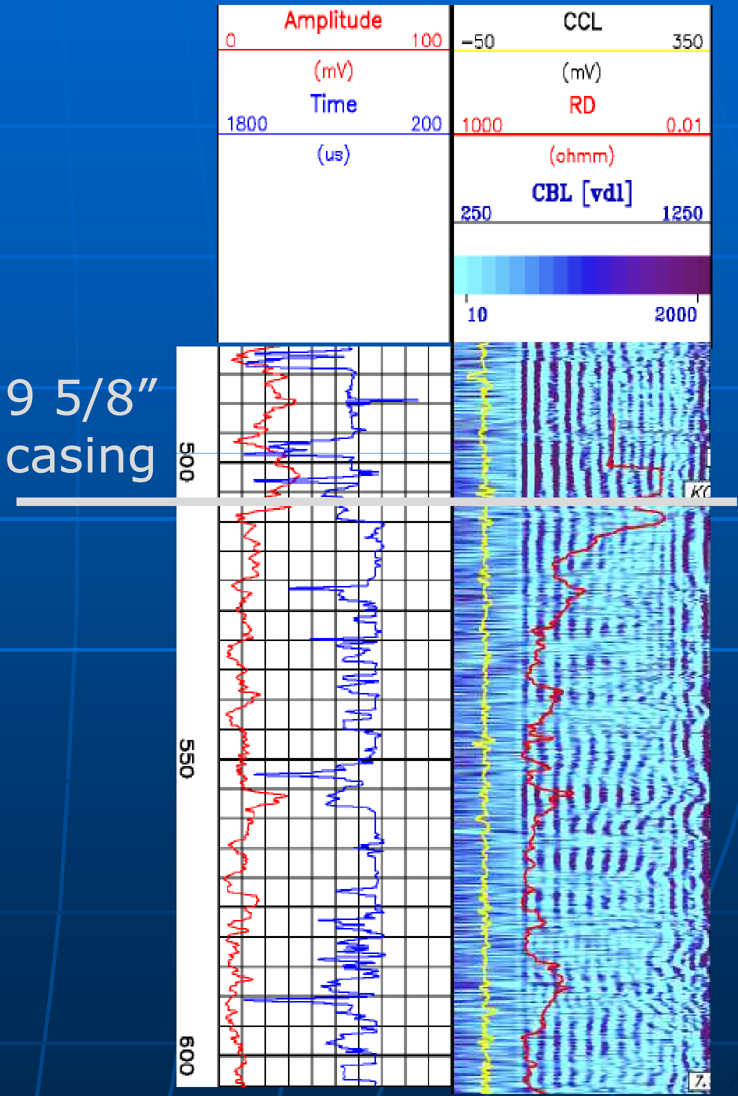
No crushing predicted based on lab tests

High mixing energy required due to coating

Case study: Well reentry

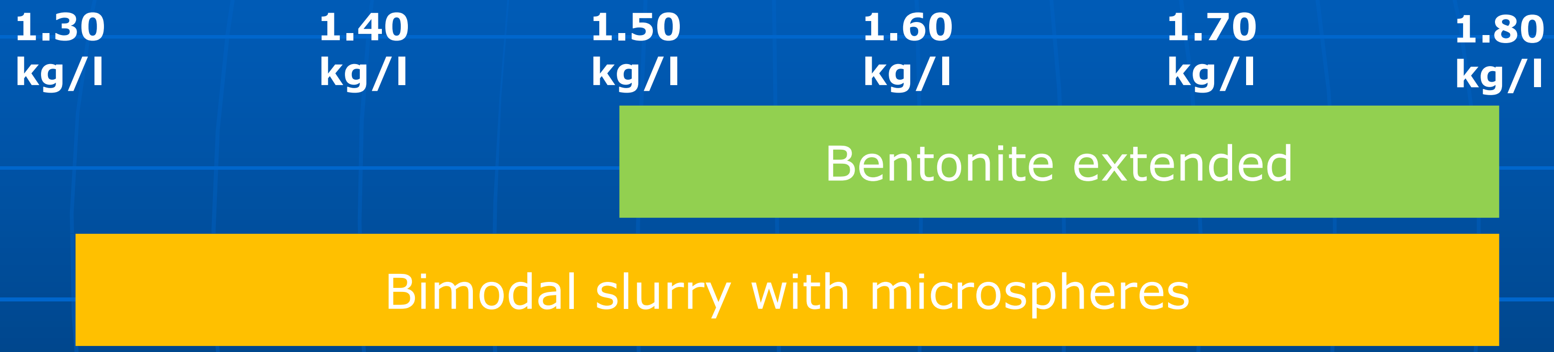
Evaluation

- Good cement bond all along section
- Top of cement as required (80 m into previous casing)
- No microannulus
- No crushing
- High mixing energy



Application summary

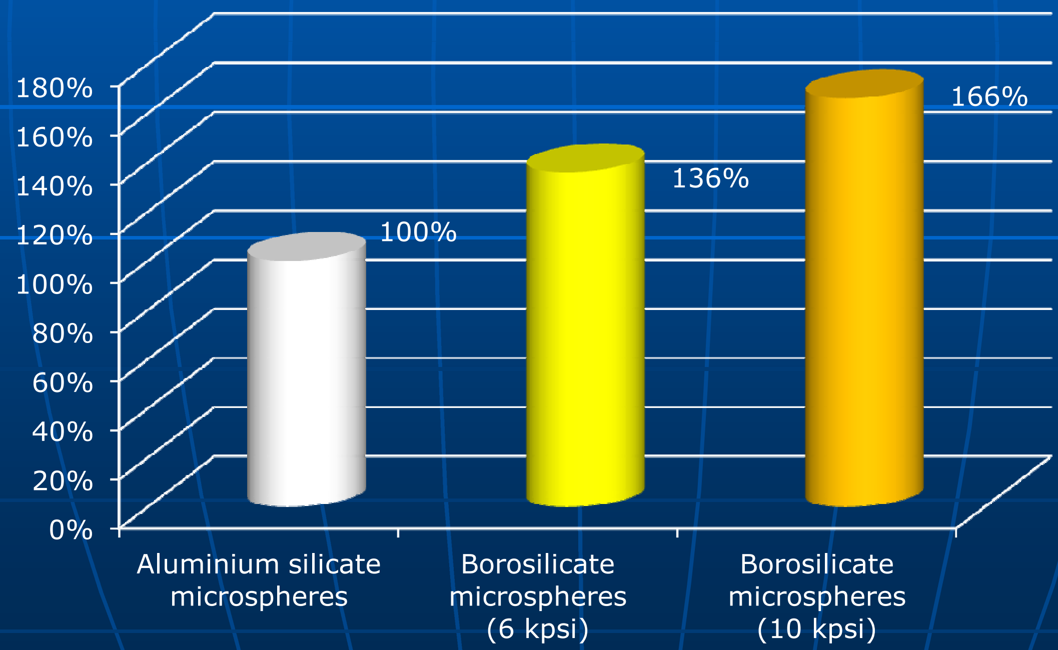
- First consideration: slurry density



- Second consideration: rig time cost
  - Is compressive strength needed on lead?
  - Wait on cement vs. increased slurry cost

Application summary

- Third consideration: downhole pressure
  - Pressure resistance with safety margin
  - Safety margin limited by slurry cost



Conclusion

- Mature fields with depleted reservoirs require extra care during cementing
- Good zonal isolation and protection of remaining HC in place is challenging
- Microspheres are a cost efficient solution for lightweight cement systems
- Careful selection of microspheres is required to satisfy technical and economical requirements

Thank you for your attention…

…WAITING FOR YOUR QUESTIONS