Fluid Issues for Unconventional Reservoirs: Shale Gas Drilling

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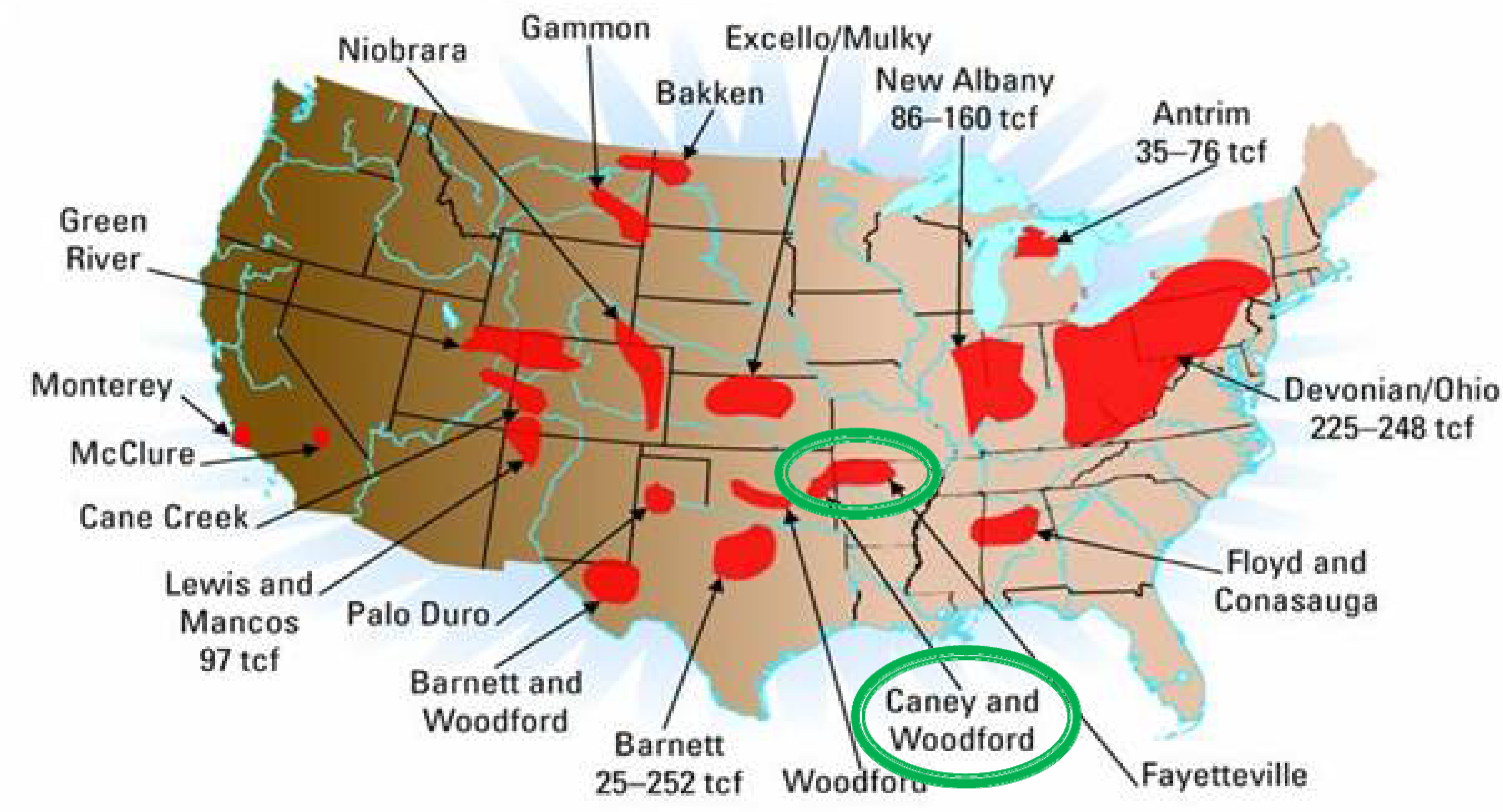


North America: 3,842 Tcf
World: 16,112 Tcf

Slide prepared by N. Pascal

Source: USGS and Rodger

What is a shale? (2)

- **WHAT ARE THE PROPORTIONS OF THE MINERALS?**
- **Caney Shale:**

Sample No.	1	2	3	4	5	6	7	8	9	10
Quartz, %	26	34	31	35	36	20	12	25	8	39
K-feldspar, %	1	1	1	2	1	2	2	1		1
Na feldspar, %	3	4	5	6	6	4	[illegible]	3	1	6
Calcite, %	22	1	—	—	—	50	4	30	72	—
Dolomite, %	1	—		—	—	4	67	1	—	—
Siderite, %	—	—	8	2	2	—	—	1	1	4
Pyrite, %	5	9	9	2	2	—	—	5	7	6
Kaolinite, %	5	6	6	6	8	3	2	7	4	[illegible]
Chlorite, %	1	2	1	—	1	—	—	2	[illegible]	1
Illite/mica, %	10	14	13	21	16	5	4	8	3	15
Mixed layer, %	26	29	26	26	28	12	6	19	5	21

A lot of quartz!!!

OFTEN, THE PROPORTION OF CLAY MINERALS IS < 50% !!!

Much more carbonates than clay minerals!!!

SHALE = VERY HETEROGENEOUS COMPOSITION!!!

<40% clay minerals

Slide prepared by N. Pascal

Main Characteristics of Shales

- Porosity: 1 to 8 vol%
- Permeability: 0.0001 to 0.1 mD
- Organic material, a sources of produced gases
- Clays, tight formation cause problems

Removal of Mn_3O_4-based Filter Cake

A. Al Moajil & H.A. Nasr-El-Din
A. Al-Yami

Mn_3O_4 Particles

- Spherical shape, 1-2 µm in diameter, & SG = 4.8 g/cm^3
- Introduced to K-formate drilling fluid (Sevendsen et al., 1995)
- Then, to OBM (Franks et al., 2004)
- Finally, to WBM (Al-Yami et al., 2007)
- No study on FCR of Mn_3O_4-based DIF

Current FC Breakers

1. HCl → Dissolve $CaCO_3$ particles
2. Organic acids → Dissolve $CaCO_3$ particles
3. Chelating agents → Dissolve $CaCO_3$ particles
4. *In-situ* organic acids → Dissolve $CaCO_3$ particles
5. Oxidizers → Degrade polymers
6. Enzymes → Degrade polymers

7. Combination of These Chemicals

Manganese Oxides Reactions

- Factors affect the reaction of Mn(oxides) with organic acids (Kemmitt et al., 2001)
  1. Stoichiometry of Mn (oxide) to the acid
  2. Structure of the acid
  3. Ability to chelate
- $Mn_3O_4 + 8HCl = 2MnCl_2 + MnCl_4 + 4H_2O$

  (Thomson et al., 1891)
- $Mn_3O_4 + 4HCl = 2MnCl_2 + MnO_2 + 2H_2O$

  (De Beni, 1975)

Objectives

- Examine reaction of various acids with Mn_3O_4
- Measure the solubility of Mn_3O_4 in various fluids
- Determine the thermal stability of the cleaning fluid systems
- Evaluate and design the filter cake removal cleaning fluid system

Experimental Studies

Mn_3O_4-based Drilling Fluids*

Additive	Function	Field Unit (Per bbl)	
		Quantity	Unit
Water	Base	0.822	bbl
Defoamer	Prohibit foaming	0.01	gal
XC-polymer	Viscosifier	1	lb
Starch	Fluid loss control agent	6	lb
PAC-R	Viscosifer\ fluid loss	0.75	lb
KCl	Density and shale inhibition	41	lb
KOH	pH control	0.5	lb
$Ca(OH)_2$		0.25	lb
$CaCO_3$ (fine)	Weighting materials	3.5	lb
$CaCO_3$ (medium)		1.5	lb
Mn_3O_4		202	lb
Na_2SO_3	Oxygen scavenger	0.75	lb

* Lab Sample

Dynamic HPHT Filter Press

- Tests up to 300°F & 200 psi

Procedure:

1. Brine Filtration Test
2. Mud Cake Generation
3. Cleaning test
4. Brine Filtration Test

HPHT See-through Cell

Objectives:

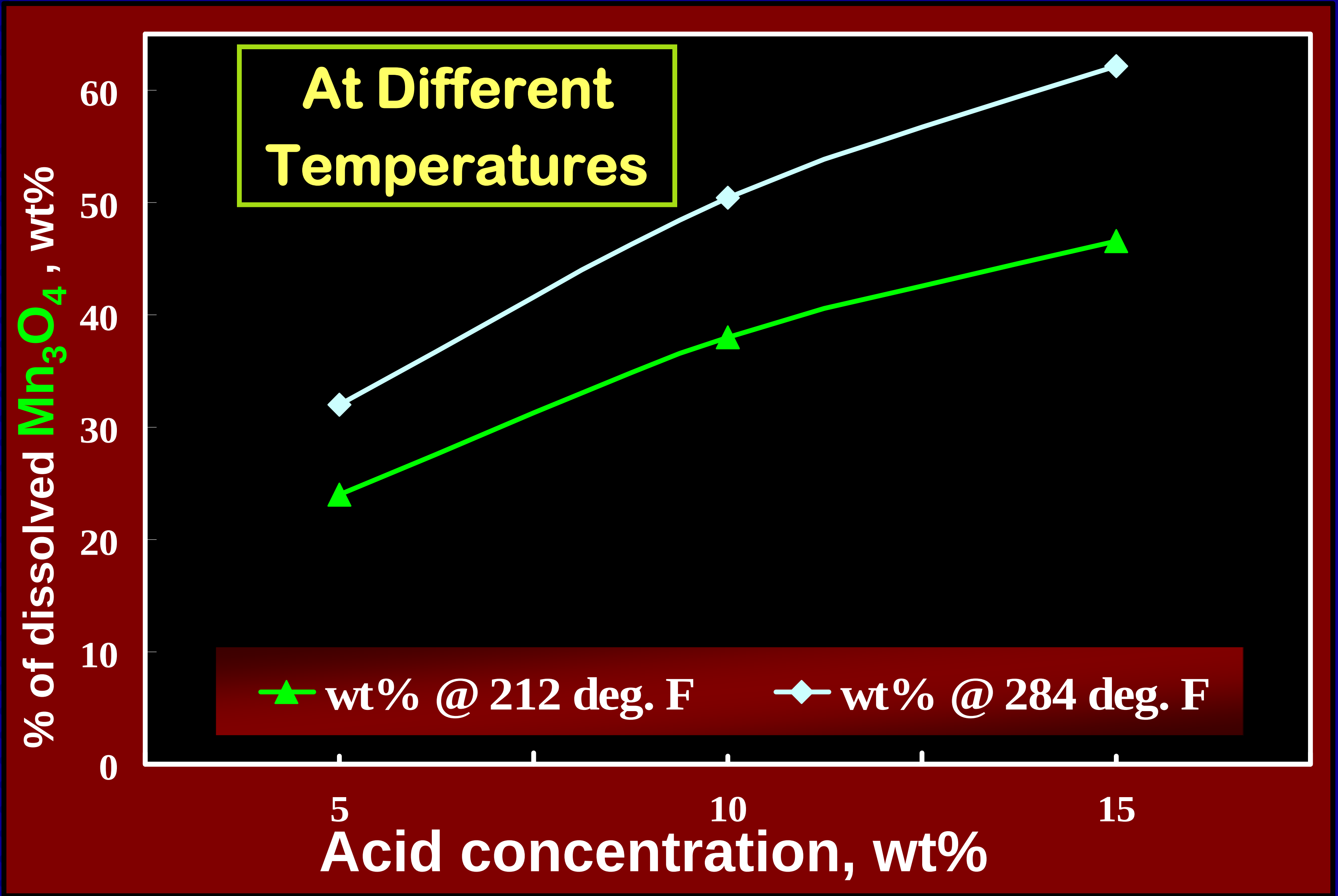
- Solubility tests
- Stability of cleaning fluids at HPHT
- Collect samples

→ GCMS Technique

Results

I. Solubility of Mn_3O_4

Solubility of Mn_3O_4 in HCl Acid



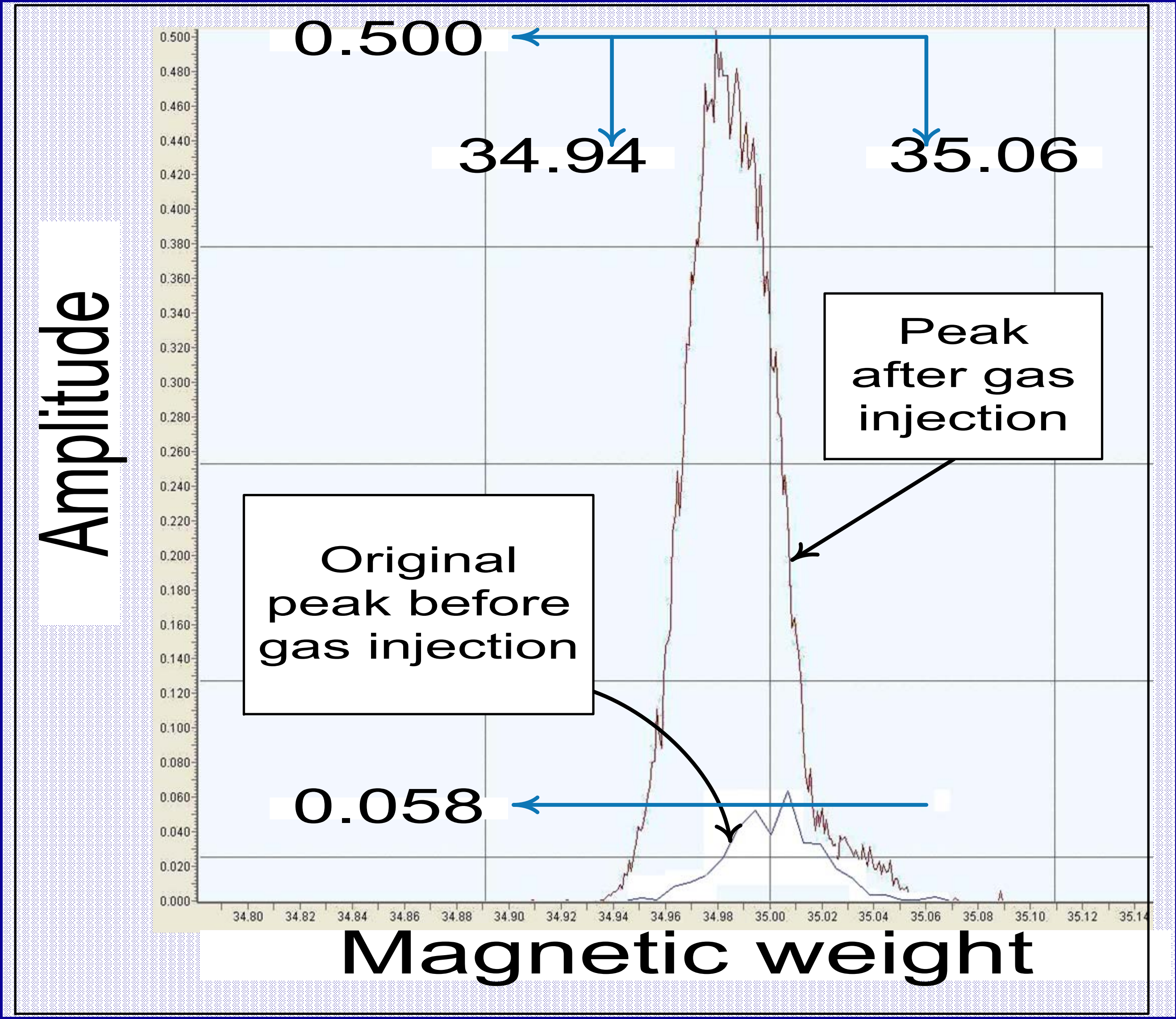
Analysis of Gases Evolved (1)

$HCl + Mn_3O_4$

Chlorine...?

15 wt% HCl

@ 284 ºF



Analysis of Gases Evolved (3)

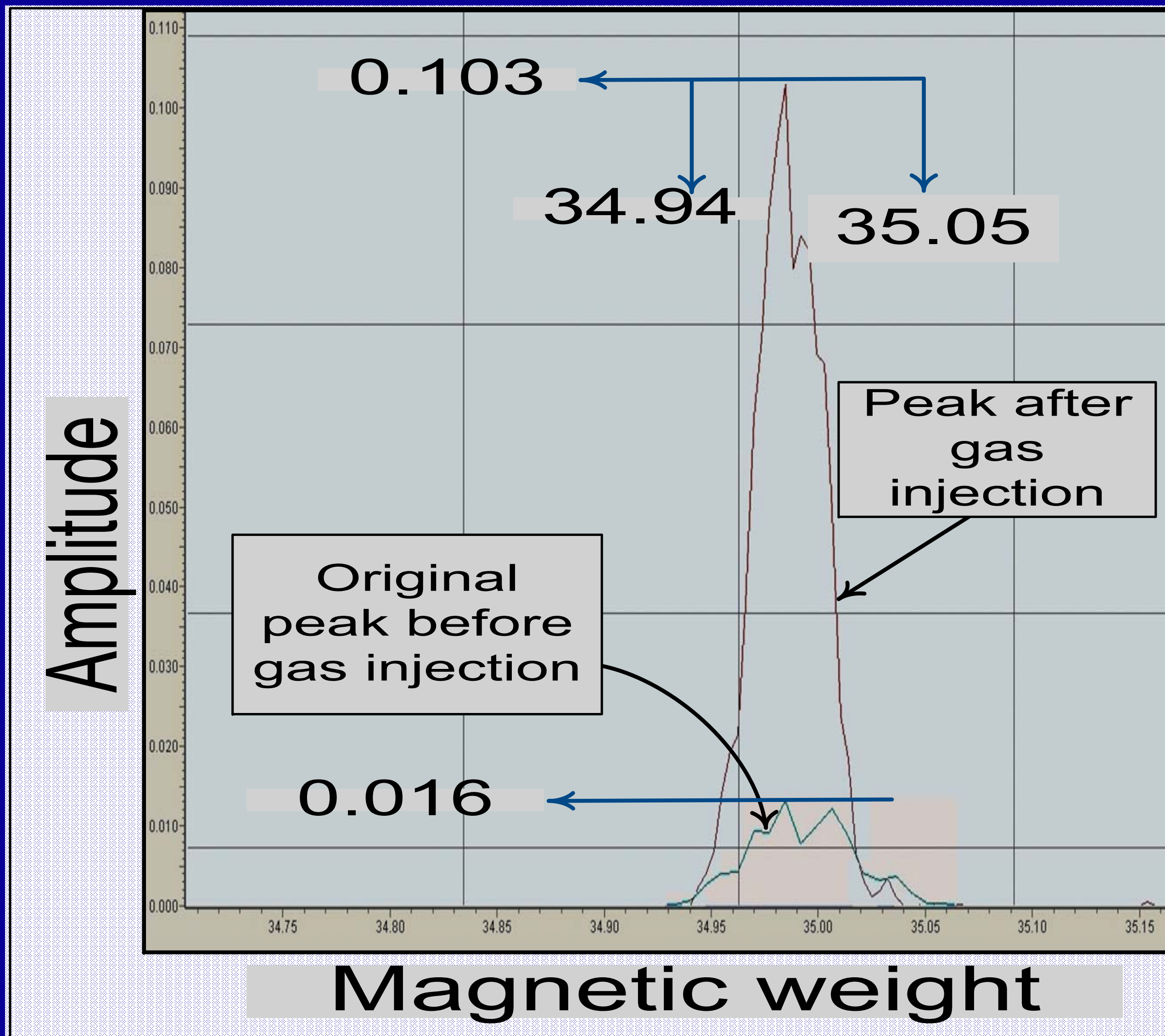
$HCl + Mn_3O_4$

↓

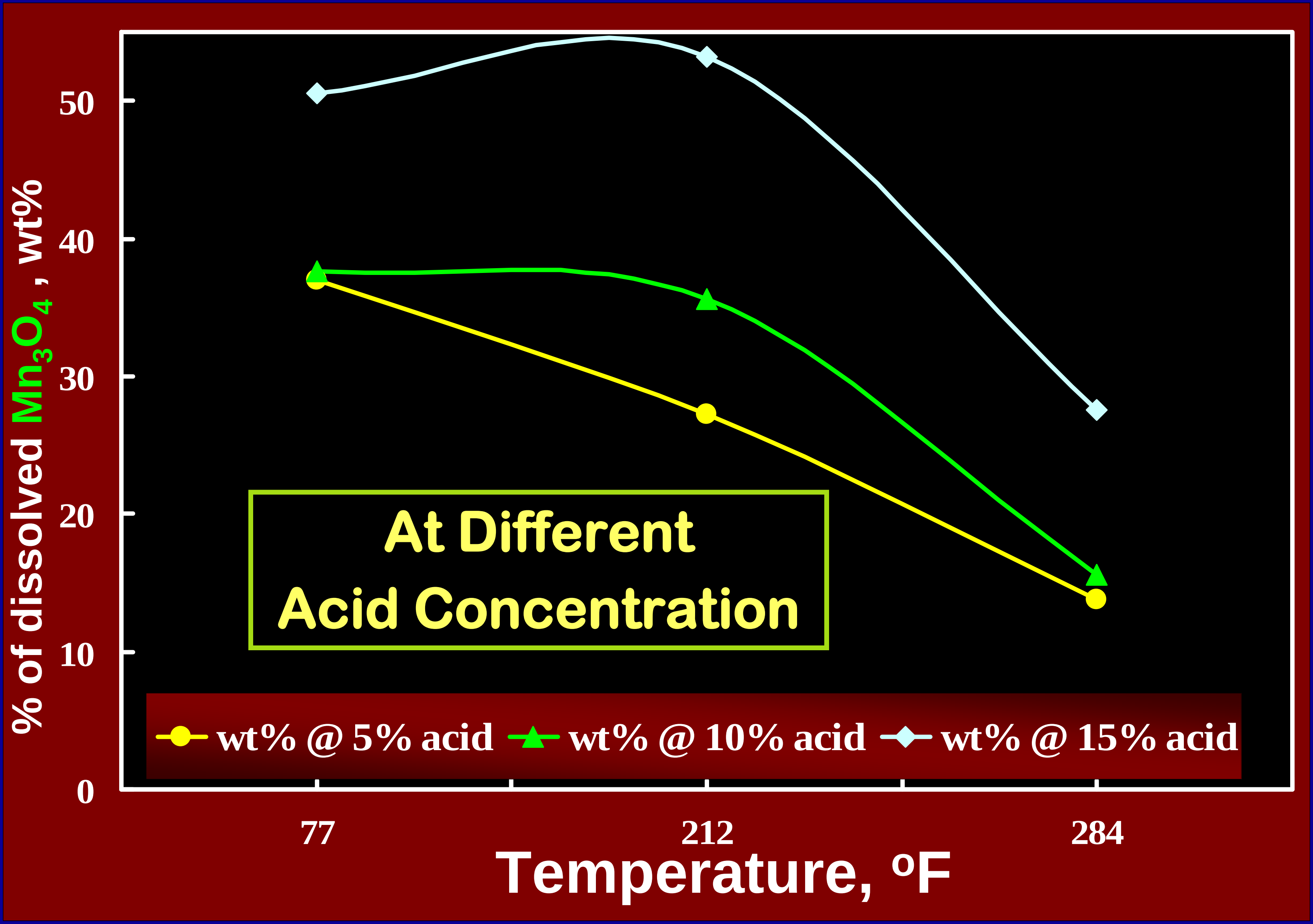
Chlorine…?

5 wt% HCl

@ 284 °F

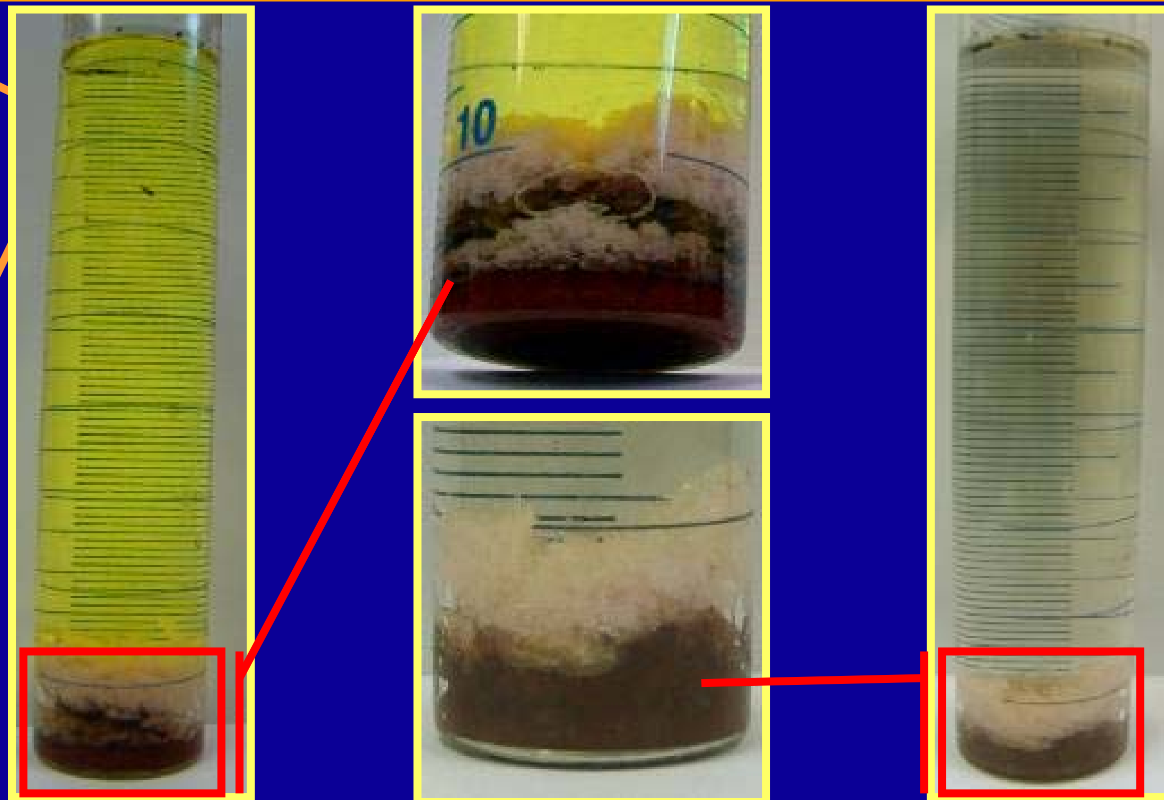


Solubility of Mn_3O_4 in Citric Acid



Reaction of 15 wt% citric acid solutions with Mn_3O_4

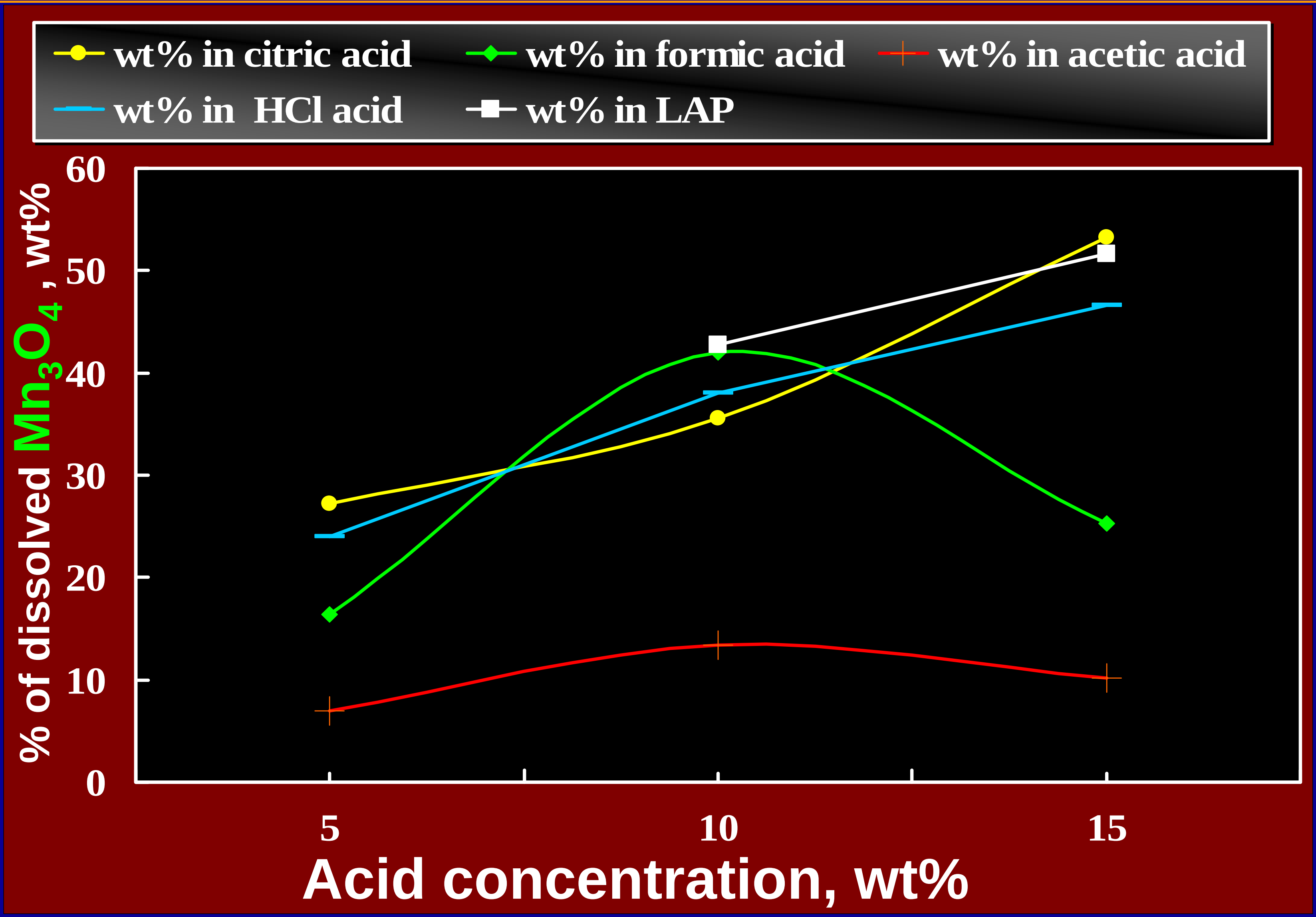
White precipitation formed



Spent citric acid
@ 212 °F & 200 psi
Acid soaking
time = 24 hrs

Spent citric acid
@ 284 °F & 200 psi
Acid soaking
time = 24 hrs

Solubility of Mn_3O_4 in Acid Solutions at 212 °F



II. HPHT Filter Press

One Stage Treatment without Enzyme

Before

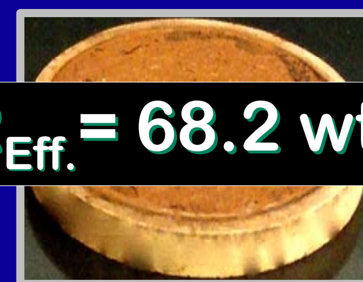
10 vol% LAP
T= 250 ºF
ST= 15 hr

15 vol% LAP
T= 250 ºF
ST= 15 hr

15 vol% LAP
T= 250 ºF
ST= 46 hr

15 vol% FAP
T= 300 ºF
ST= 46 hr

10 wt% HCl
T=250
ST= 28 hrs



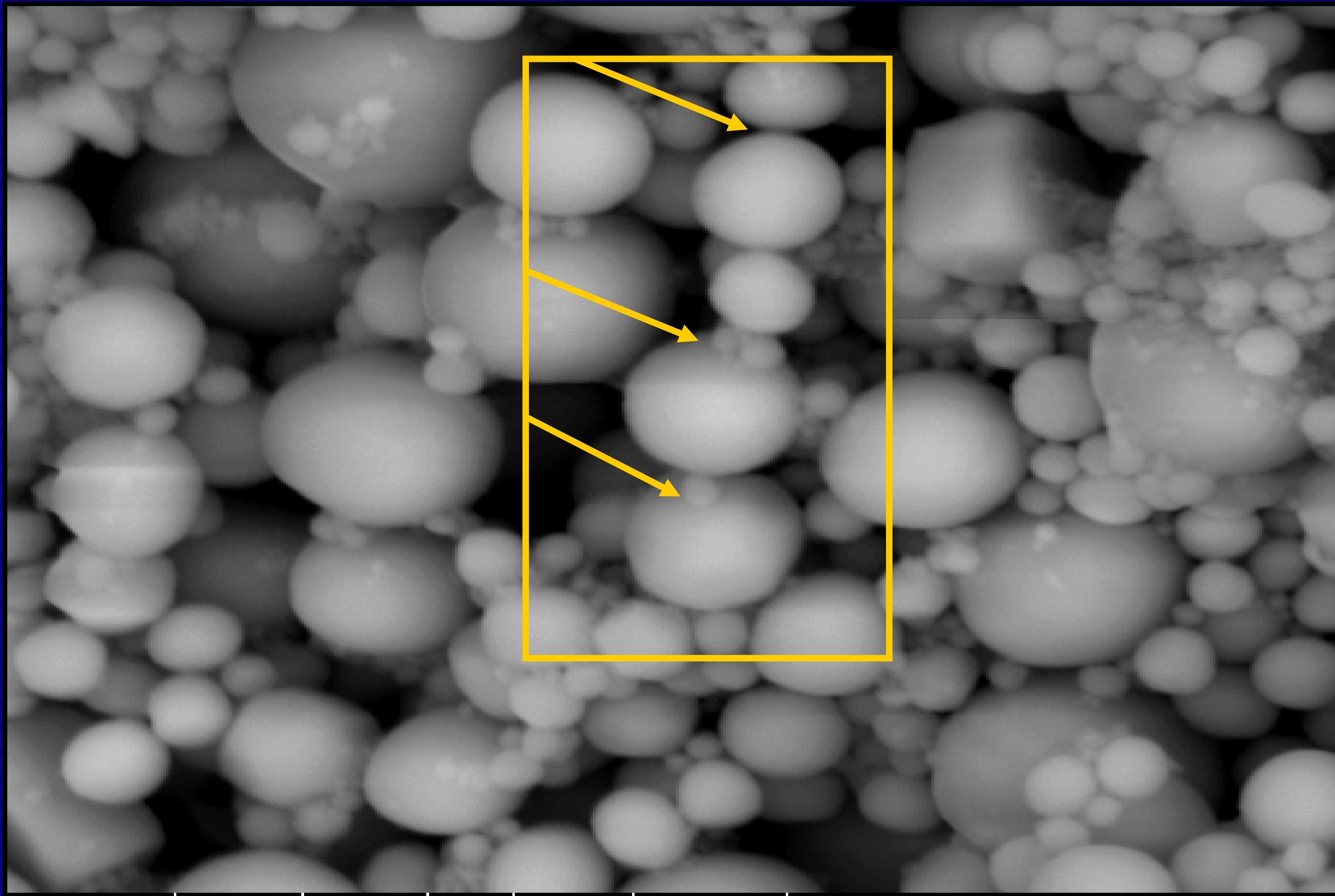
$R_{Eff.}$ = 68.2 wt%

After

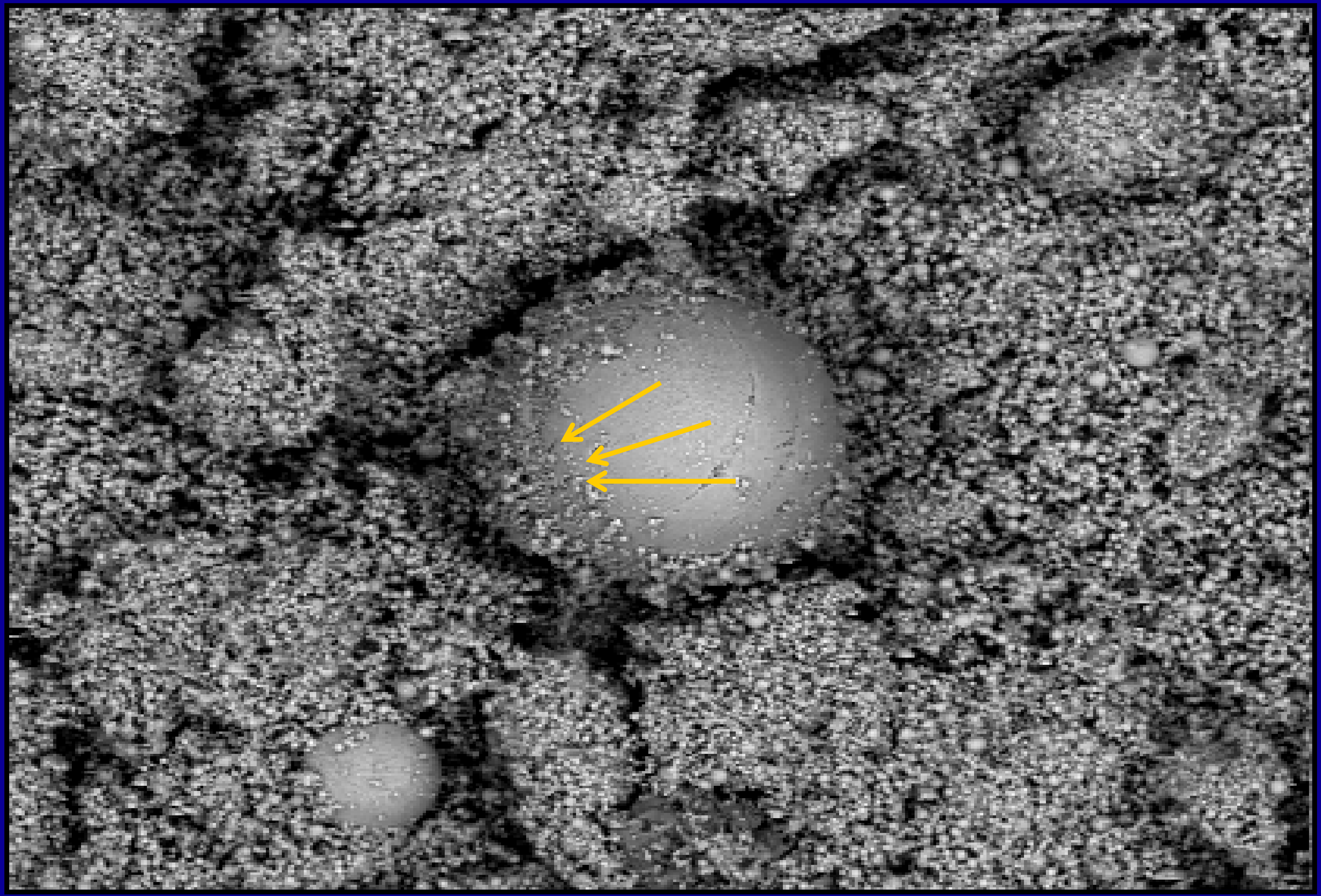
**LAP: Lactic acid precursor, FAP: Formic acid precursor, ST: Soaking time

Filter cake before & after soaking in acid solution, P = 200 psi

SEM Analysis on Untreated FC



SEM Analysis on FC after acid treatment



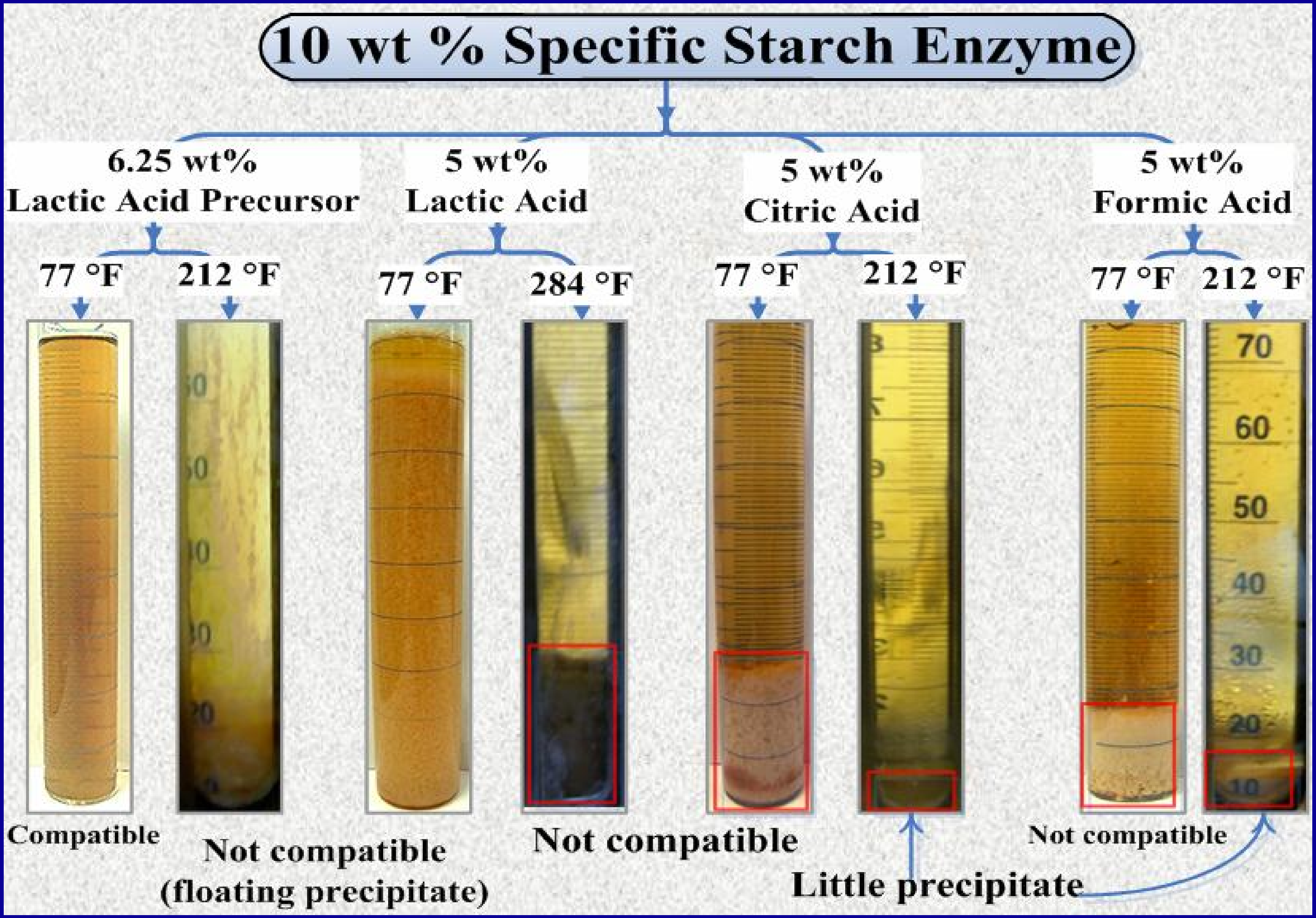
One stage Treatment with Enzyme

Filter cake before & after soaking in cleaning solution

10 wt% Lactic acid precursor
+
10 wt% Specific starch enzyme

T = 253 ºF
P = 200 psi
Soaking time = 18 hr

Compatibility of enzyme-A with organic acids



Two-Stage Treatment (1)

24 hrs enzyme soaking time

Filter cake before & after soaking in cleaning solution

Before

After

After + Iodine test

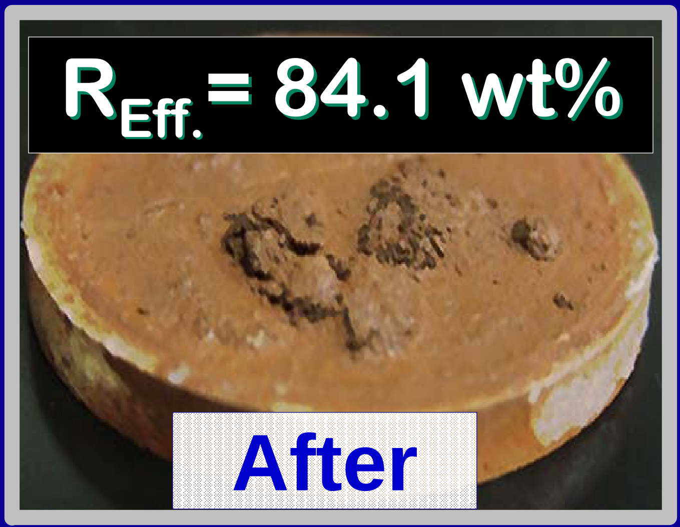
10 wt% Lactic acid precursor
+
10 wt% Specific starch enzyme

T = 253 ºF
P = 200 psi
Acid soaking time = 18 hr

Two-Stage Treatment (2)

4 days enzyme soaking time

Filter cake before & after soaking in cleaning solution



10 wt% In-situ Lactic acid
+
10 wt% Specific starch enzyme

T = 244 ºF, P = 200 psi
Acid soaking time = 24 hr

Characteristics and Removal of Filter Cake Formed by Formate-based Drilling Mud

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TEXAS A&M PETROLEUM ENGINEERING

Background

Formate Brines

- Range of clear fluid densities (11.1-19.2 ppg)
- Stabilize polymers to 350°F
- Stabilize shale
- Easily recycled
- Corrosion, ????
- Compatible with formation fluids…???
- Removal of filter cake …???

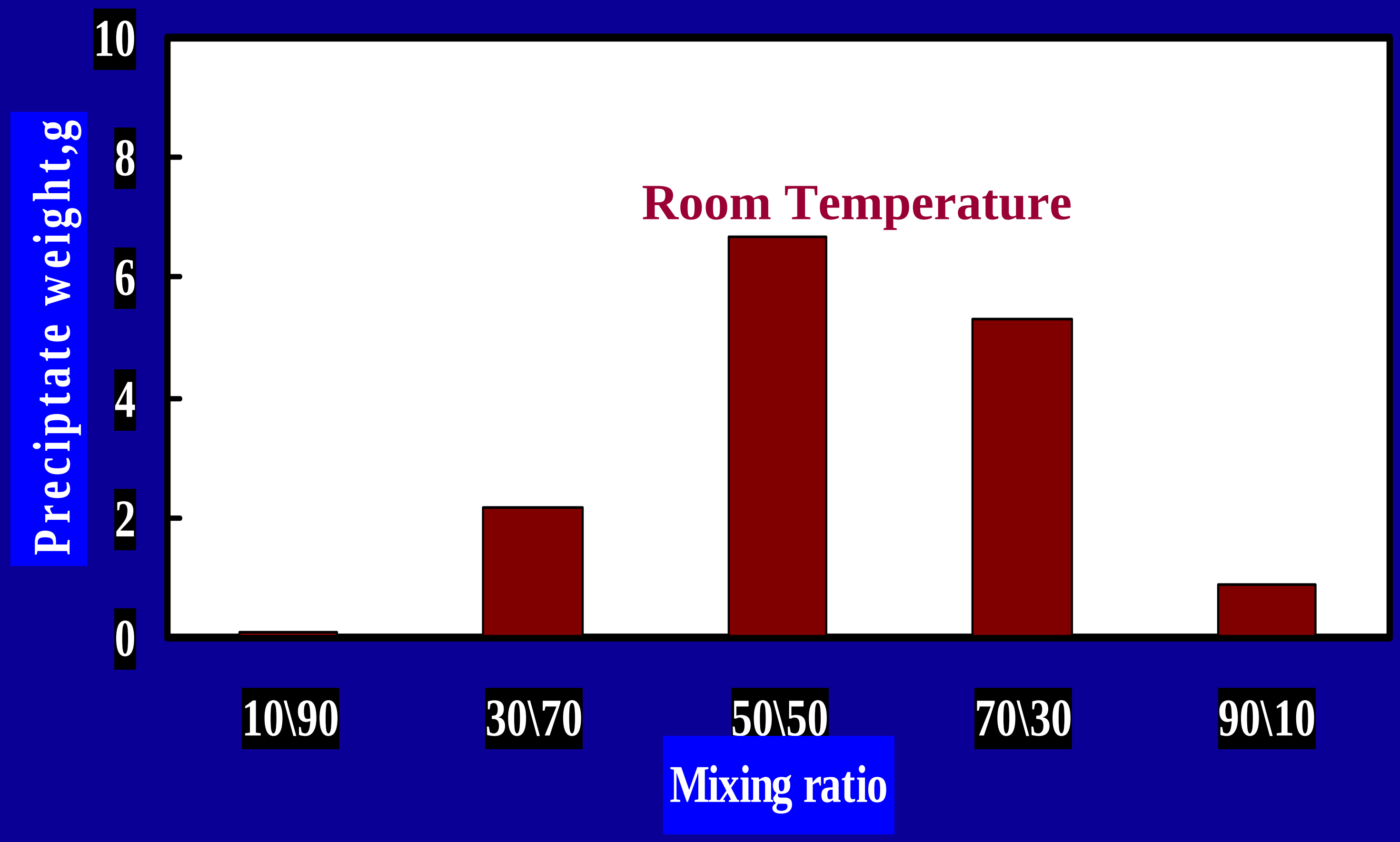
Potassium Formate Brine (PFB) Mixed with Unyazah Formation Brine (UFB)

Brine Sample Composition

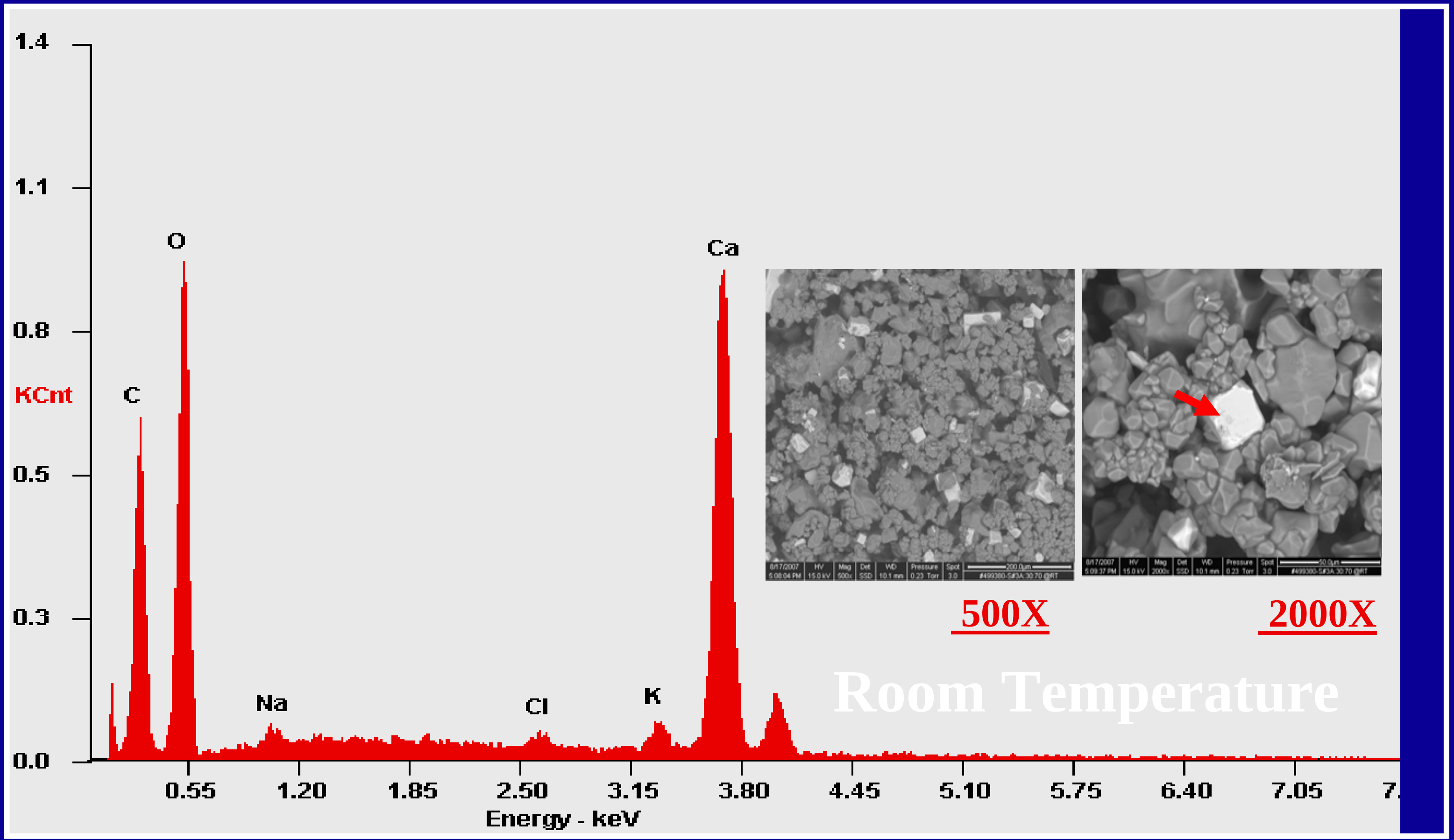
Compound	Concentration, g/l
$NaCl$	142.57
$CaCl_2.2H_2O$	76.759
$MgCl_2.6H_2O$	9.8259
Na_2SO_4	0.1479
$NaHCO_3$	0.7889

Ions, mg/l								pH	Density, ppg
Na	Ca	Mg	SO_4	Cl	CO_3	HCO_3	TDS		
56,356	20,926	1,175	100	126,935	0	573	206,065	6.031	9.5

Compatibility Tests between PFB and UFB



Backscattered Electron Images and EDS X-ray Spectra



70:30 (PFB/UFB)

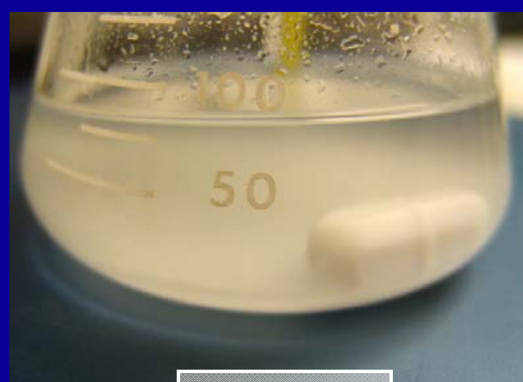
Compatibility of PFB with UFB

Temperature: 113-127ºF

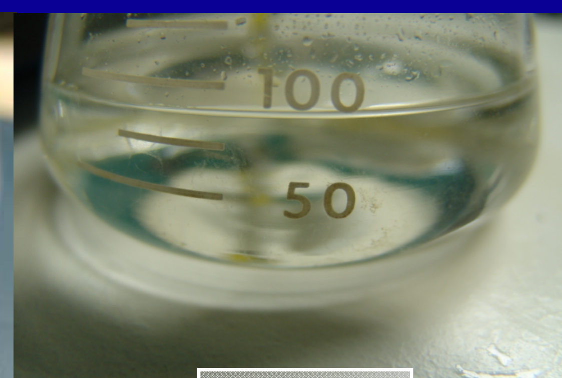
10:90

30:70

50:50

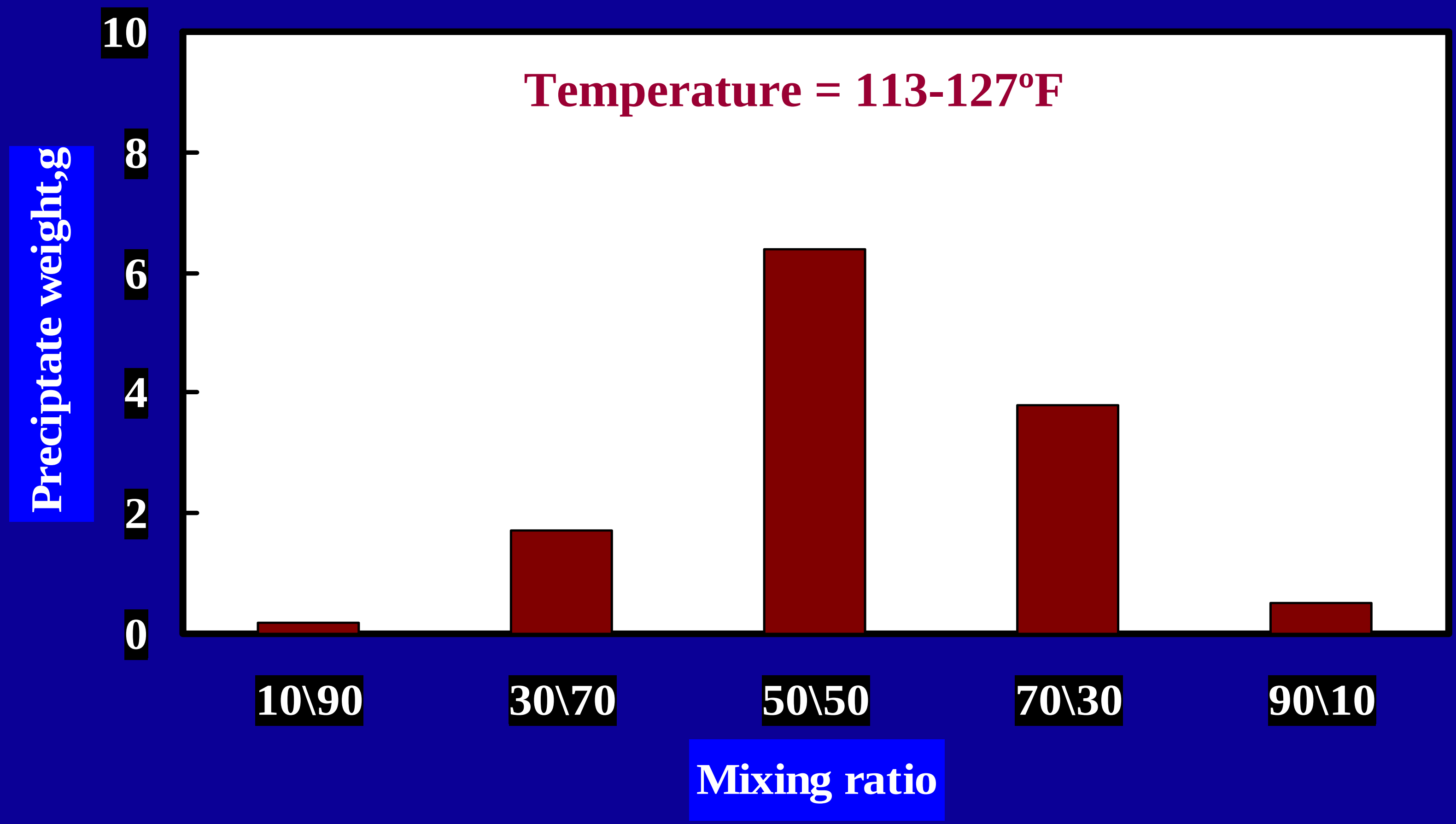


70:30

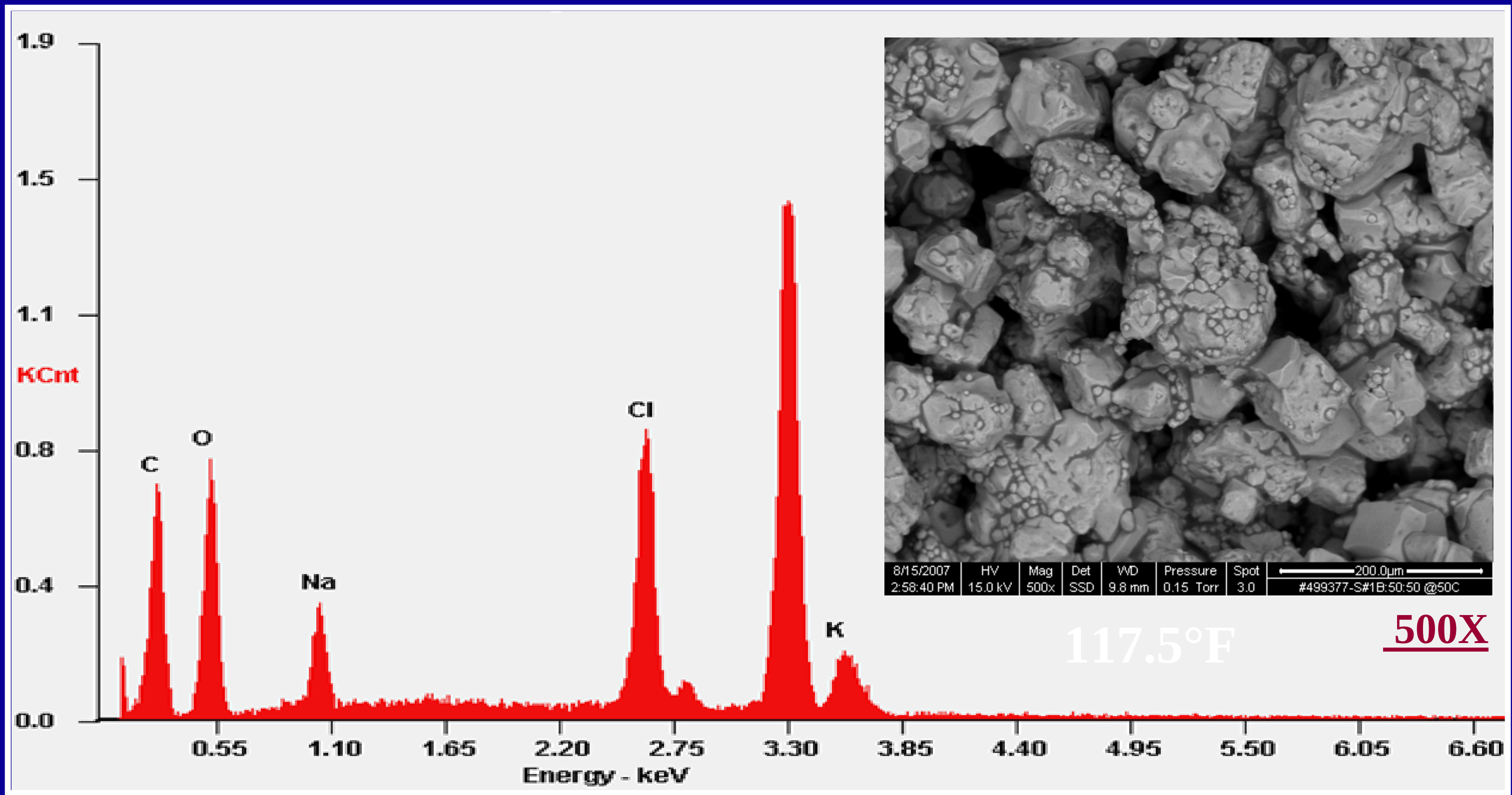


90:10

Compatibility Tests between PFB and UFB



Backscattered Electron Images…..

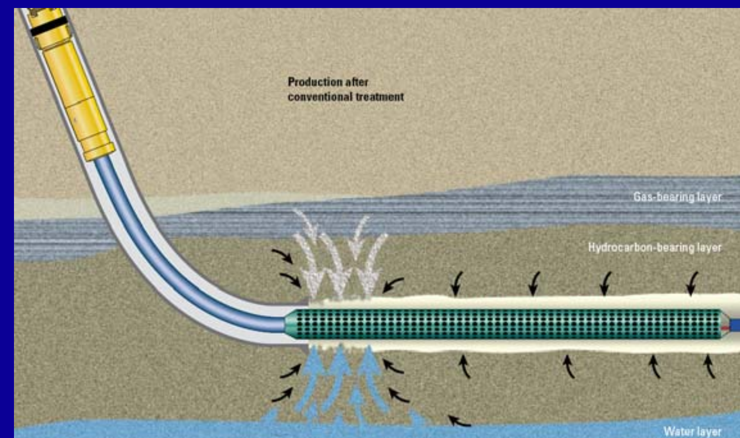


50:50 (PFB/UFB)

Potassium Formate Brine (PFB) Mixed with Cleaning Solution

Cleaning Fluids

- HCl (strong acid)
- Organic acids
- Esters
- Oxidizers
- Chelating agent
- Enzymes
- Jetting

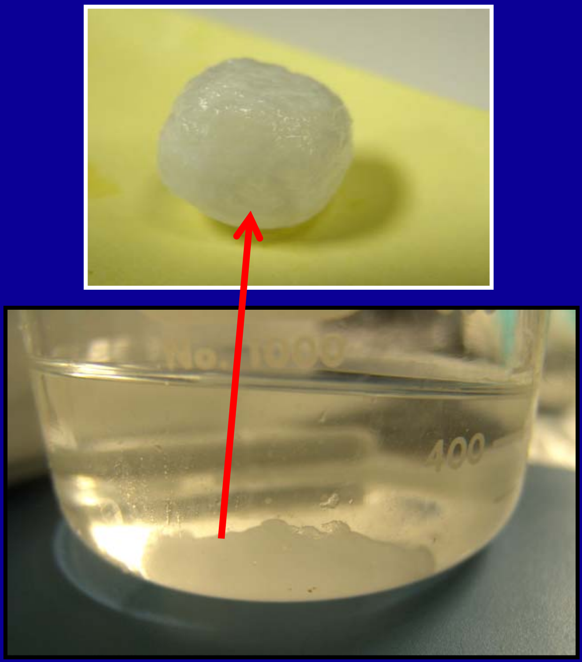


www.slb.com

10 wt% Citric Acid in PFB

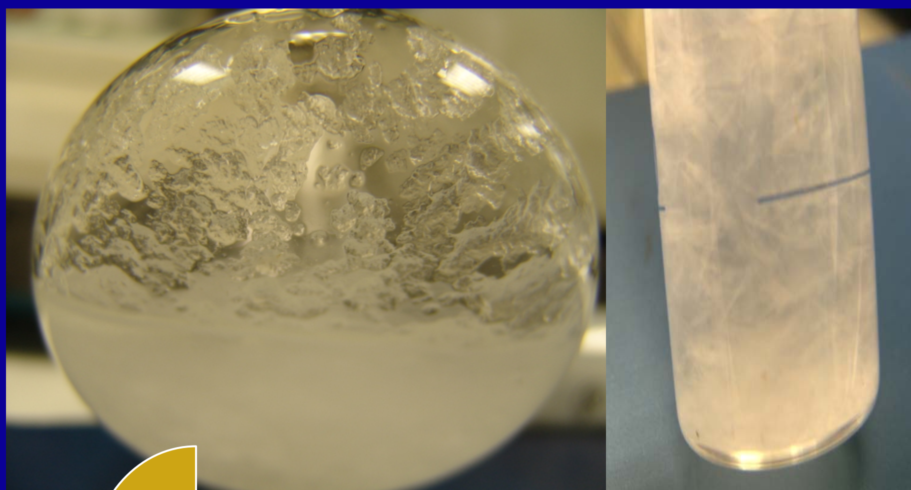
At room temperature

After heating at 158°F

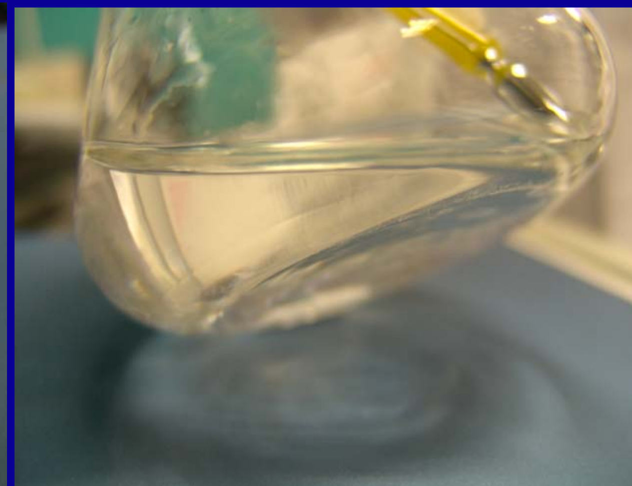


Potassium hydrogen citrate

10 wt% Formic Acid in PFB



Gel fluid at room temperature

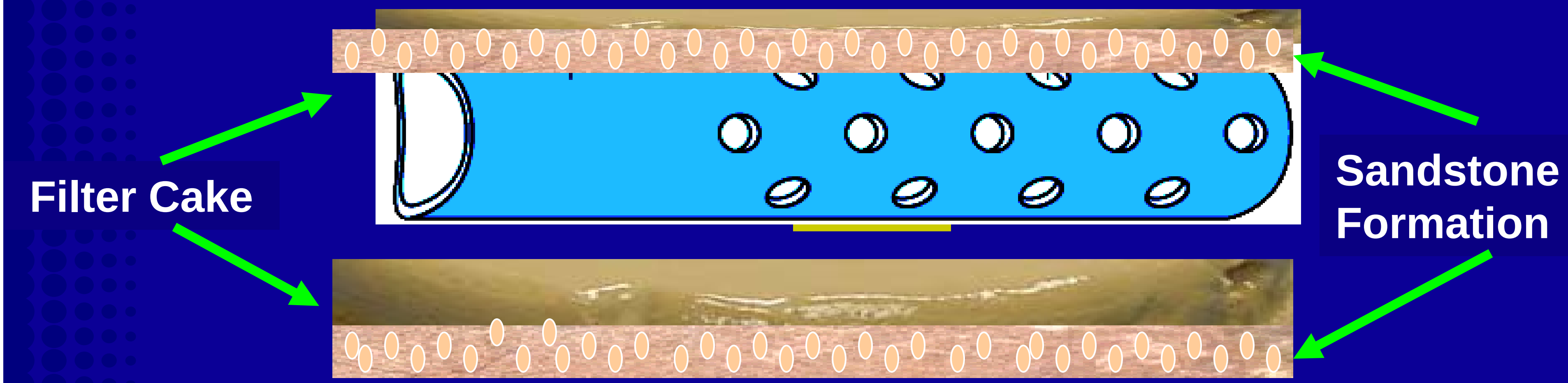


Solution prepared at 140ºF

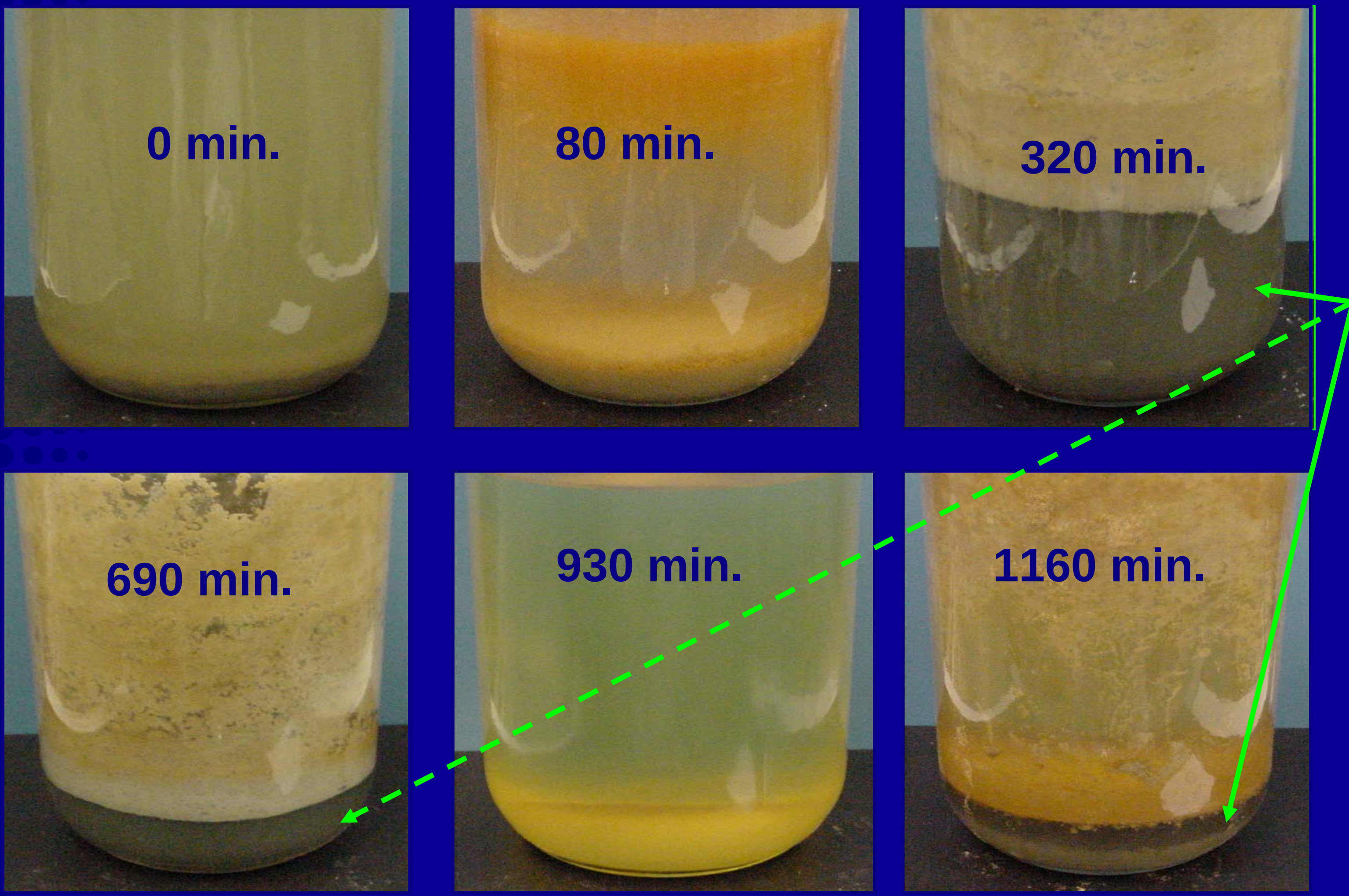
Potassium hydrogen formate

Pre-Drilled Liner, Well H

- Low-carbon steel
- 98 wt% Fe, 1.5 wt% Mn
- Poor resistance to CO_2 corrosion

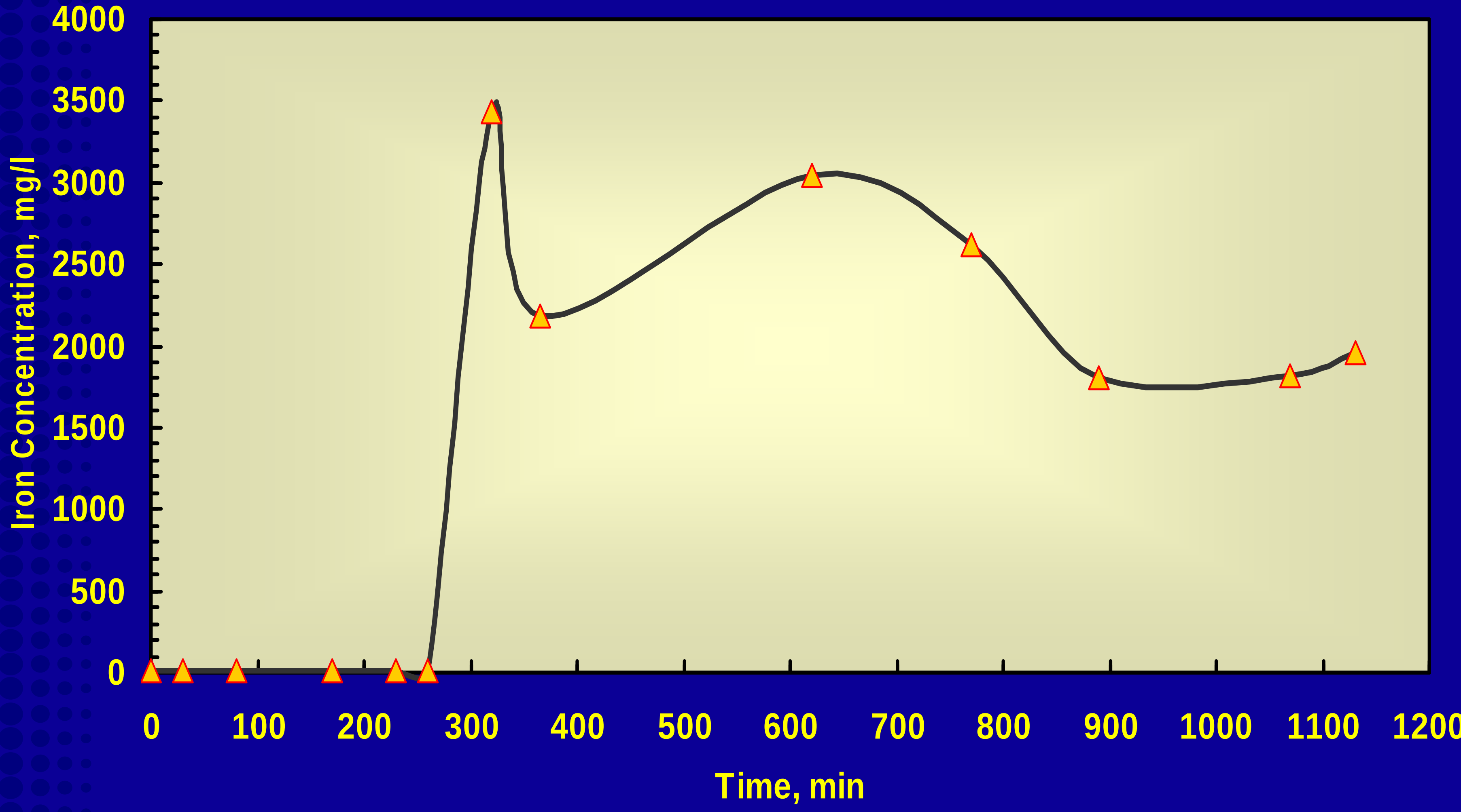


Samples Collected from Well H

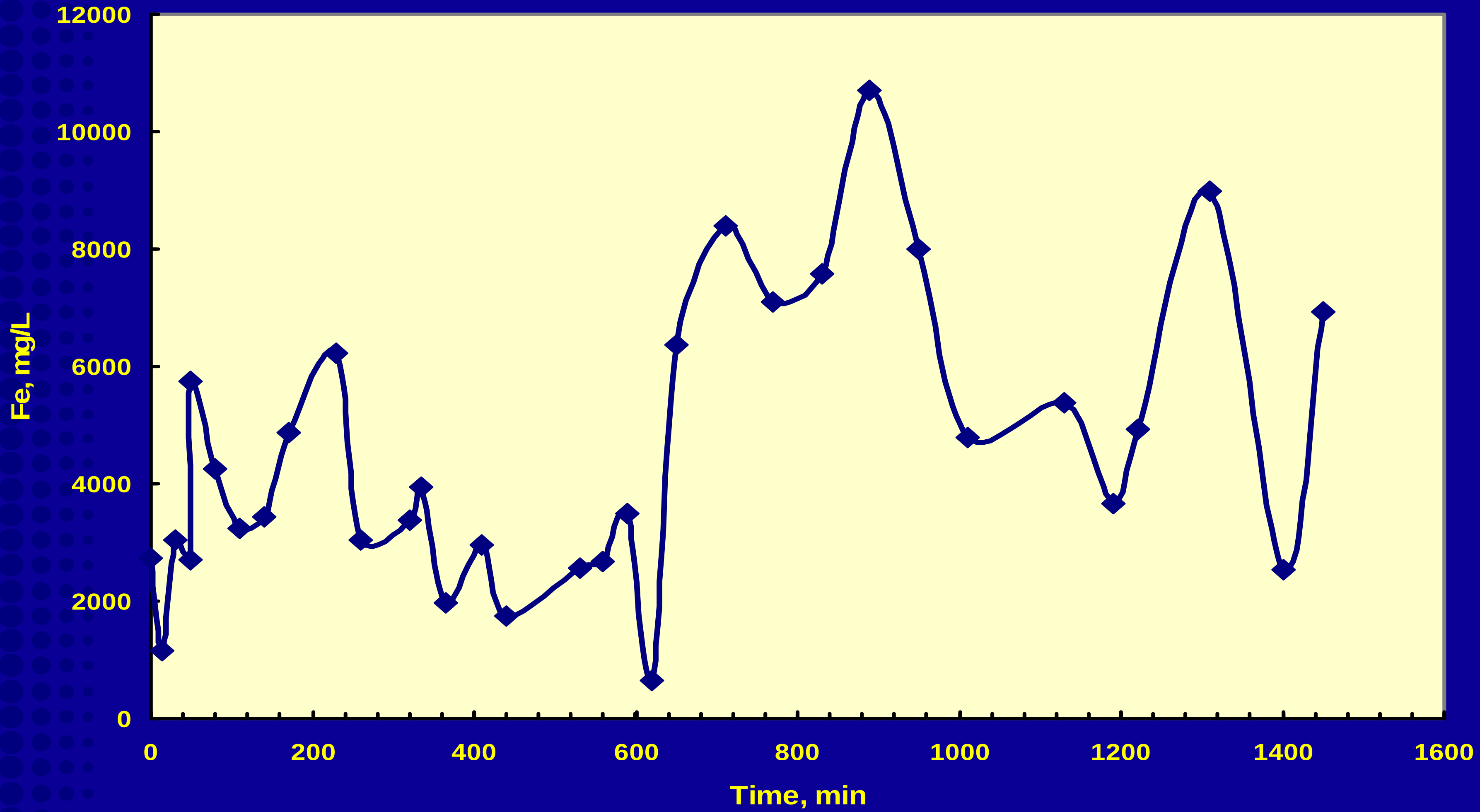


(Green Color) **Iron**

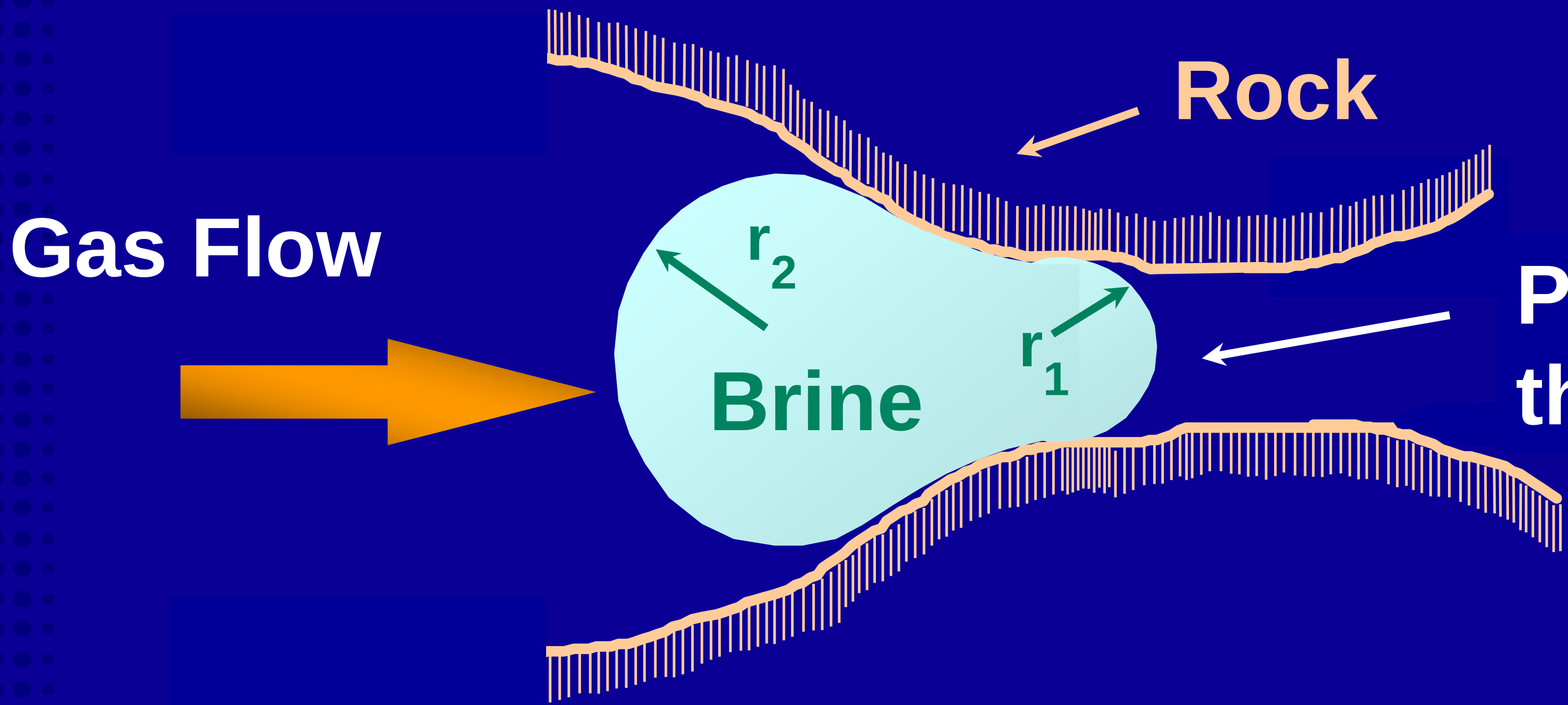
Total Iron, Well H



Total Iron in Supernatant, Well H

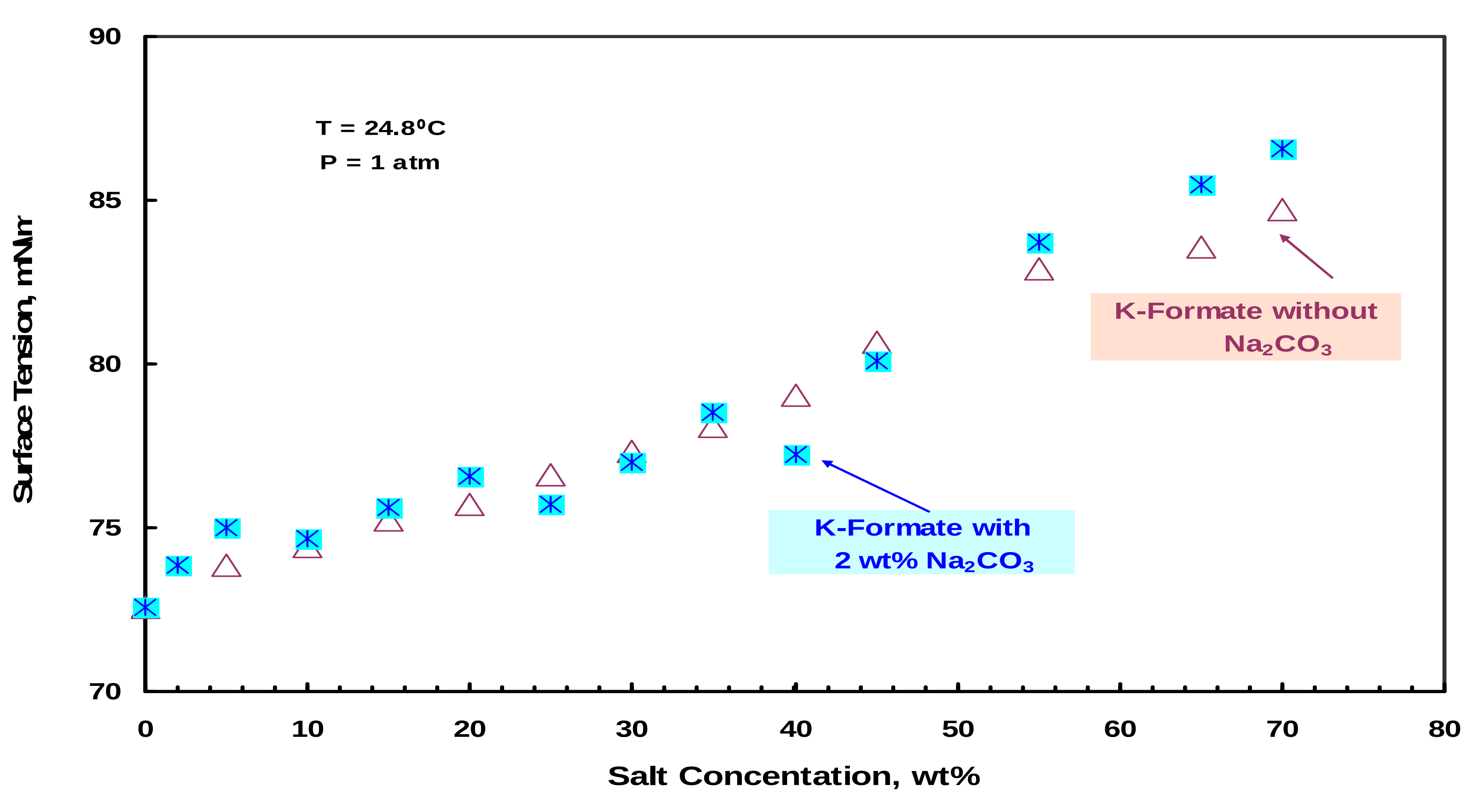


Trapping of Aqueous Solutions



Laplace Equation: $$\Delta p = 2\sigma\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$$

Surface Tension of K-Formate Solutions



The Bottomline

- New fluids and weighing materials were introduced
- There is a need to examine filter cake generated by these fluids
- Also more work is needed to find methods to remove filter cake
- Watch for filtrate, and how to recover it