MIC in Long Oil Pipelines: Diagnosis, Treatment and Monitoring

ISMOS 3
Calgary, Alberta

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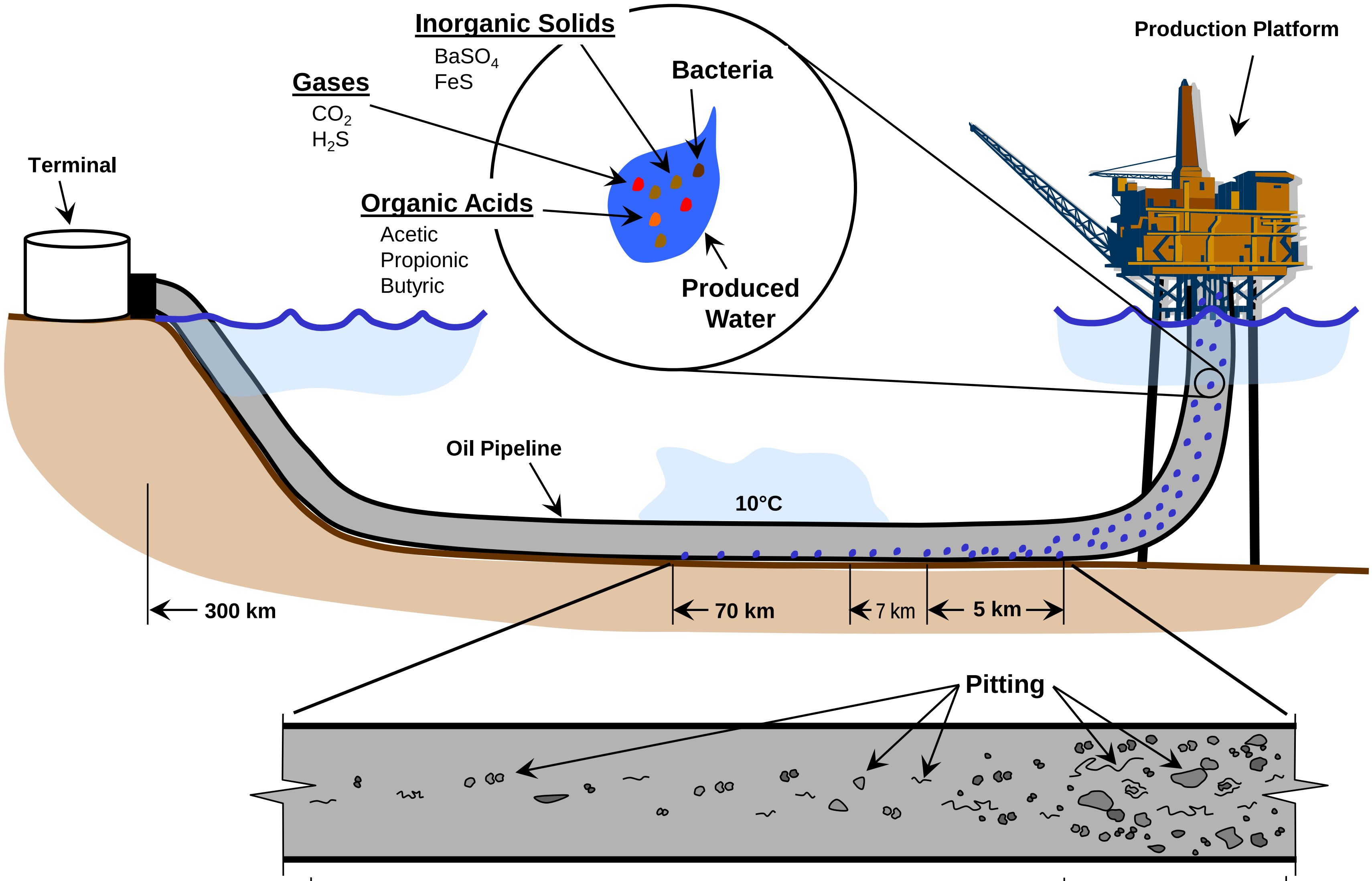
Problem



Pitting in the first 70 Km

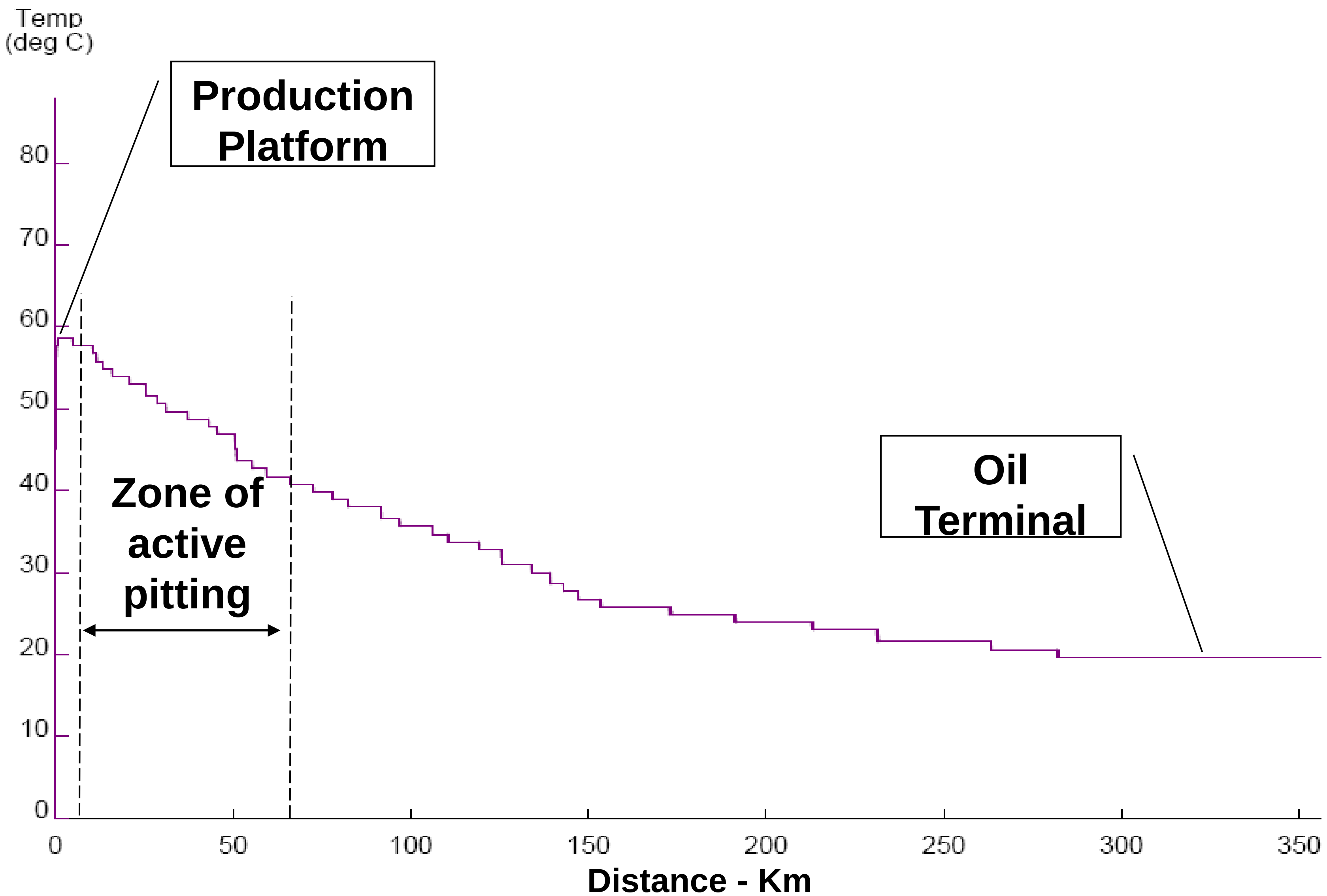
Is it MIC?

MIC does not produce any unique type of corrosion and there are no definitive tests or specific observations that can be used to detect MIC.

B. J. Little

- Biological
  - Are environmental conditions conducive to microbial growth and metabolism?
- Chemical
  - Are environmental conditions such that abiotic mechanism could explain observed rates?
- Metallurgical
  - Are corrosion products and features characteristic of MIC present?
- Operational
  - Have changes occurred that may enhance the activity of microorganisms?

Temperature Gradient

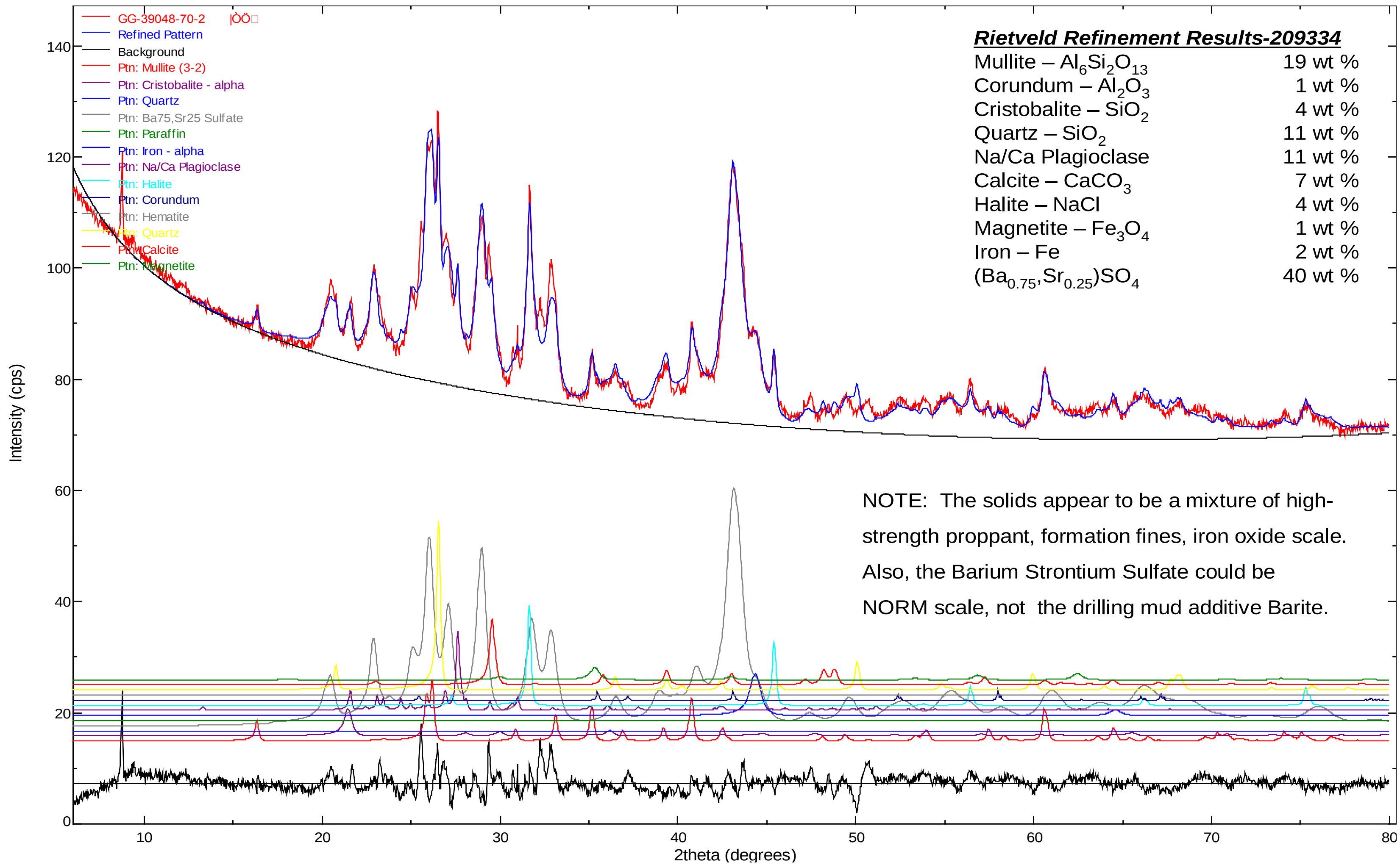


Analyte	Units	1/27/05	2/9/05	2/24/05	3/14/05
pH	----	5.9	6.2	5.5	6.0
Susp. Solids > 0.45 μ	mg/l	340	490	300	161
Total Organic Carbon	mg/l	830	852	662	1370
Total Sulfide	mg/l	0.5	0.7	0.7	<1
Soluble Fe	mg/l	30	26	43	28
Phosphorus as PO4	mg/l	6.1	18.1	7.3	5.5
Calcium	mg/l	710	860	5660	1190
Potassium	mg/l	340	260	410	390
Magnesium	mg/l	160	250	400	530
Sodium	mg/l	9100	13200	16200	13900
Strontium	mg/l	80	120	160	120
Ammonium	mg/l	27	42	51	48.4
Chloride	mg/l	14200	22000	29800	26400
Sulfate	mg/l	90	155	280	610
Methanol	mg/l	10	30	80	1010
Ethanol	mg/l	15	5	49	145
Acetaldehyde	mg/l	1	7	22	140
Acetic Acid	mg/l	350	760	700	630
Propionic Acid	mg/l	145	240	130	40
Butyric Acid	mg/l	15	11	14	9

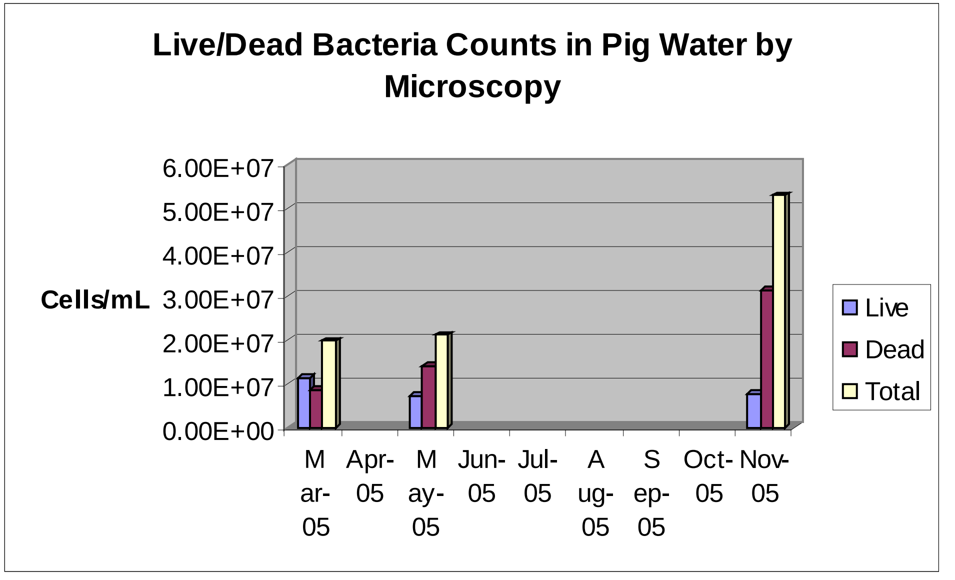
- Chemical analyses of water from pig runs.

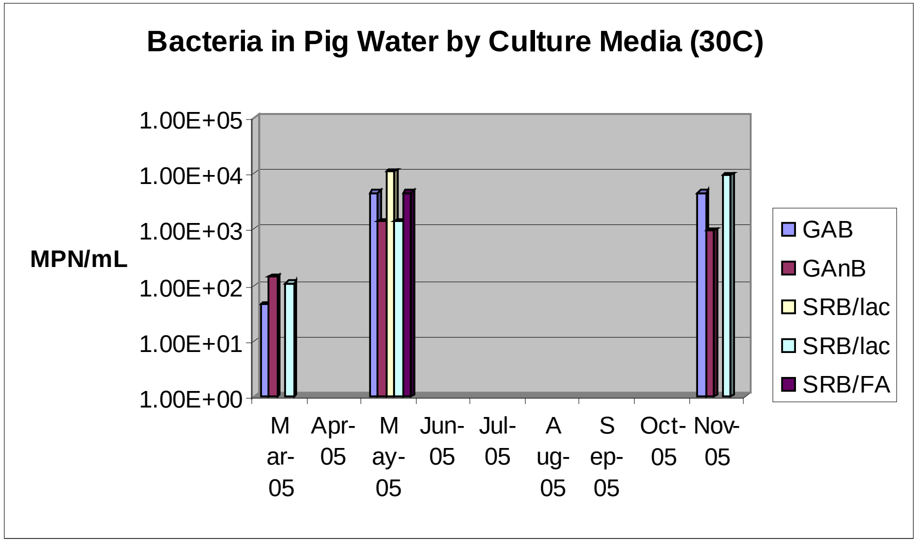
Disc Pig

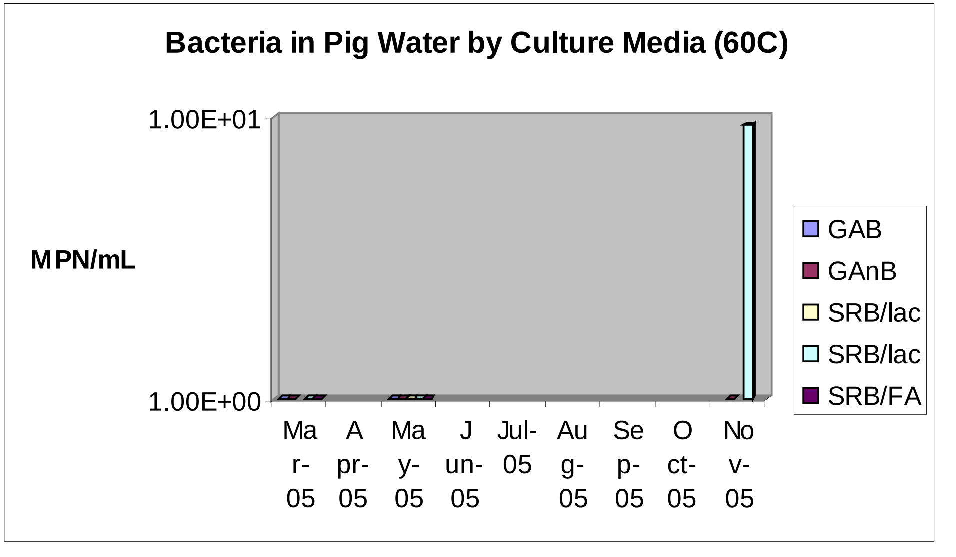
XRD of Pig Sludge Solids



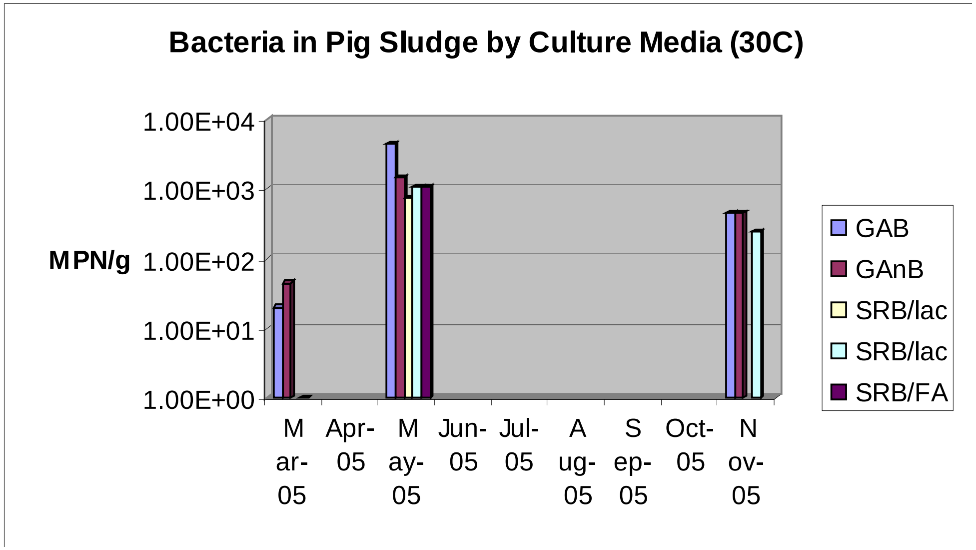
Bacteria Analyses in PL Pig Water

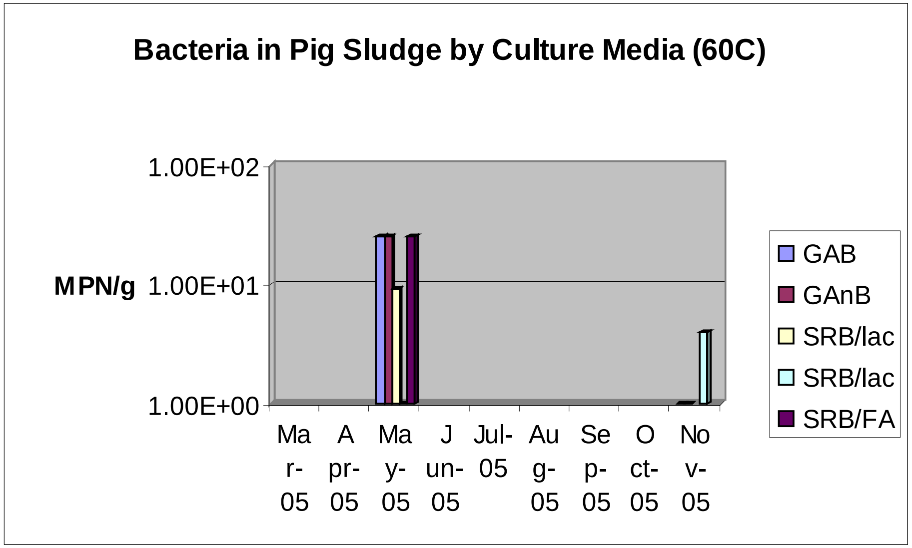


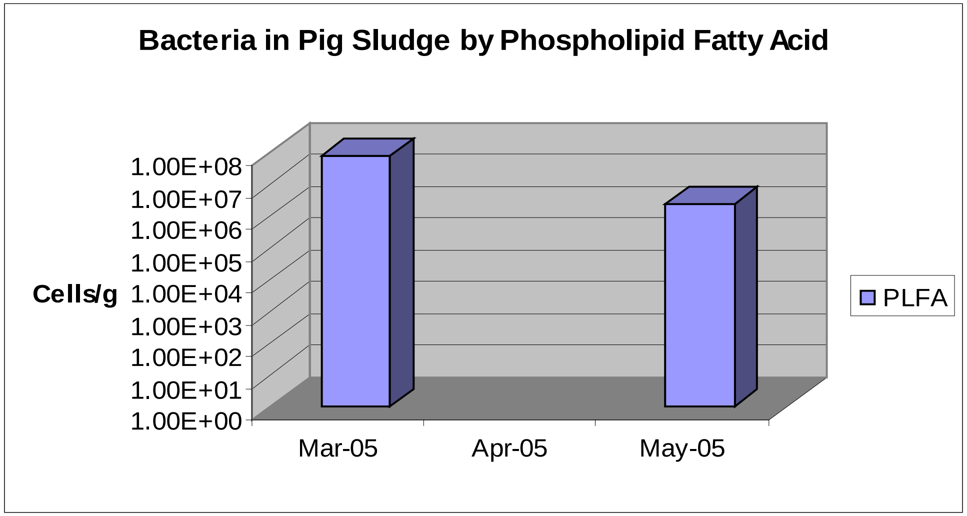


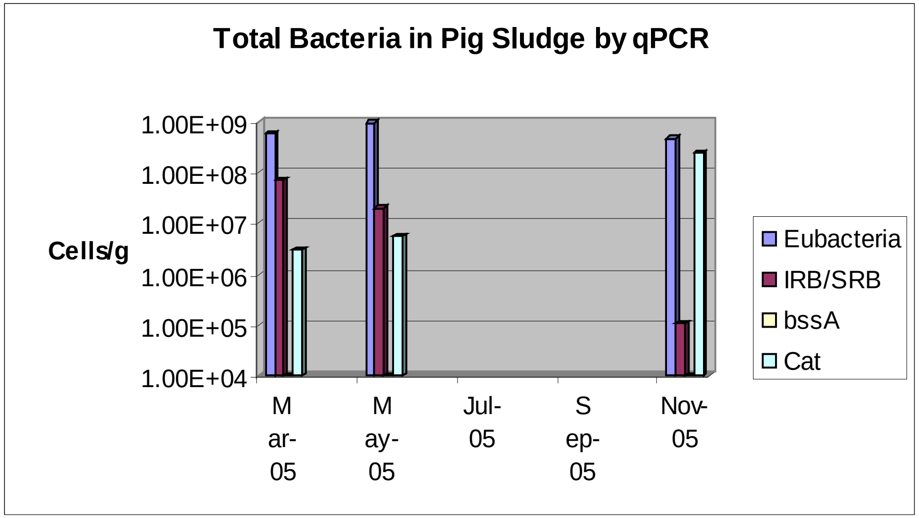


Bacteria Analysis in Pig Sludge





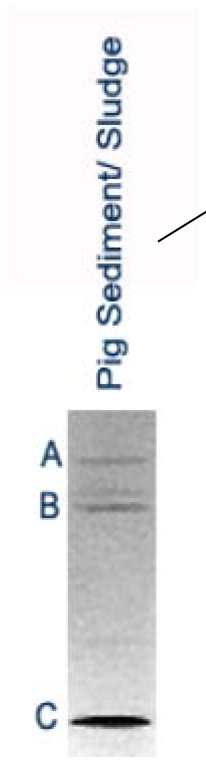




Community Structure of PL Pig Sludge by PLFA Analyses

Date	Biomass	Community Structure (% total PLFA)					
	Cells/g	Firmicutes Anaerobic Gram (–) (TerBrSats)	Proteo-Bacteria (Monos)	Anaerobic Metal Reducers (BrMonos)	SRB/ Actino-mycetes (MidBrSats)	General (Nsats)	Eukaryotes (Polyenoics)
3-14	7.73×10^7	39.1	9.7	1.1	1.1	49.0	0.0
5-09	2.59×10^6	46.4	7.5	0.0	0.0	46.1	0.0

DGGE of PL Pig Sludge – Mar. 14



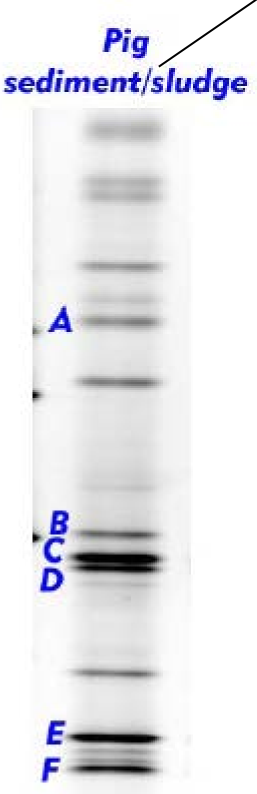
March 14

Sludge sample

Band	Similar genus	Similarity Index	Donors	Acceptors	Habitat
A C	*Desulfovibrio*	0.732 0.684	organics	$SO_4^{=}$, S^0	Soils, sediment, halophilic sulfate reducer
B	*Desulfomicrobium*	0.649	organics, H_2	$SO_4^{=}$, $S_2O_3^{=}$	anaerobic sediments

Sequence results from bands excised from Figure 5 (March 14). Similarity indices above .900 are considered excellent, .700-.800 are good, and below .600 are considered to be unique sequences.

DGGE of PL Pig Sludge – May 9



May 9

Sludge sample

Band	Similar genus	Similarity Index	Donors	Acceptors	Habitat
C	*Desulfovibrio sp.*	0.690	organics	$SO_4^=$, S^0	Marine sediment
D	*Desulfocaldus sp.*	0.627	organics, H_2	$SO_4^=$, $S_2O_3^=$	anaerobic sediments
E	*Pelobacter sp.*	0.763	H_2, formate, short chain alcohols	Fe^{3+}, S^0	Marine and freshwater sediments and abundant in sewage
F	Uncultured Bacterium	0.755			Gen Bank Reference # AY426471
A,B	Failed				

Sequence results from bands excised from Figure 5 (May 9). Similarity indices above .900 are considered excellent, .700-.800 are good, and below .600 are considered to be unique sequences.

Biometabolite Analysis

- 23 putative hydrocarbon biometabolites were identified.
- Biometabolites of the biodegradation of aromatic HC were especially prevalent (5 to 7 μM).
- Biometabolites for the anaerobic biodegradation of aromatic HC (e.g, BTEX) were also detectable.
- Evidence for anaerobic biodegradation of n-alkanes (e.g., fumarate addition products) were only weakly detectable.

Operational Considerations

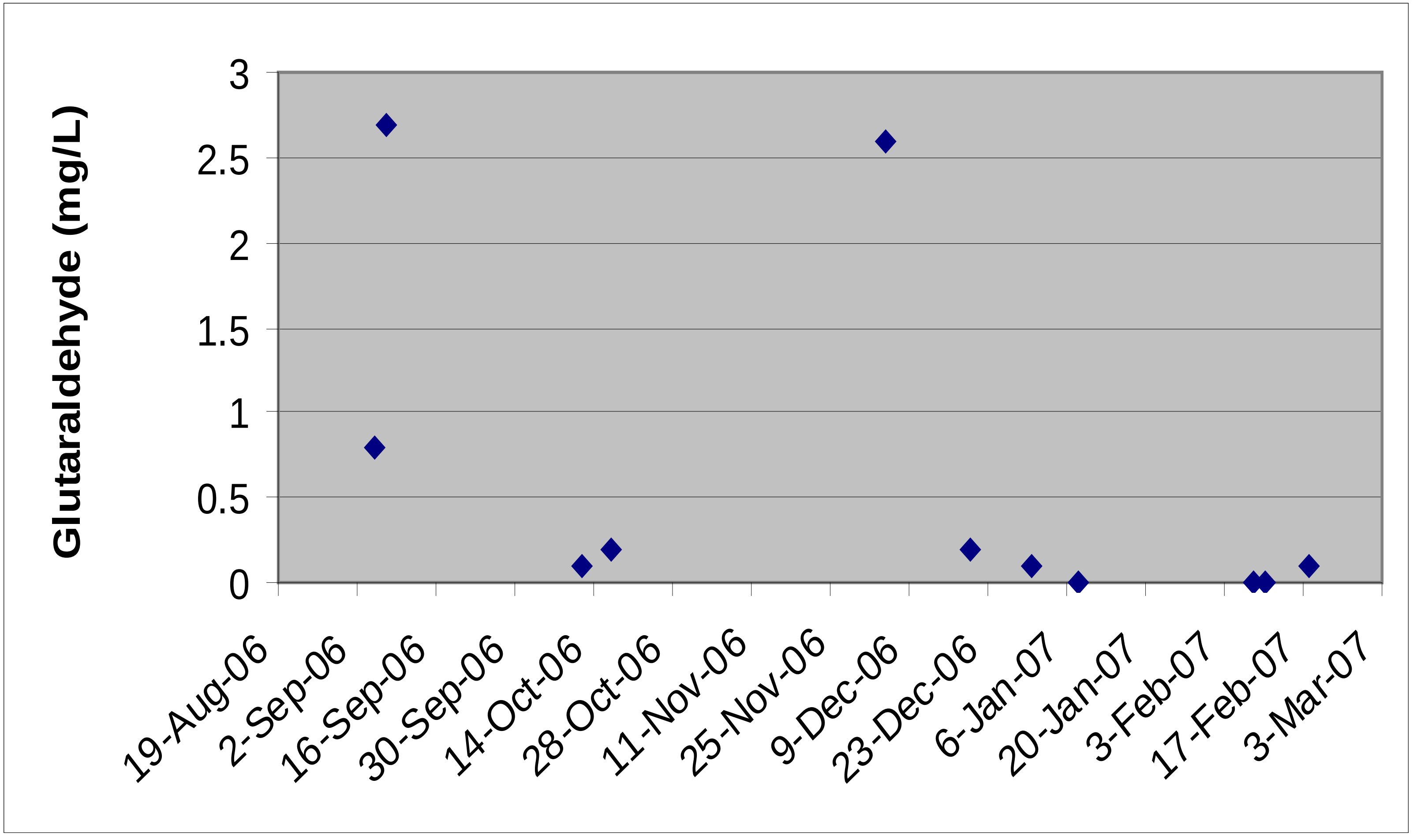
- Soured reservoir
- History of MIC in upstream pipelines
- Velocity - < 1.5 m/s
- Presence of solids – scale, suspended solids
- Water slugging
- Oxygen
- 3rd party lines

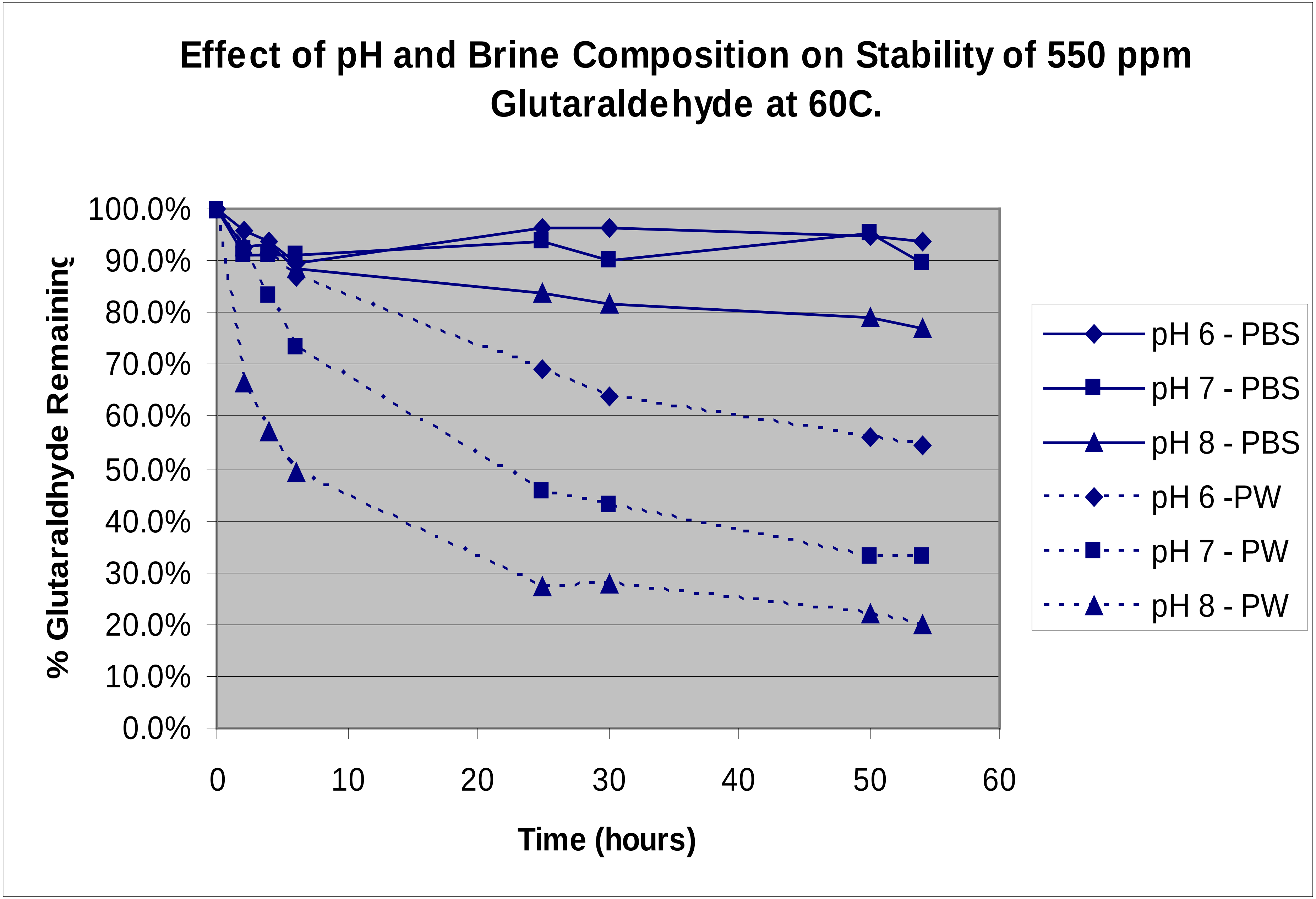
Is it MIC?

- Microbiological, chemical, metallurgical and operational evidence suggest that MIC is a likely mechanism.

Biocide/Mitigation Program

Glutaraldehyde residuals in pig envelope water by GC-ECD.




Effect of pH and Brine Composition on Stability of 550 ppm Glutaraldehyde at 60C.
% Glutaraldhyde Remaining
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
0
10
20
30
40
50
60
Time (hours)
pH 6 - PBS
pH 7 - PBS
pH 8 - PBS
pH 6 -PW
pH 7 - PW
pH 8 - PW

Synthetic seawater was amended with:

- sodium bicarbonate
- ammonium chloride
- ethylene glycol
- acetic acid
- boric acid
- *iron (0.58 mM)
- *crude oil (50%)

Water type	$[glut]_0$, ppm	T (°C)	% degrad, 24h
Field sample	1000	60	90
Field sample	300	60	85
Synthetic PW	1000	50	80

from McGinley et al., SPE OFC Symposium (2011)

Screening of Components

Modified Synthetic PW, 55 ° C, 24h

Water type	NH_4+	% degrad
Synthetic PW	None	10
Synthetic PW	10 ppm	40
Synthetic PW	100 ppm	81

from McGinley et al., SPE OFC Symposium (2011)

Screening of Components

Amended Instant Ocean, 55 °C, 24 hrs

Sample	$[NH_4+]$	other	% degrad
1,2,3	--		0, 0, 8
4	100 ppm		20
5	--	595 ppm EG	0
6	100 ppm	595 ppm EG	30
7	--	390 ppm AcOH	12
8	100 ppm	390 ppm AcOH	45
9	--	49 ppm boron	14

* Complete Synthetic PW has 100 ppm ammonium

from McGinley et al., SPE OFC Symposium (2011)

Successful Mitigation Measures

- Increase CO_2 inhibitor concentration
- Remove sources of oxygen ingress.
- Increase continuous biocide concentration (GA/QAC)
- Batch biocide and batch corrosion inhibitor every 5th week following aggressive pit cleaning tool.
- Scale inhibitor injection

Acknowledgments

- The authors would like to thank ConocoPhillips for the opportunity to present this work.