



Microorganisms involved in MIC

ISMOS-3, June 13-15 2011, Calgary

- The MIC challenge
 - Development of qPCR tools
 - Application and results
 - Implications for MIC risk assessment
-
- The background of the slide features a stylized globe with a white grid of latitude and longitude lines. Overlaid on the globe is a solid orange map of the world. The globe is centered behind the text, and the orange map covers the entire width of the slide, with the globe's grid visible through it. There are three vertical white bars on the left, middle, and right sides of the slide, partially overlapping the orange map.



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R&D partners and sponsors

- Maersk Oil
 - DONG Energy
 - Saudi Aramco R&DC
 - Danish Applied Research Foundation
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- A stylized graphic of a globe with orange landmasses and a grey grid of latitude and longitude lines. The globe is centered in the background of the slide.

MIC = Microbiologically Influenced Corrosion



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www.dental-health-index.com

Pigging
Biocide treatment
Acid treatment
Limit nutrients

Toothbrushing
Toothpaste
Mouthwash
Low sugar diet

Problem typically discovered when damage is done

Expensive to repair

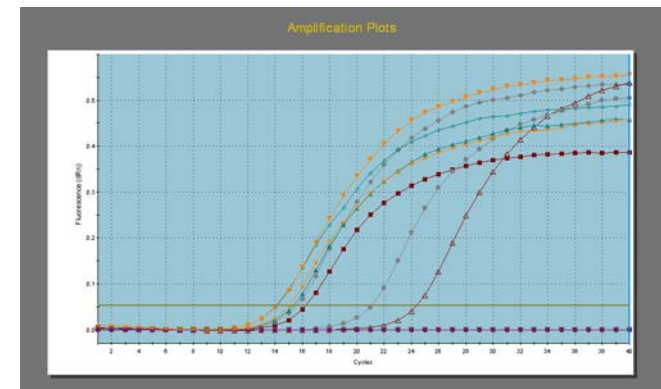
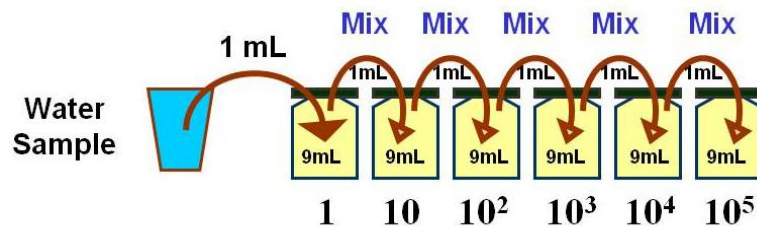
1000 ×



MIC is a widespread problem



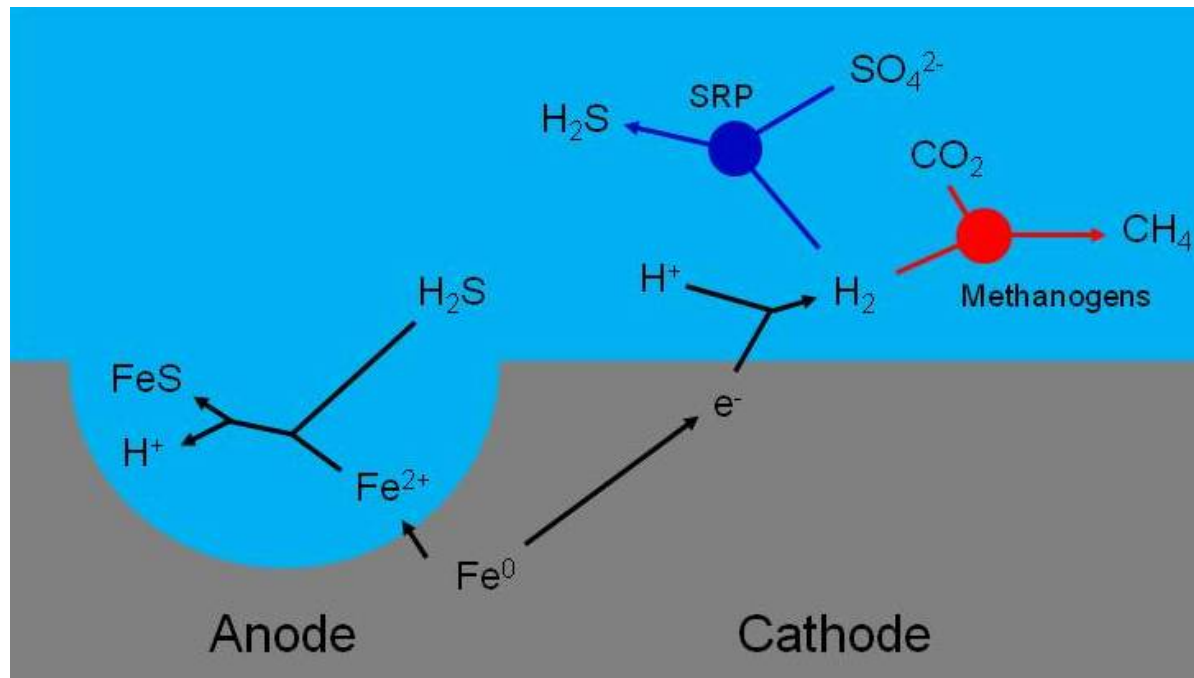
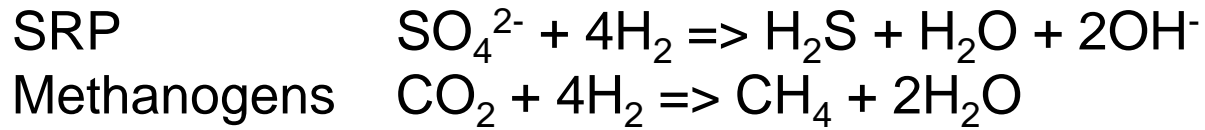
- Historically MIC has been difficult to detect and assess
 - Culture-dependent detection principles
 - Affected surfaces are often inaccessible
 - Complex mechanism
 - Concurrent with other corrosion types



Cathodic depolarization caused by microorganisms (von Wolzogen, van der Vlugt, 1934)



Hydrogen consumption at cathode increases corrosion rate



MIC – mechanisms



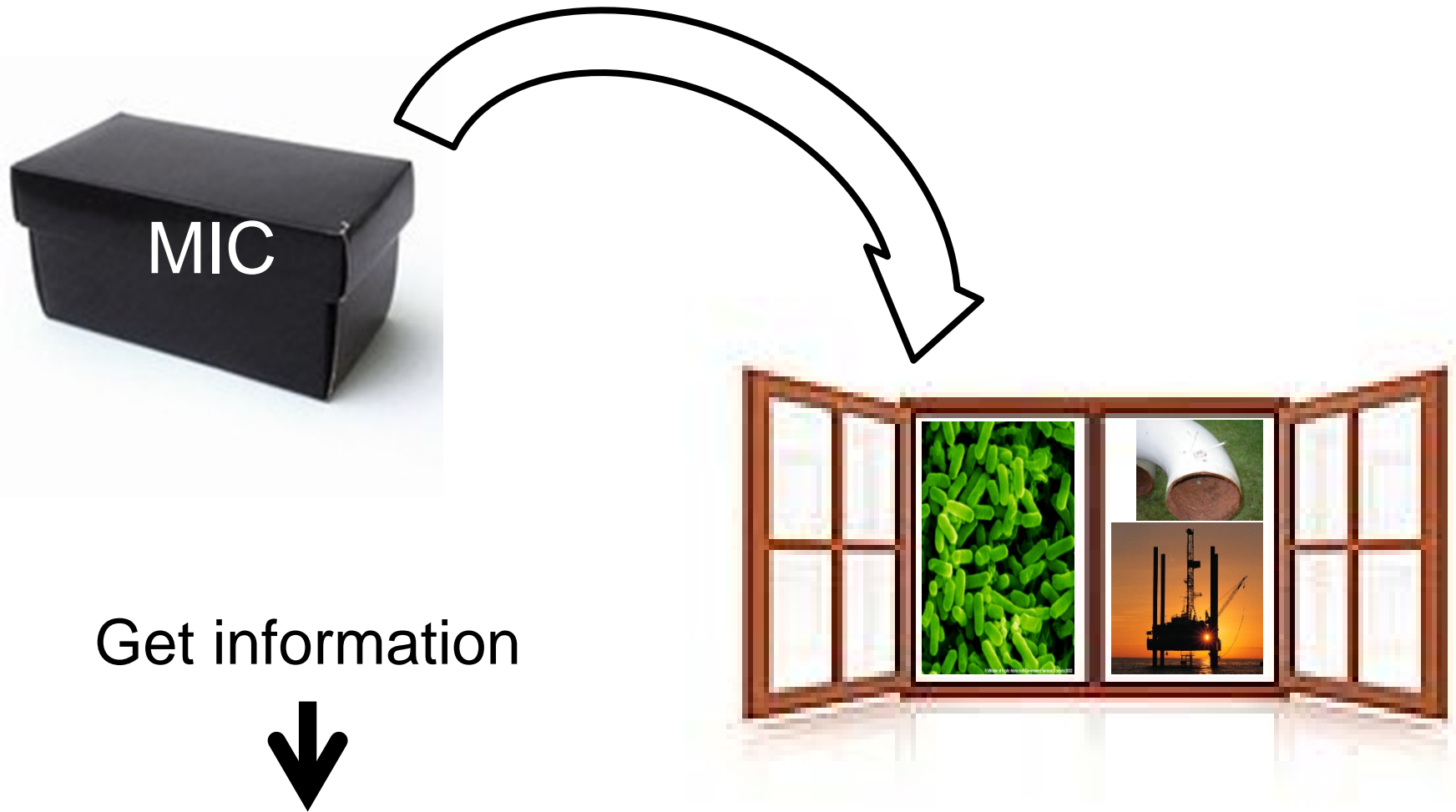
- Biofilm formation
- Hydrogen consumption
- Sulfide production by SRB/SRA
- Production of acids
- Anode-cathode formation
- Electron shuttling
- ...



The MIC challenge



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Get information



Take action



How many sulphate-reducers and methanogens are there in the North Sea oil fields?

A lot - sometimes

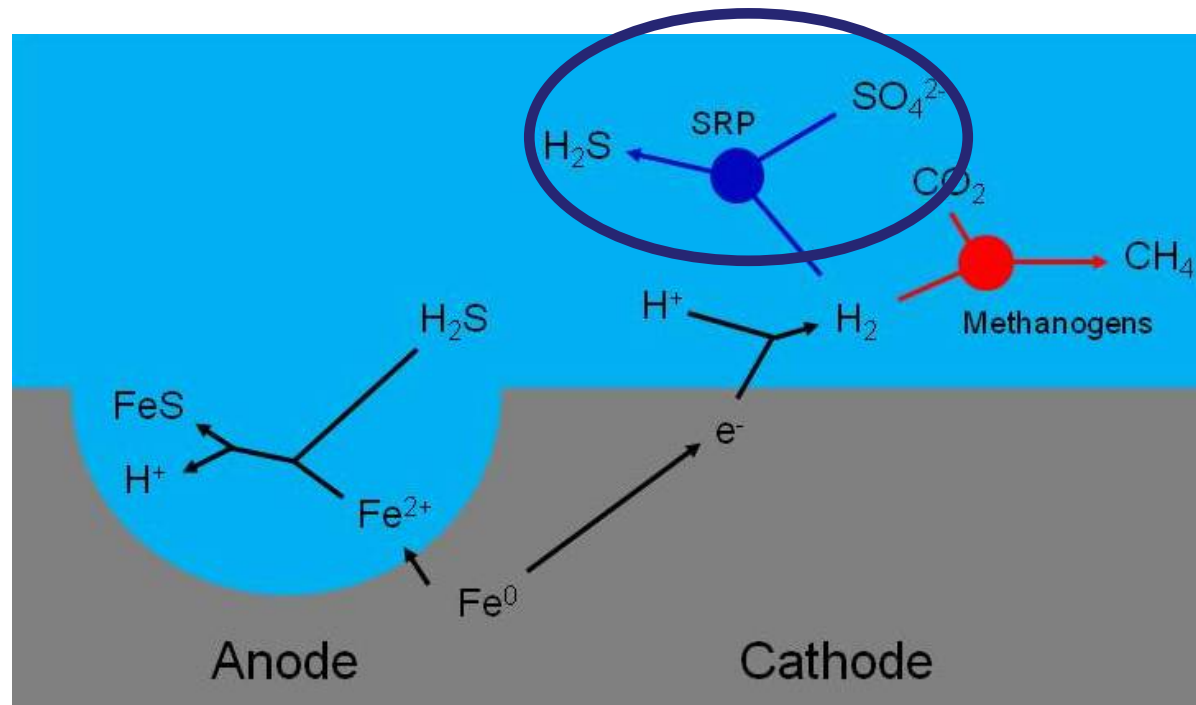
Can we evaluate MIC risk based on microbial numbers?

Yes



SRP increase corrosion rates of metals

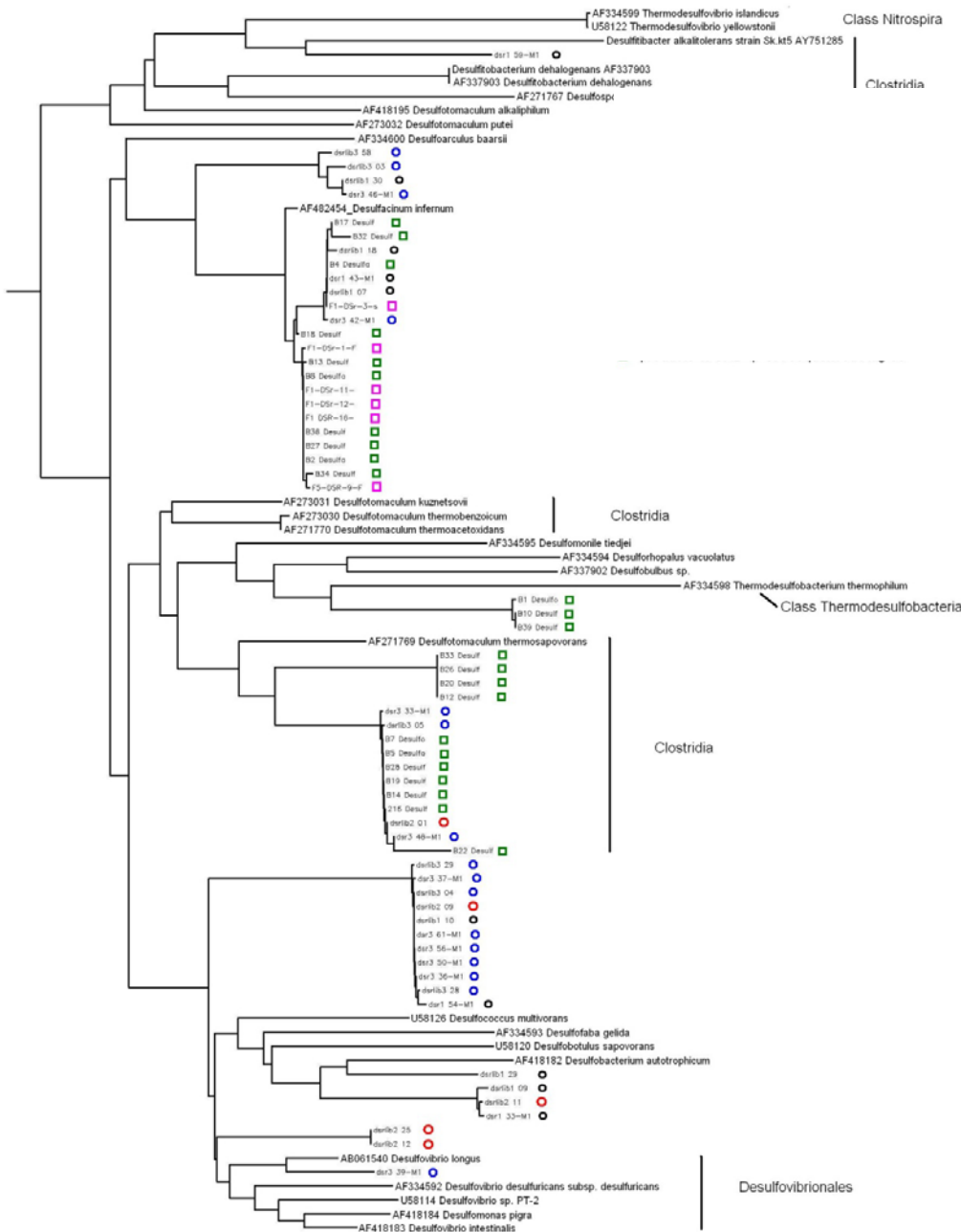
- The classical biocorrosive microorganism in the Oil and Gas industry
- Sulfide is the final product – readily detected both in the field and in culture tubes
- Widespread in the marine environment
- Many are thermophilic
- *dsrAB* may serve as a marker gene for (RT-)qPCR



DsrAB-genes in North Sea oil fields



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Several bacterial groups detected

Abundant archaeal *dsrAB* genes (*Archaeoglobus*)

Phylogenetic orders detected

Archaeoglobales

Desulfovibrionales

Clostridiales

Syntrophobacterales

Thermodesulfobacterales

2 uncertain

DsrAB-genes in North Sea oil fields

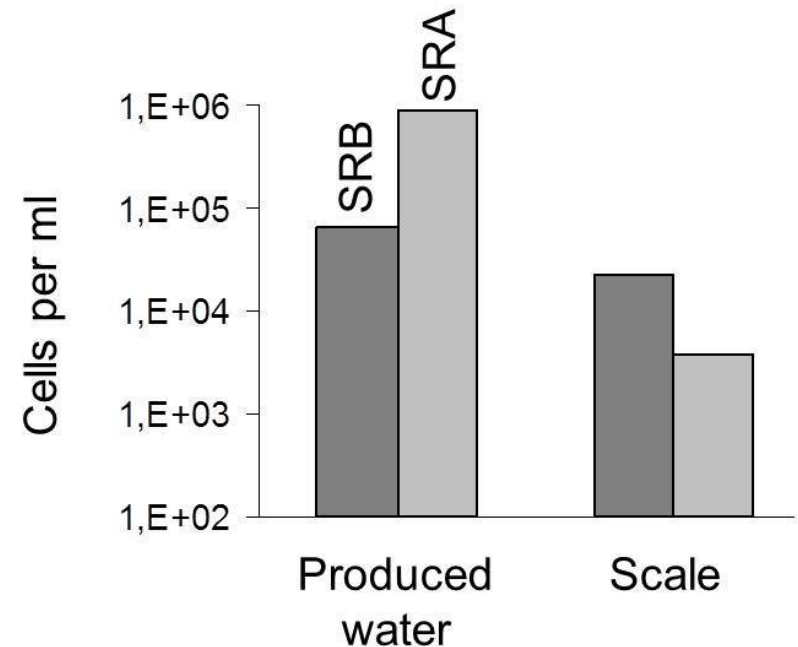


Two qPCR assays for enumeration of the detected *dsrAB*-phylotypes:

Set 1: SRA (*Archaeoglobus*)
Set 2: Bacterial groups

Implications:

- SRA included in MIC Risk Assessment
- Biogeographical patterns emerge – it makes sense!

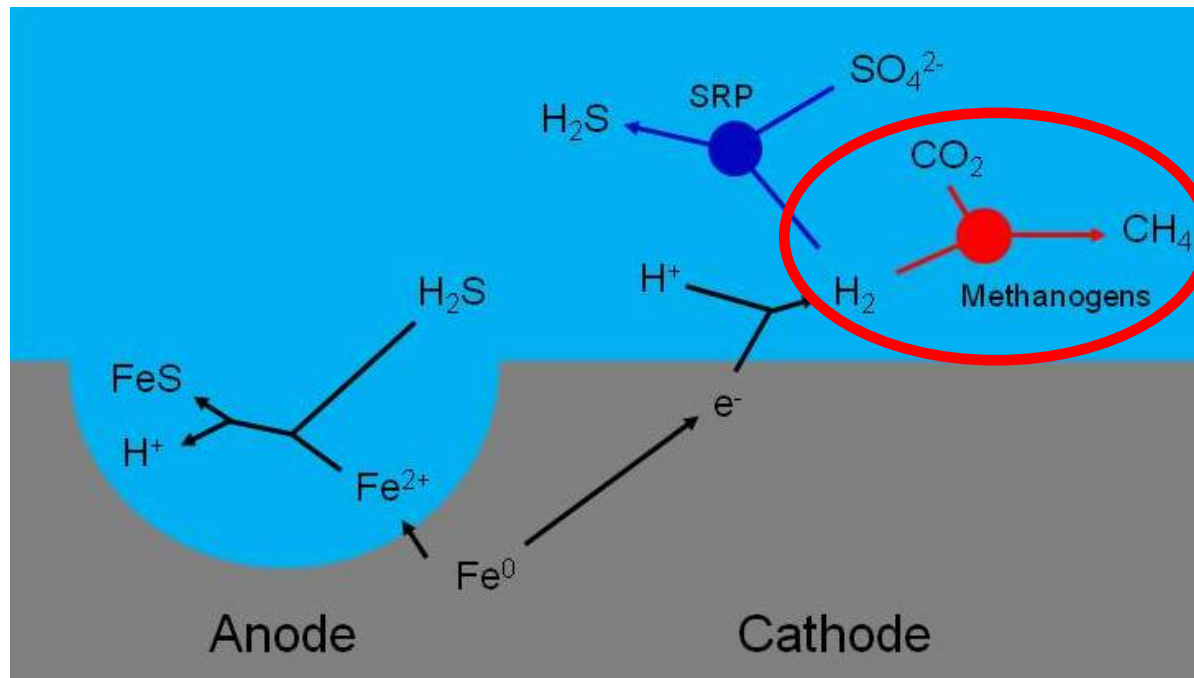


Larsen et al 2009, NACE corrosion

Methanogens increase corrosion rates of metals



- Methane is the final product - often overlooked
- Widespread in marine environments
- Many are thermophilic
- *mcrA* may serve as a marker gene for (RT-)qPCR



mcrA genes in the North Sea oil production systems

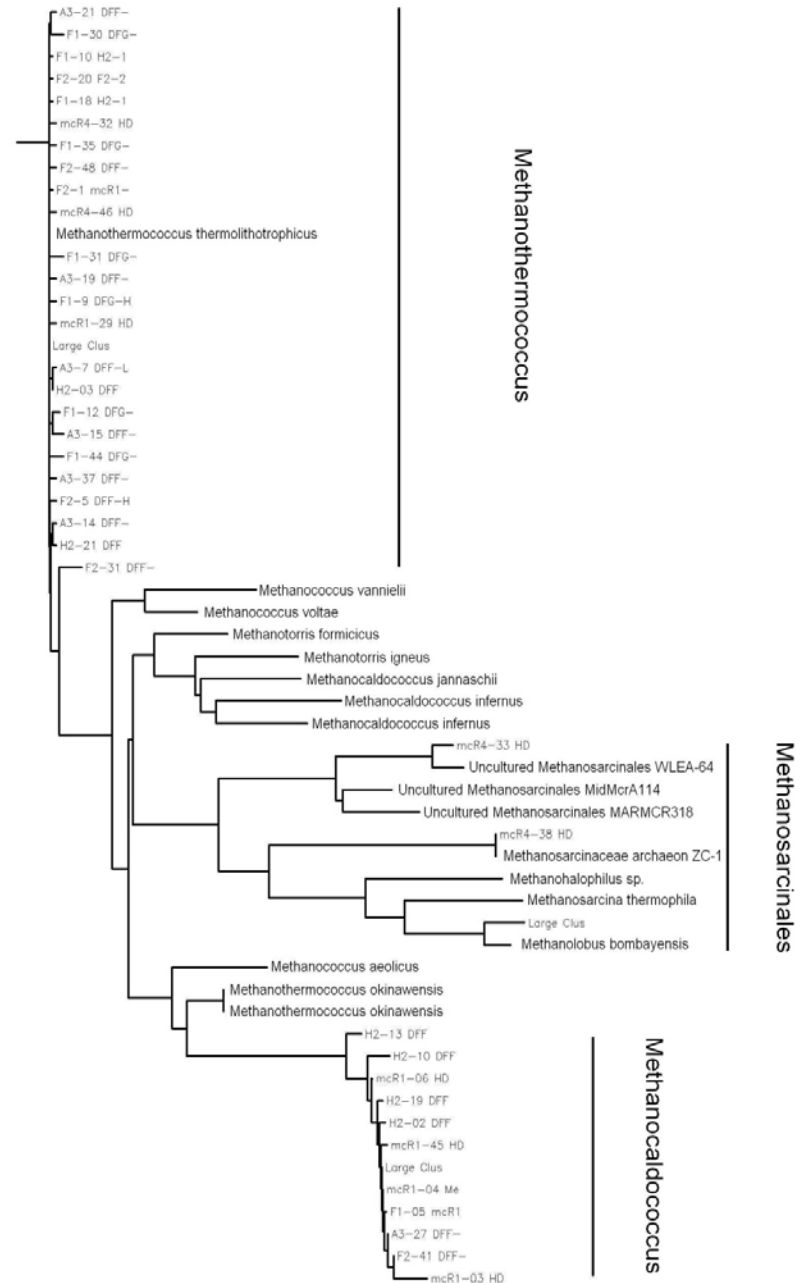


Three different phylogenetic groups have been found:

Group 1
Methanothermococcus

Group 2
Methanosarcinales

Group 3
Related to *Methanocaldococcus*



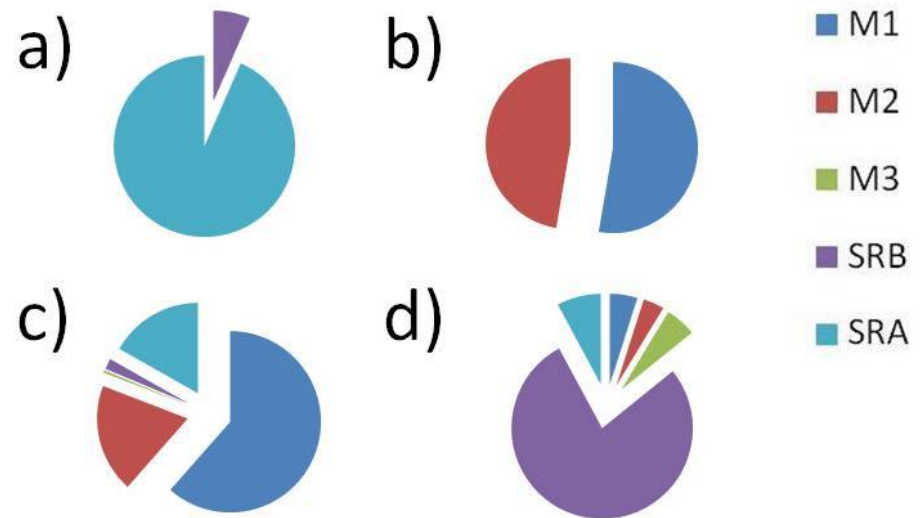
mcrA genes in the North Sea oil production systems

qPCR-assays for each of the 3 groups were designed

Implications:

- Methanogens was included in MIC risk assessment
- Growth of SRP not correlated with growth of methanogens
- All groups must be measured independently

Examples from North Sea oil production



Example 1. Microorganisms involved in topside corrosion



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2004-08: ultrasonic inspections showed corrosion rates of 0.3 mm/y to 1.2 mm/y

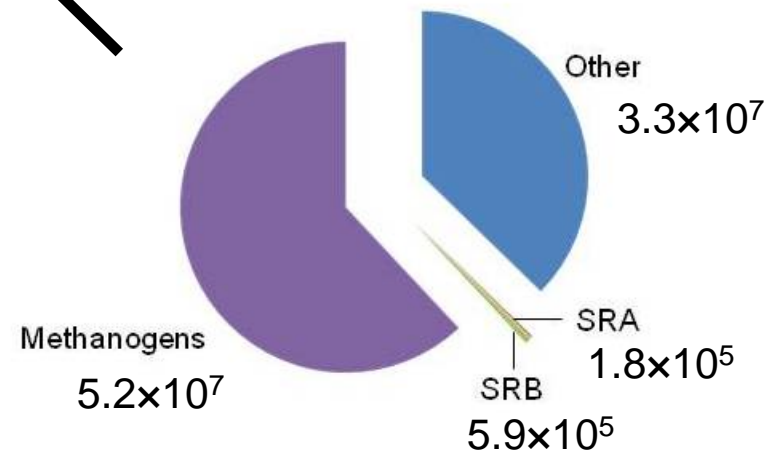
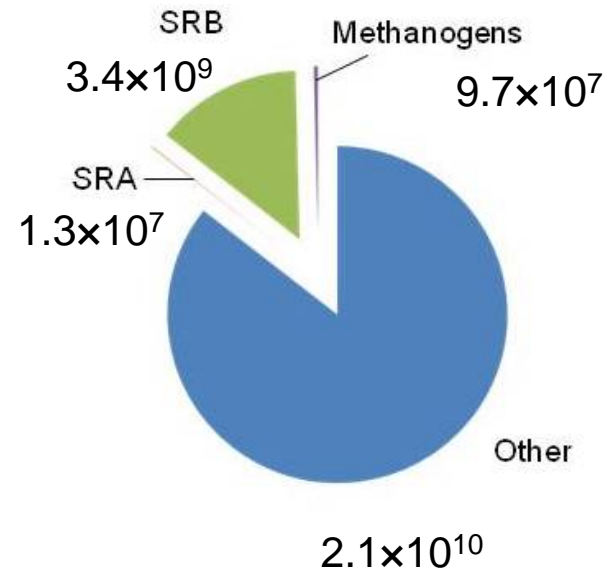
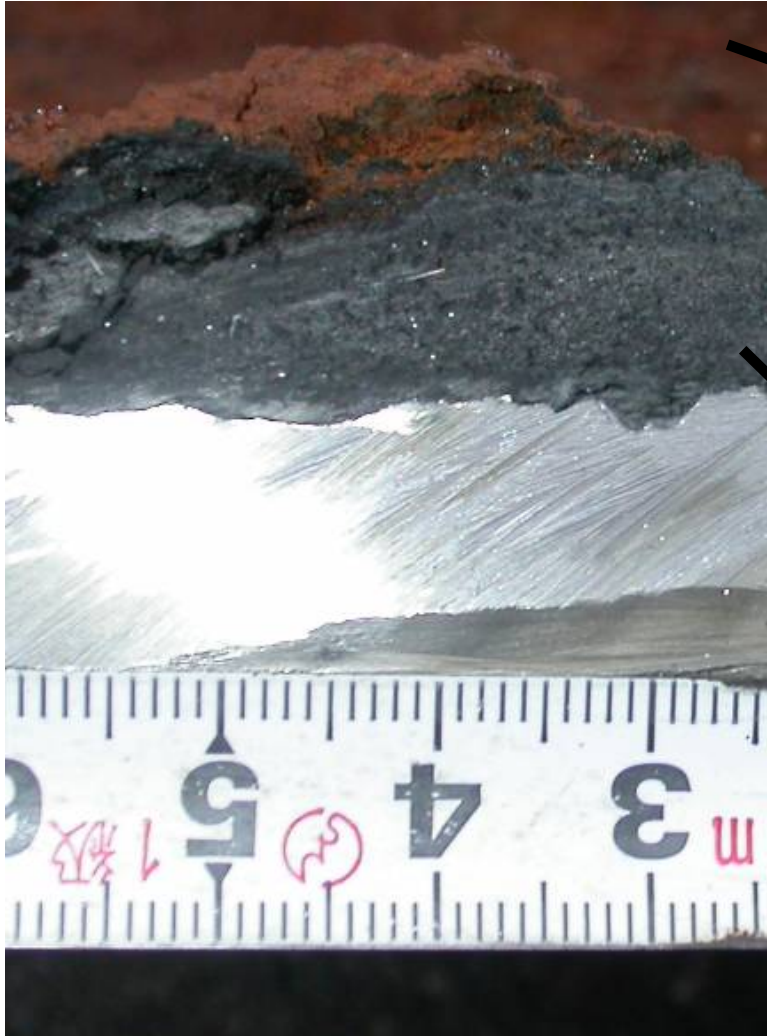
2008: locally very high corrosion rate of 2.6 mm/y. Wall thickness close to the minimum allowable wall thickness



Stratified microbial community



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Larsen et al 2009, NACE corrosion

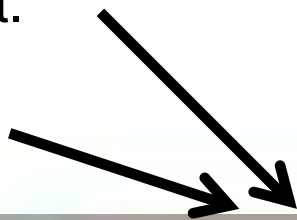
Hypothesis based on distribution



MIC driven by methanogenic
hydrogen consumption at the
metal surface

Org. Mat.

SO_4^{2-}



Methanosarcinales
Desulfovibrio

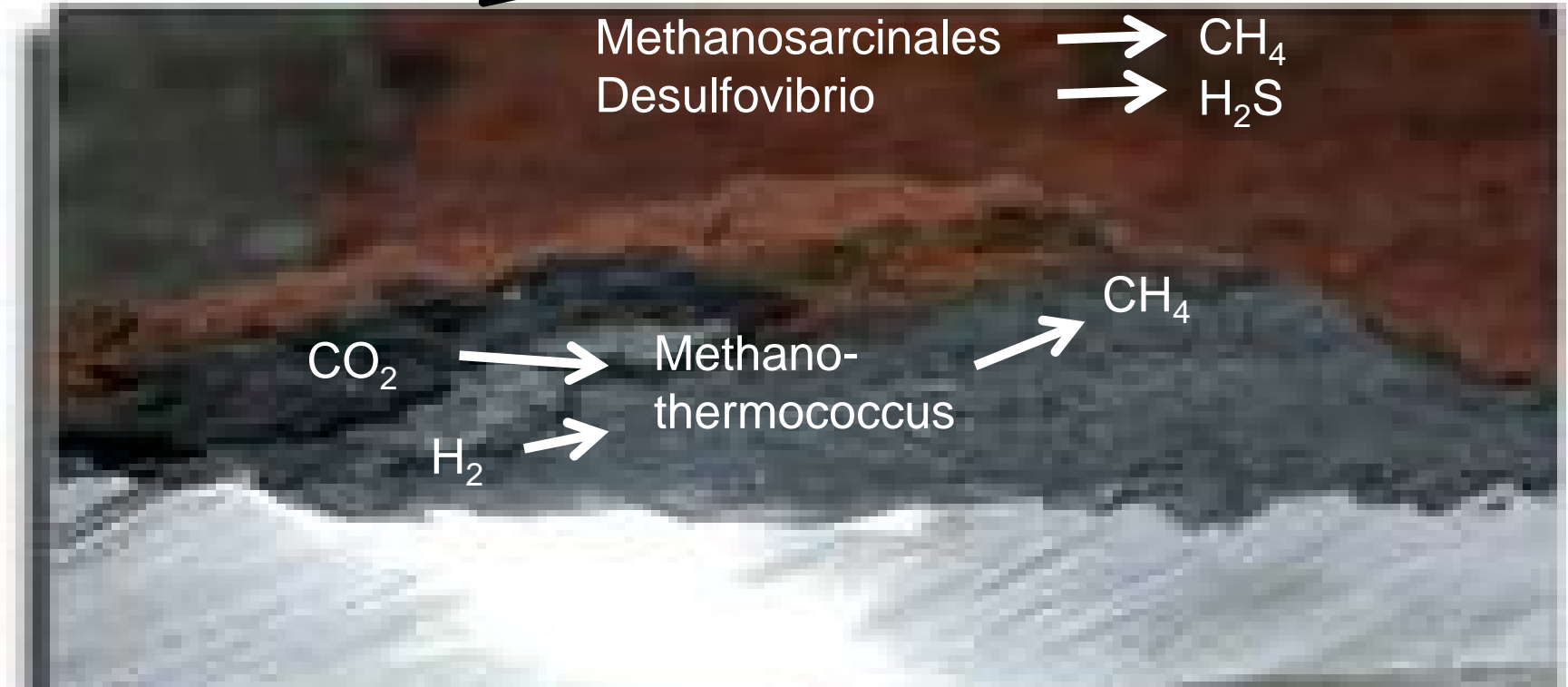
CH_4
 H_2S

CO_2

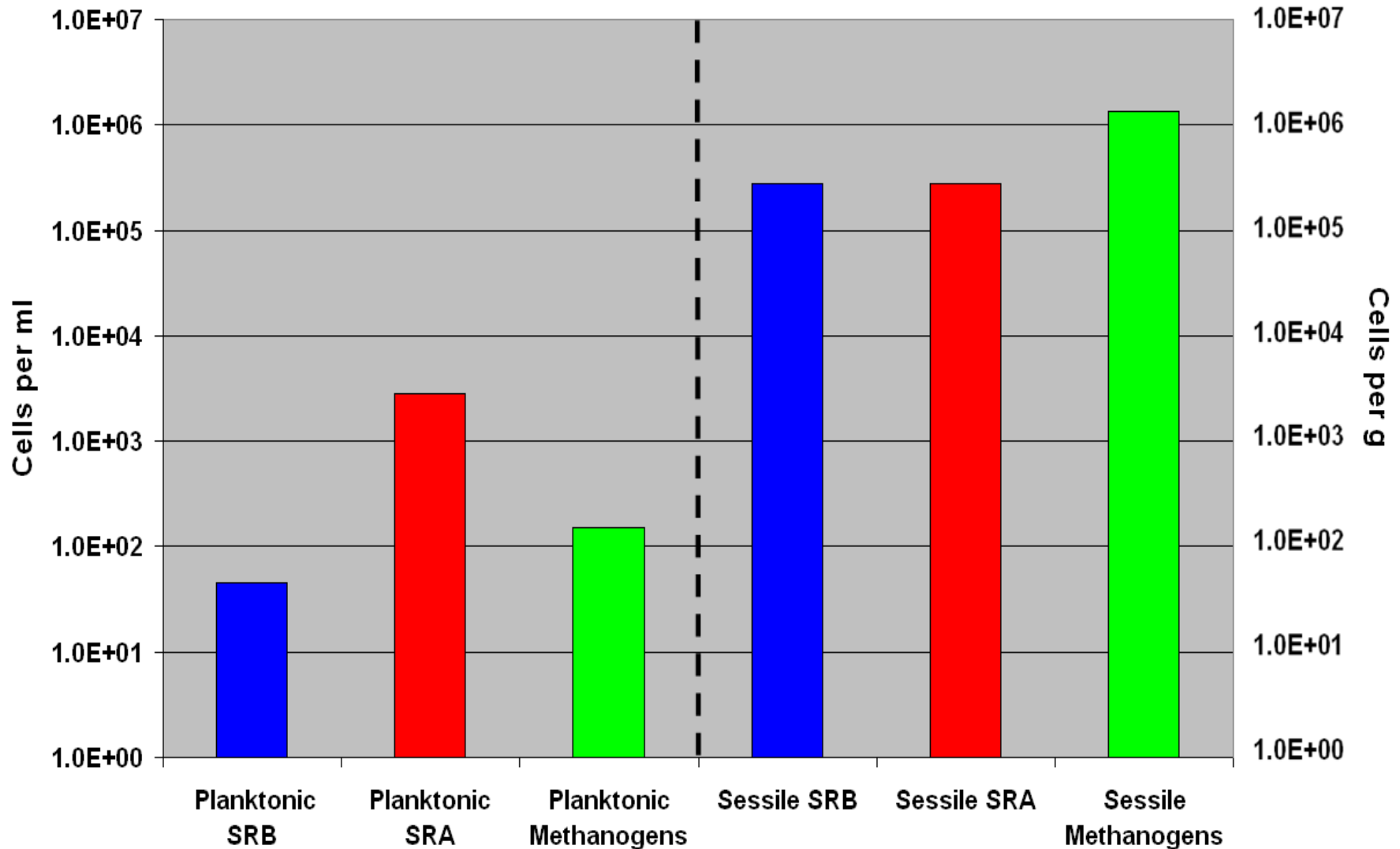
H_2

Methano-
thermococcus

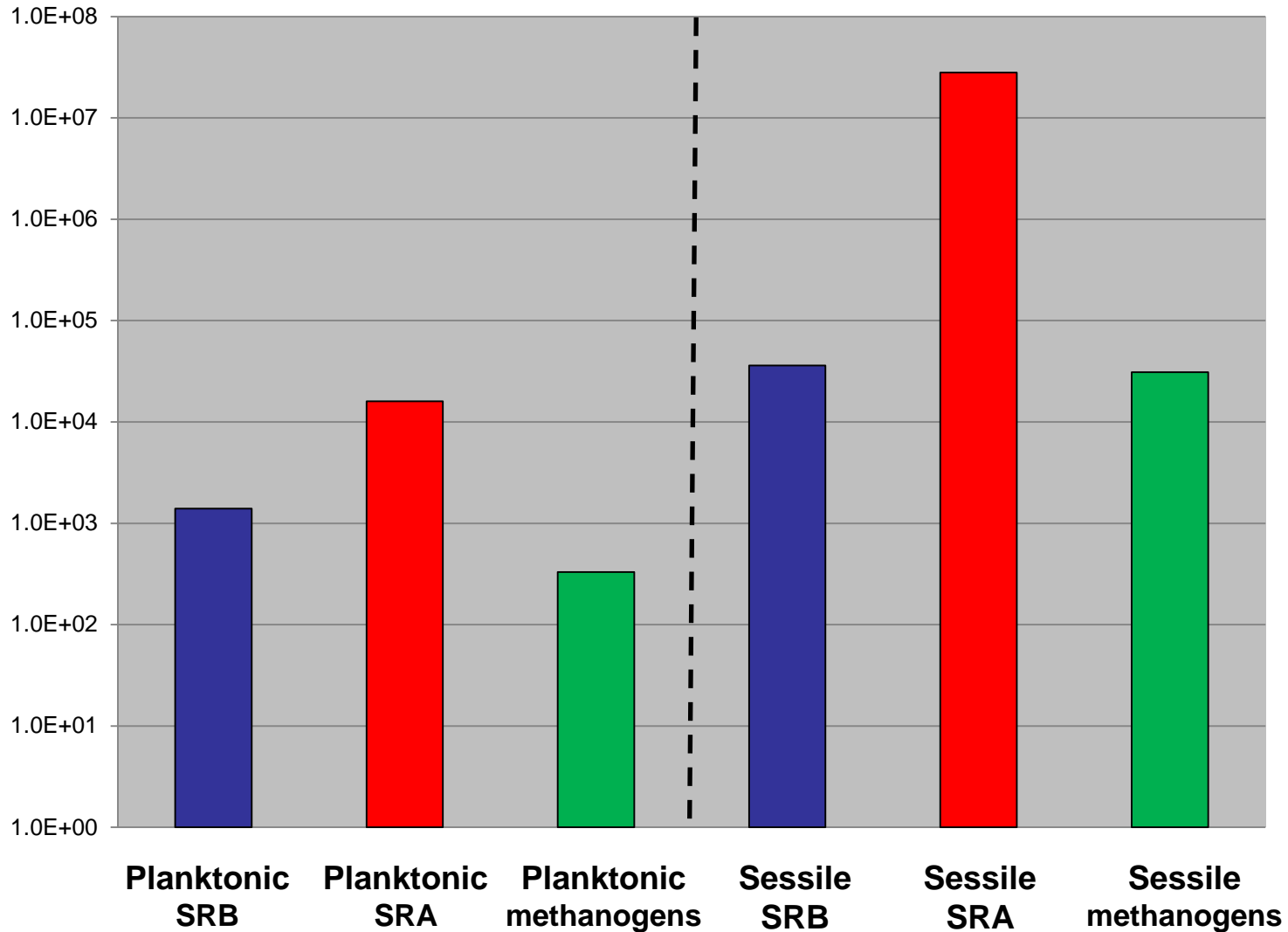
CH_4



Example 2, Microbial community in producing well X



Example 2, Microbial community in producing well Y

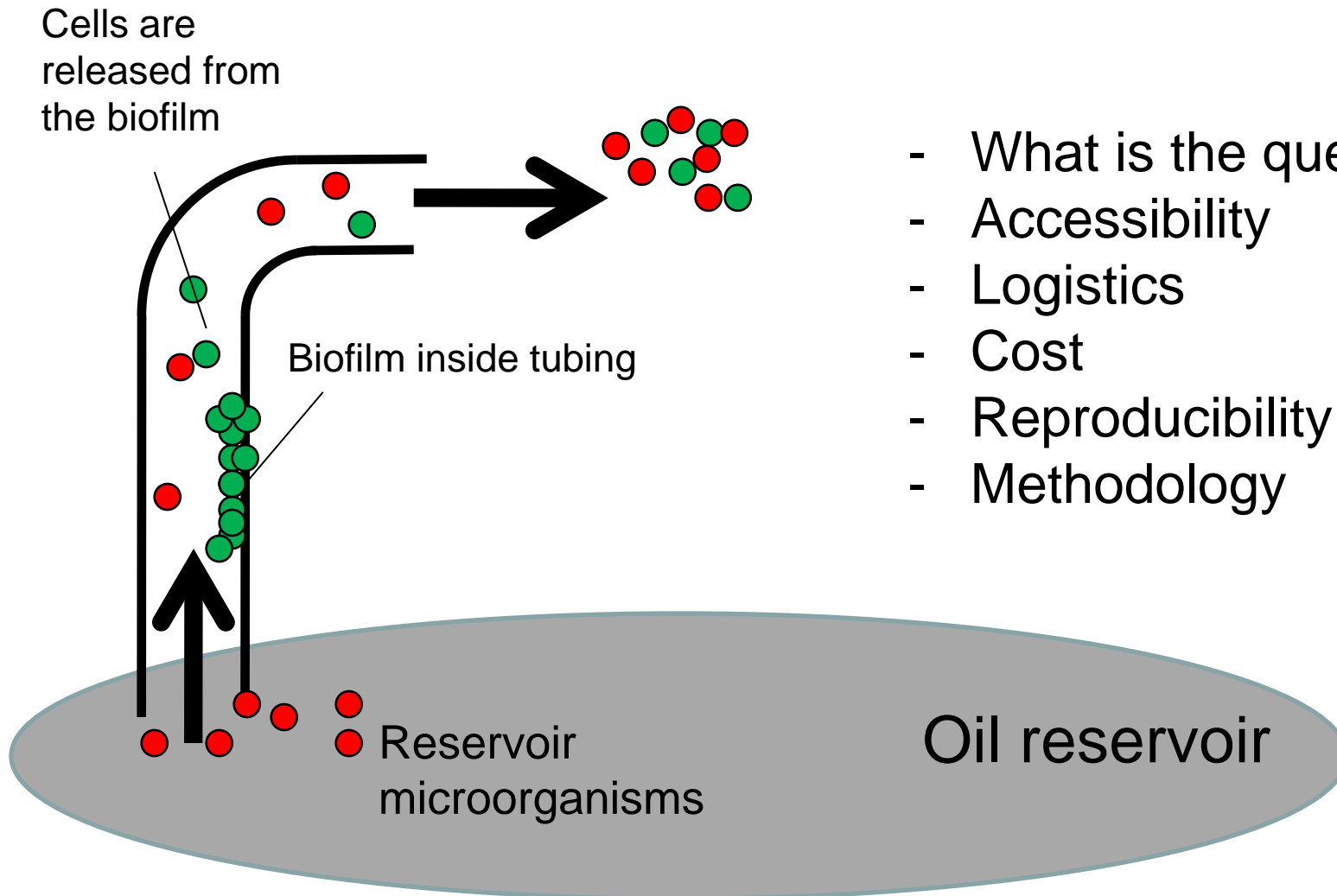




- Numbers of microorganisms in downhole solids much higher than in water
- Ratios between sessile and planktonic populations varies widely
- MIC assessment:

Intact solids > scrapings (e.g. pigging debris) > water

Water samples or solid samples?



- What is the question?
- Accessibility
- Logistics
- Cost
- Reproducibility
- Methodology



At least three groups of microorganisms (methanogens, SRB, SRA) are present in North Sea oil fields and may promote MIC

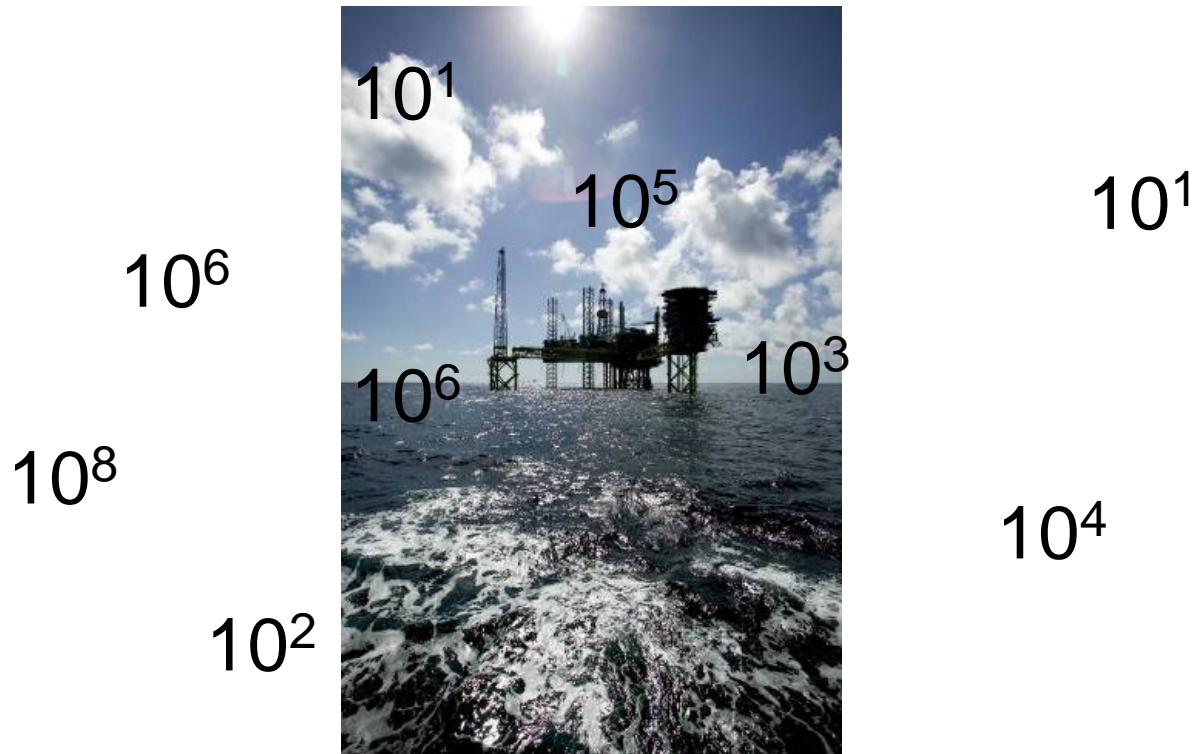
The different groups are distributed differently

MIC surveillance and failure analysis in North Sea oil fields must include all three groups



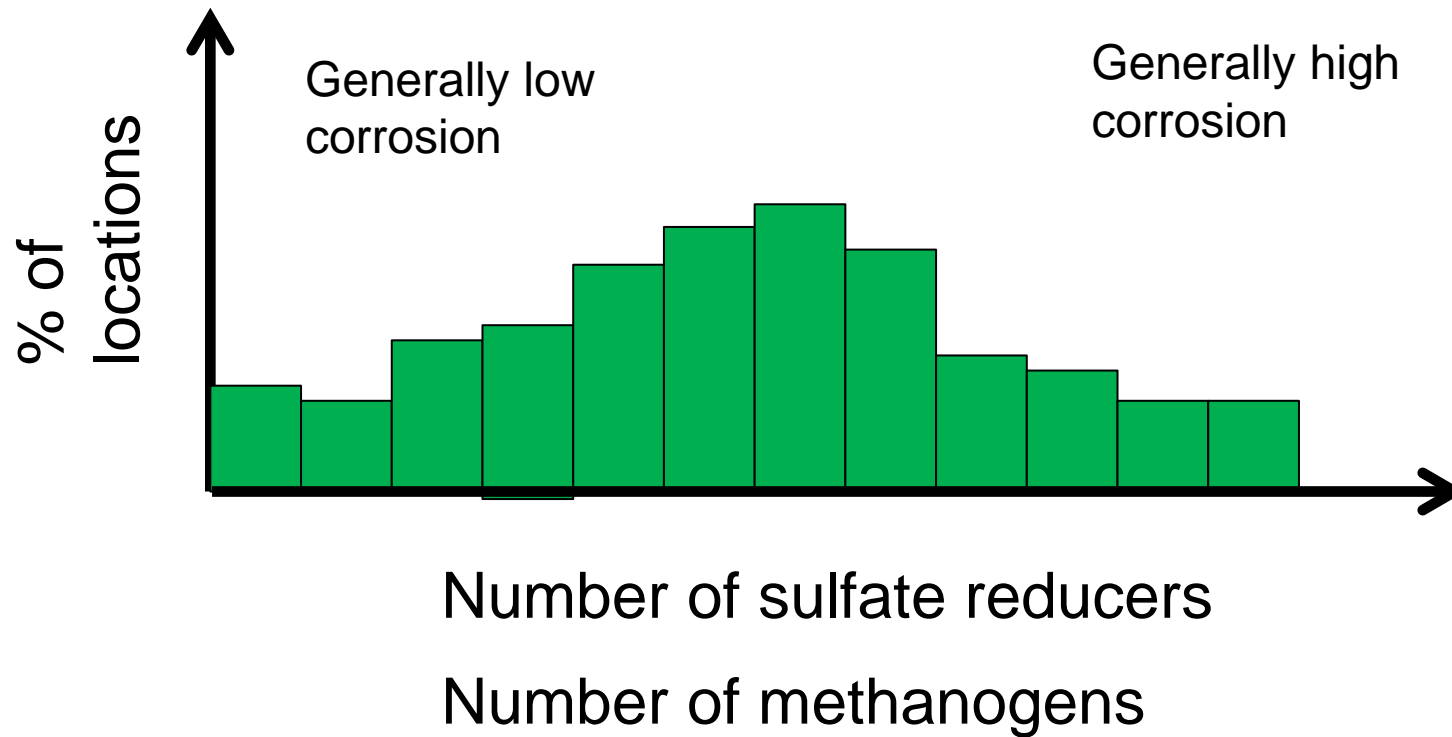


How to evaluate MIC risk?





Empirical approach





Conclusions

- In addition to SRB, several other microbial groups are involved in MIC in North Sea oil fields

- MIC risk assessment includes:
 - Numbers of microorganisms
 - System data (T, P, production history,...)
 - Empirical knowledge of distribution and levels of microorganisms in the system

- For MIC risk assessment:

Intact solids > scrapings (e.g. pigging debris) > water