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Marine Corrosion in Fuel Systems

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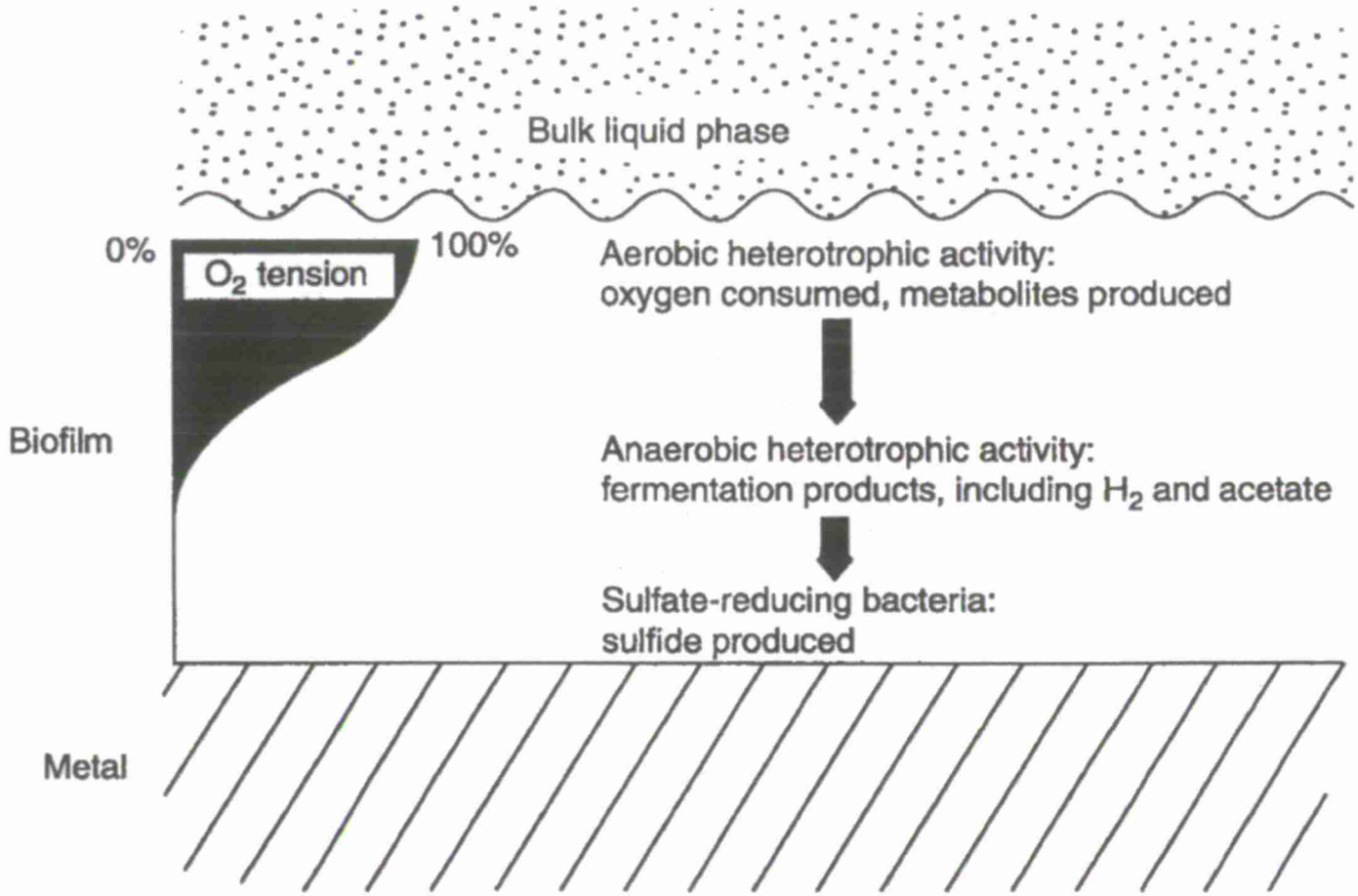
20121203011

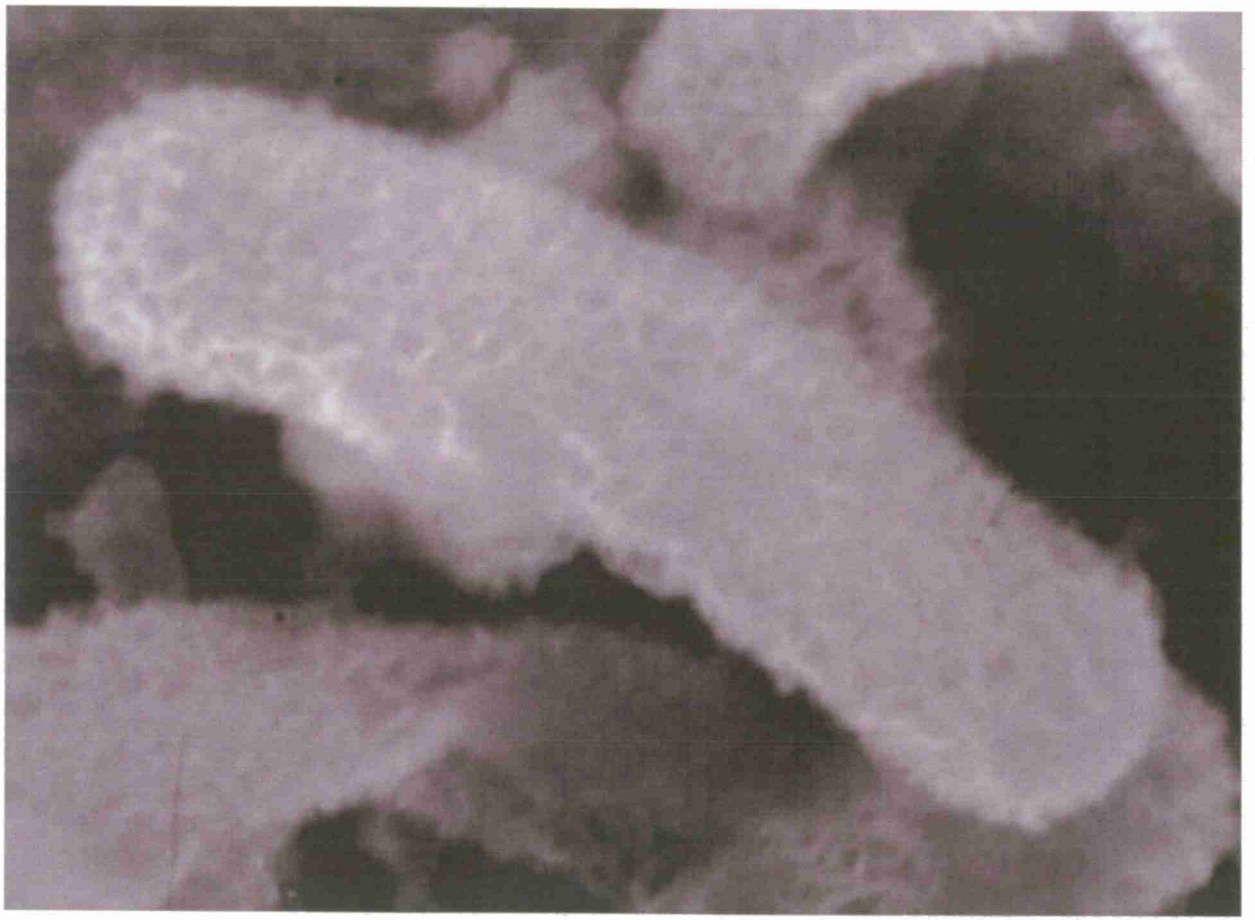
Sulfide Derivitization

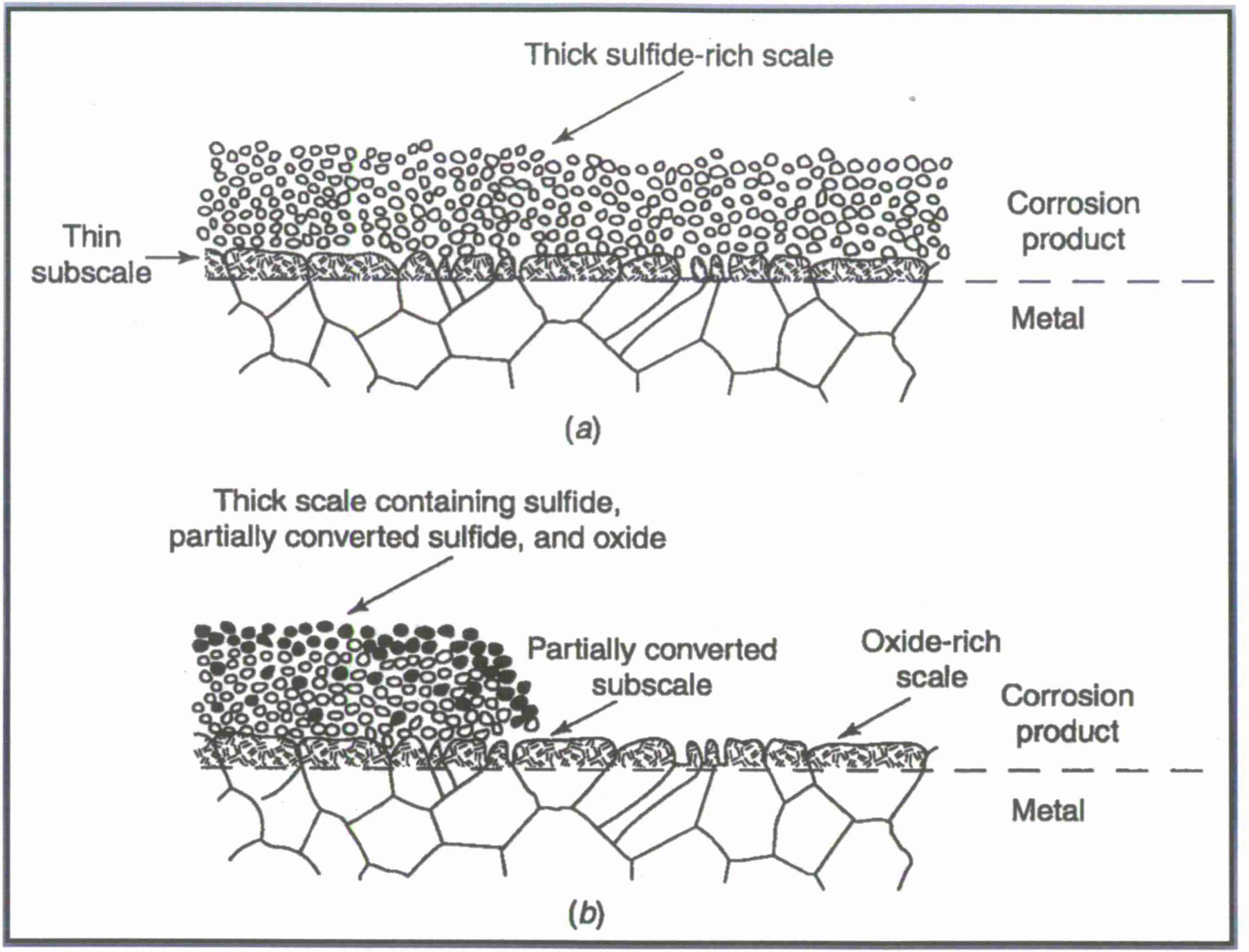
Seawater contains 2.0 grams L^{-1} sulfate



Hamilton (1985)

Sulfate-Reducing Bacteria

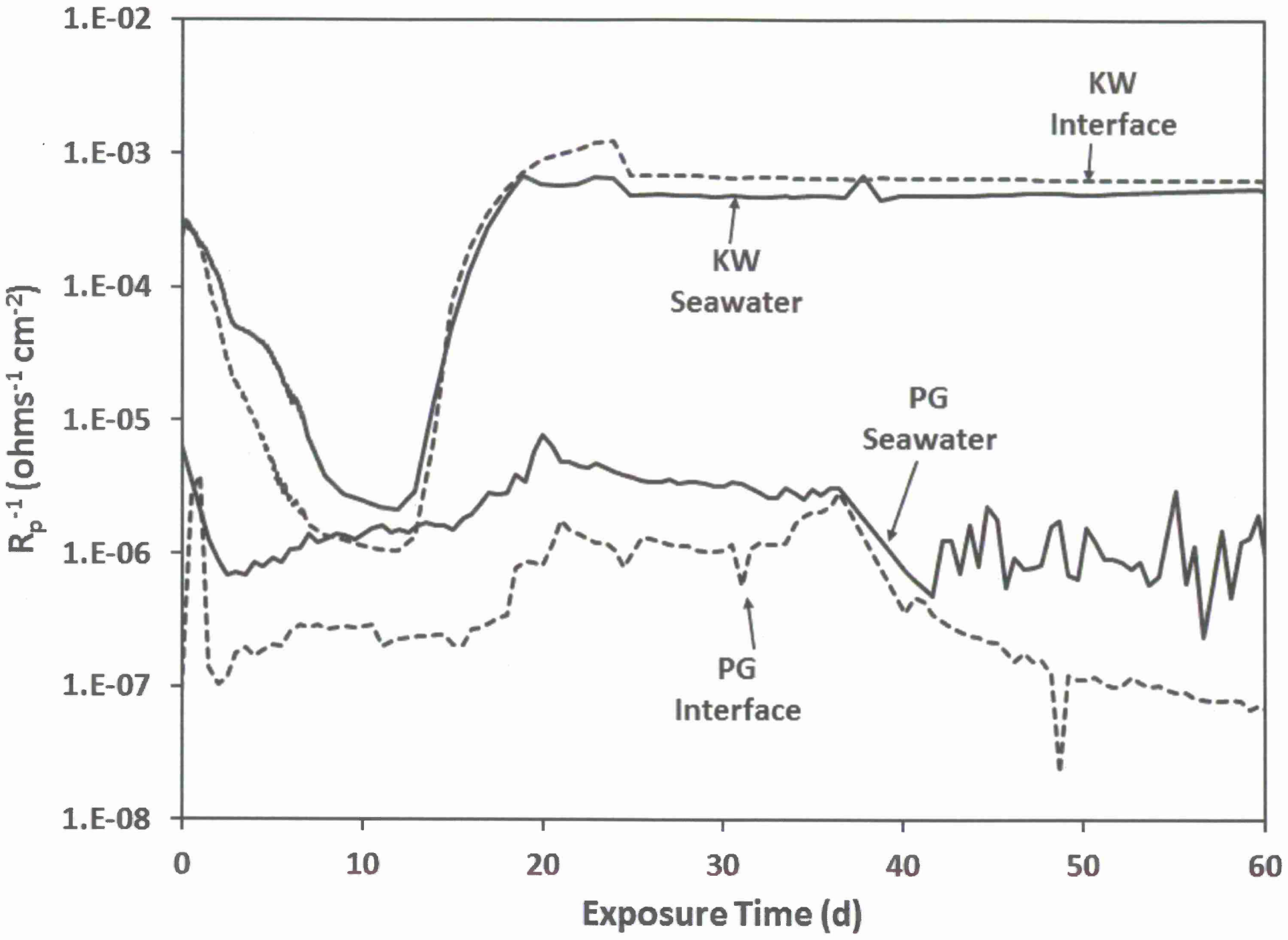



Thick sulfide-rich scale
Thin subscale
Corrosion product
Metal
(a)
Thick scale containing sulfide, partially converted sulfide, and oxide
Partially converted subscale
Oxide-rich scale
Corrosion product
Metal
(b)

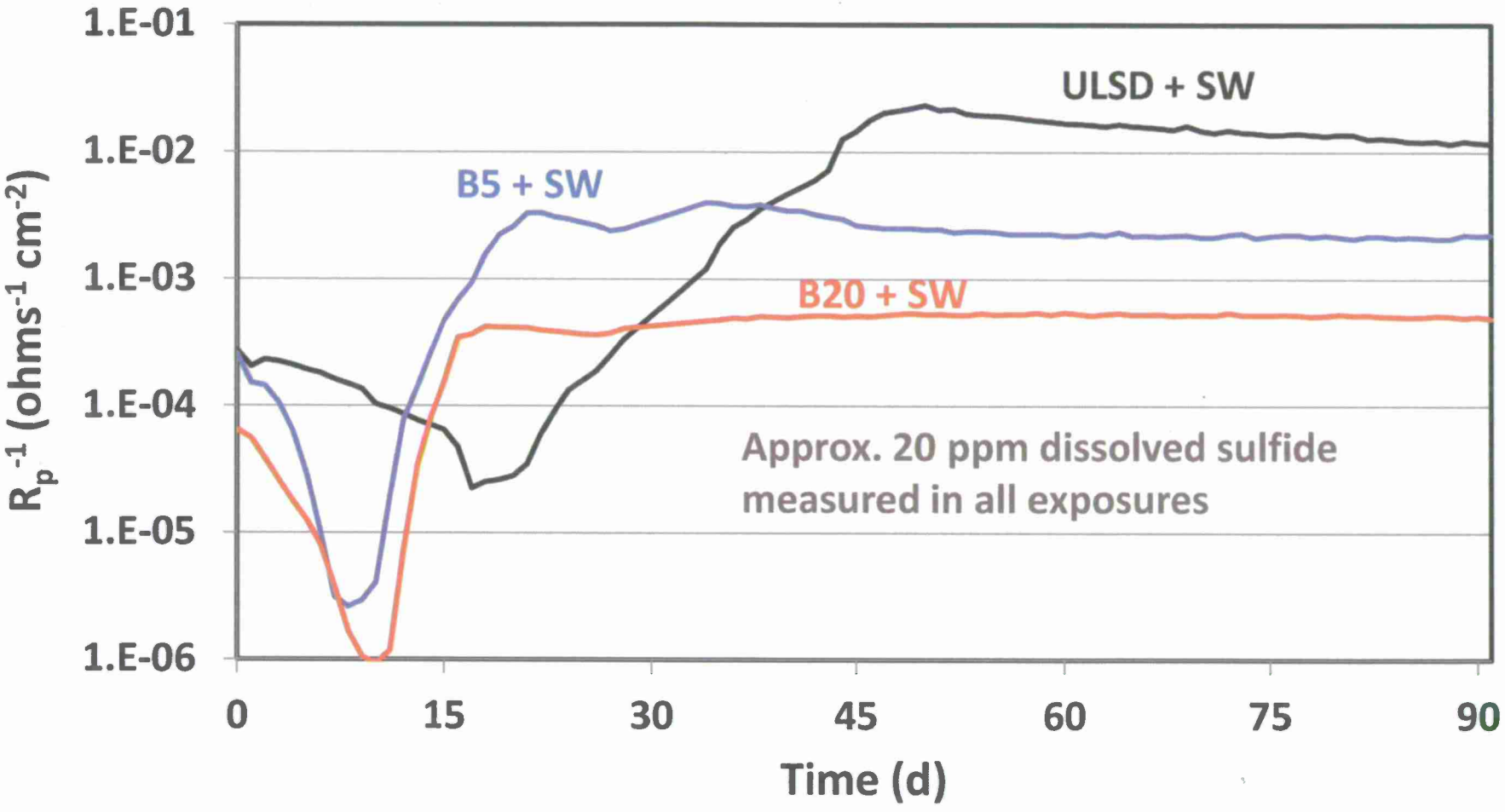
Syrett 1981

Initial Chemistries

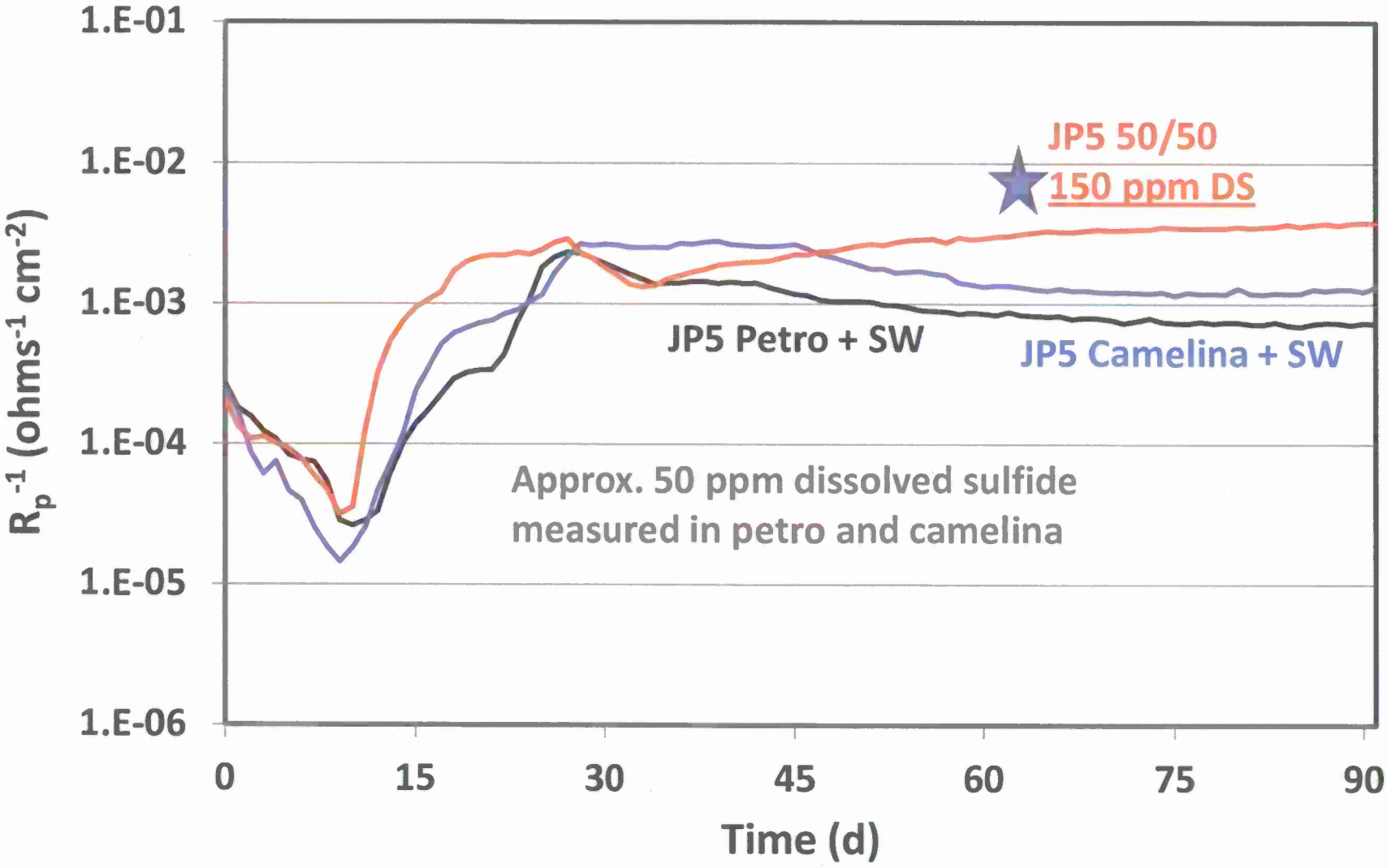
Seawaters	pH	Salinity (g/L)	Total Organic Carbon (mg/L)	Sulfate (mg/L)
Key West	7.82	38	1.79	3864
Persian Gulf	7.98	44	1.94	4696


1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1.E-08
R_p^{-1} (ohms^{-1} cm^{-2})
0
10
20
30
40
50
60
Exposure Time (d)
KW
Interface
KW
Seawater
PG
Seawater
PG
Interface

ULSD/FAME: Electrochemistry



JP5: Electrochemistry



Rates of sulphate reduction activity (SRA) in the seawater samples

Sample	SRA µmol S /L/day	SRA µmol S /L/day
	Persian Gulf Seawater PG	Key West Seawater KW
In situ (no additions)	11.96 ± 1.33	17.7 ± 3.3
Amended with lactate	23.5 ± 1.7	115
Amended with crude oil*	10.3 ± 2.3	13.95 ± 0.75
Amended with crude oil and inoculated with strain Lake**	155 ± 6.7	264 ± 40
Sterile Control	7.95 ± 1.7	7.5 ± 3.5

* sterile crude oil

***Desulfoglaeba* strain Lake, an alkane-degrading sulphate-reducing bacterium

Table 2. Estimates of the number of different cell types based on quantitative PCR analyses

Estimates from qPCR	KW*	PG	KWBD	PGBD
Bacterial cells/mL	2.75×10^7	2.66×10^7	4.97×10^5	1.72×10^5
Dsr-bearing cells/mL**	3.17	BDL	BDL	BDL
Aps-bearing cells/mL***	BDL	BDL	BDL	BDL
Archaeal cells/mL	3.05×10^3	2.19×10^3	BDL	BDL
Mcr-bearing cells/mL****	2.48×10^3	25	121	47.4

*KW: Key West seawater; PG: Persian Gulf seawater; KWBD: FAME diesel incubated with KW seawater; PGBD: FAME diesel incubated with PG seawater.

** Dsr-bearing cells: cells that contain a copy of the gene coding for dissimulatory (bi)sulphite reductase, e.g. SRB.

*** Aps-bearing cells: cells that contain a copy of the gene coding for adenosine-5'-phosphosulphate reductase, e.g. SRB.

**** Mcr-bearing cells: cells that contain a copy of the gene coding for subunit *a* of methyl-S-CoM methylreductase, e.g. methanogens.

Table 3. Number of sequences classified as those of genera containing strains capable of degrading hydrocarbons

Genus	KW	PG	KWBD	PGBD
Kordiimonas (α)*	14	0	9	0
Gaetbulibacter (Bact)**	4	1	0	0
Marinobacter (γ)***	0	1	1410	1918
Alcanivorax (γ)	4	9	0	0
Cycloclasticus (γ)	18	0	0	0
Alteromonas (γ)	4	10	2	5
Pseudomonas (γ)	1	1	0	0
Shewanella (γ)	0	2	0	0

* α: Alphaproteobacteria

** Bact: Bacteroidetes

*** γ: Gammaproteobacteria

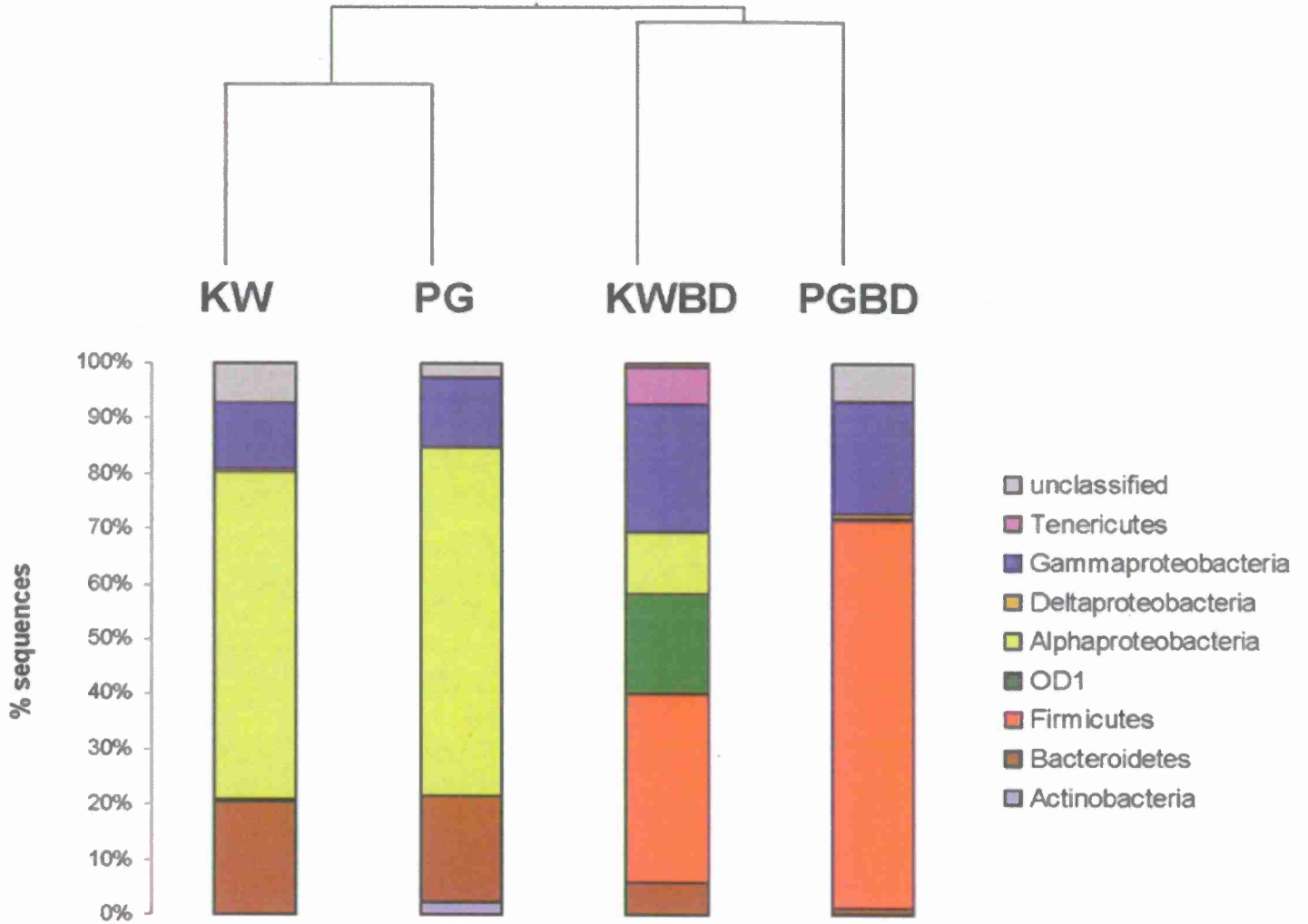
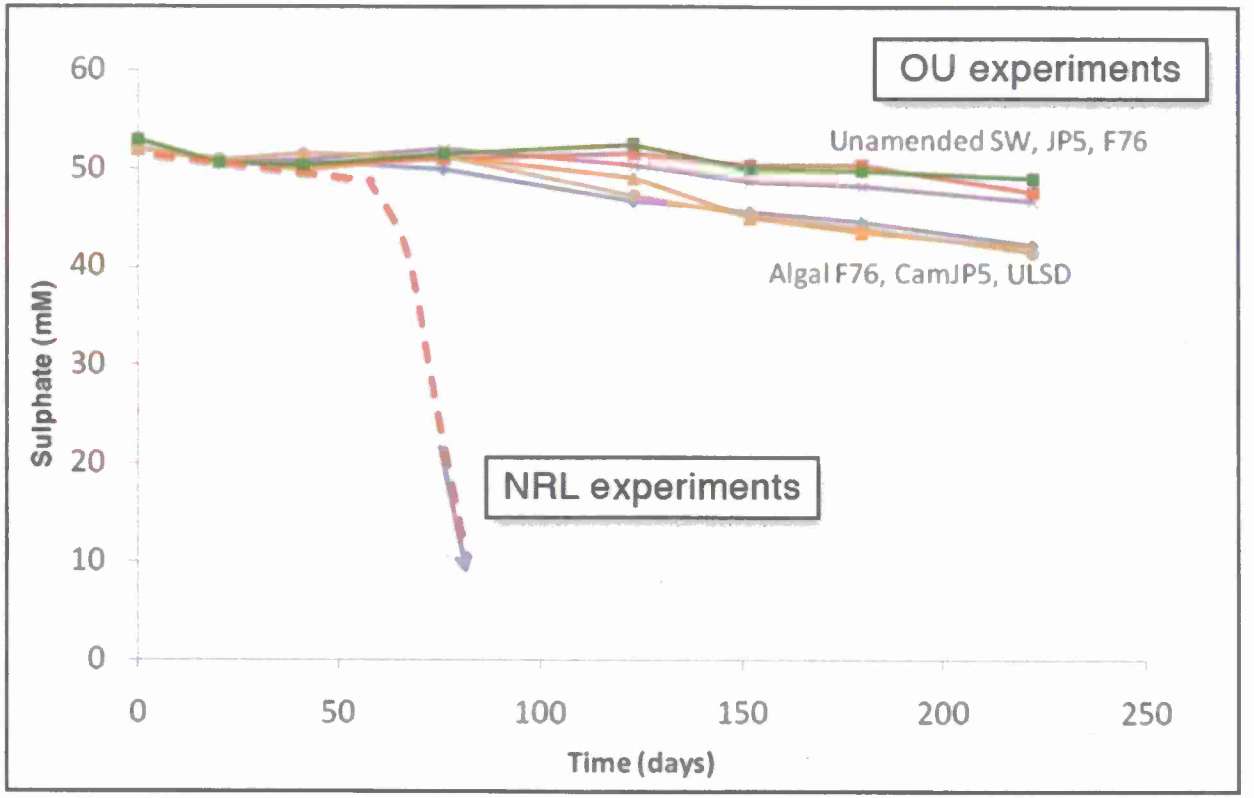


Figure 1. Analysis of bacterial 16S rRNA gene libraries created by pyrosequencing. Top. Dendrogram showing similarity among natural seawater samples (KW, PG) and FAME diesel/seawater incubations (KWBD, PGBD) based on a measurement of community structure (θ_{YC}) (Yue and Clayton 2005). Bottom: Relative abundances of sequences at the level of Phylum (Proteobacteria represented as Classes). Analyses were performed using the mothur software package (Schloss et al. 2009).

Sulfate removal during anaerobic biodegradation of fuels



SW: seawater
JP5: jet petroleum
F76: petroleum diesel

algal F76: Algal derived diesel
Cam/JP5: camelina-derived jet fuel

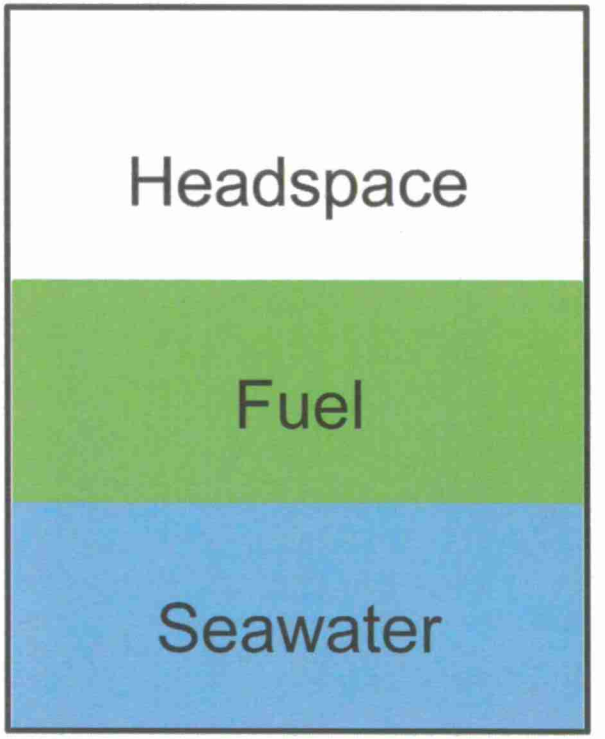
Initial Oxygen Conditions

NRL

OU

N_2 10%H_2 0.1%CO_2 Atmosphere

N_2/CO_2 8:2 Bubbled



Air

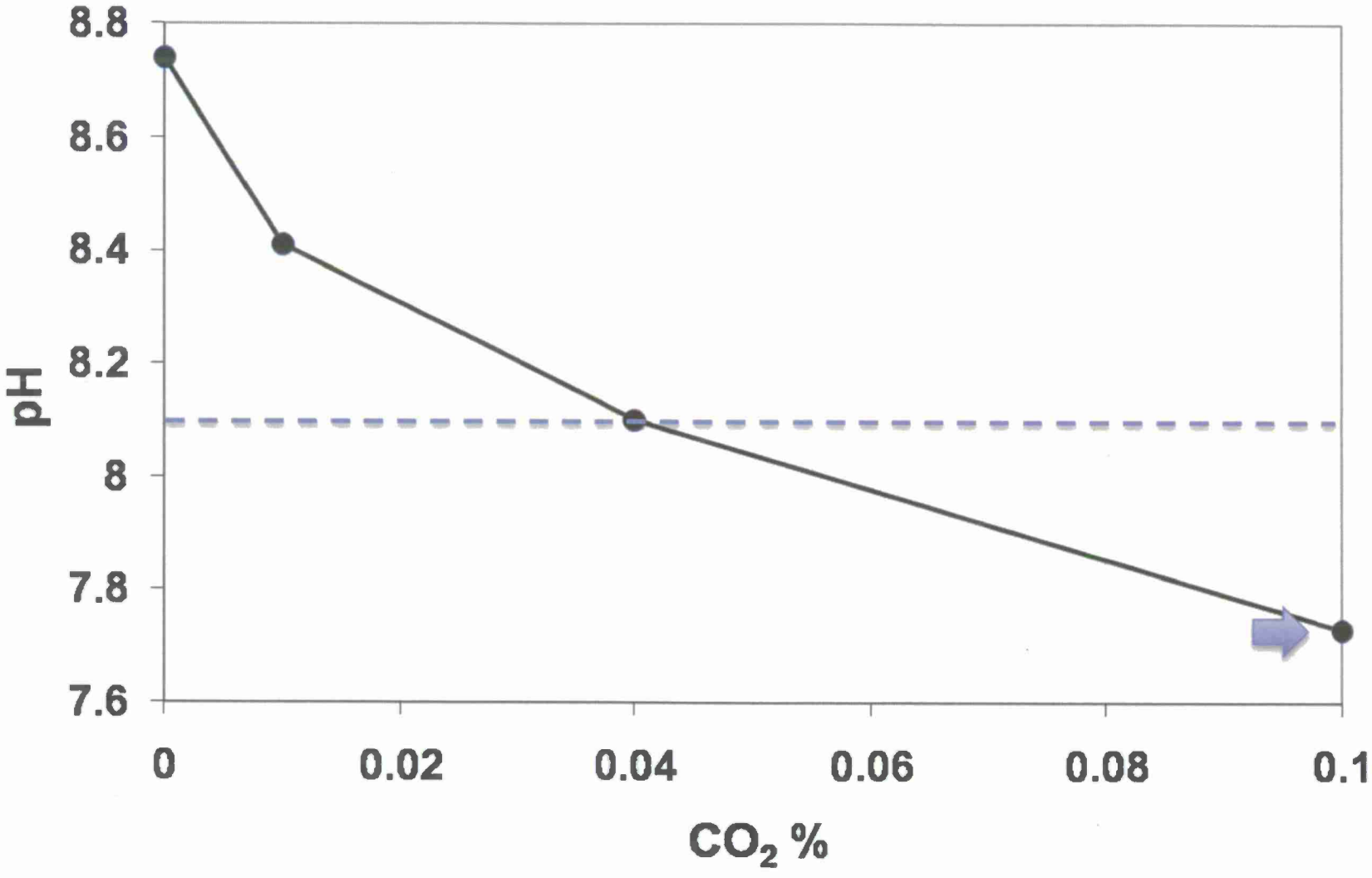
$+O_2$

$+O_2$

No O_2

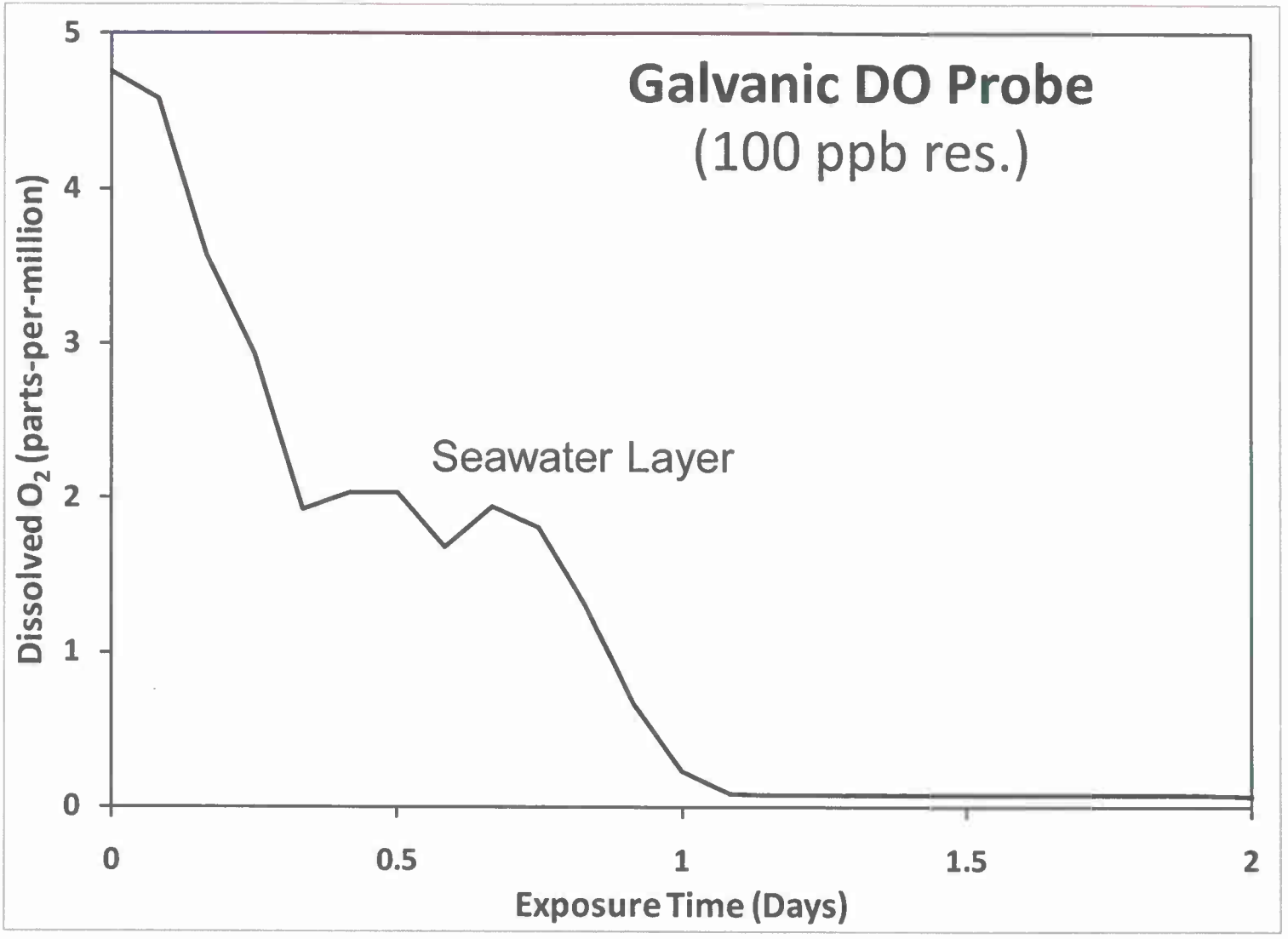
No O_2

No O_2



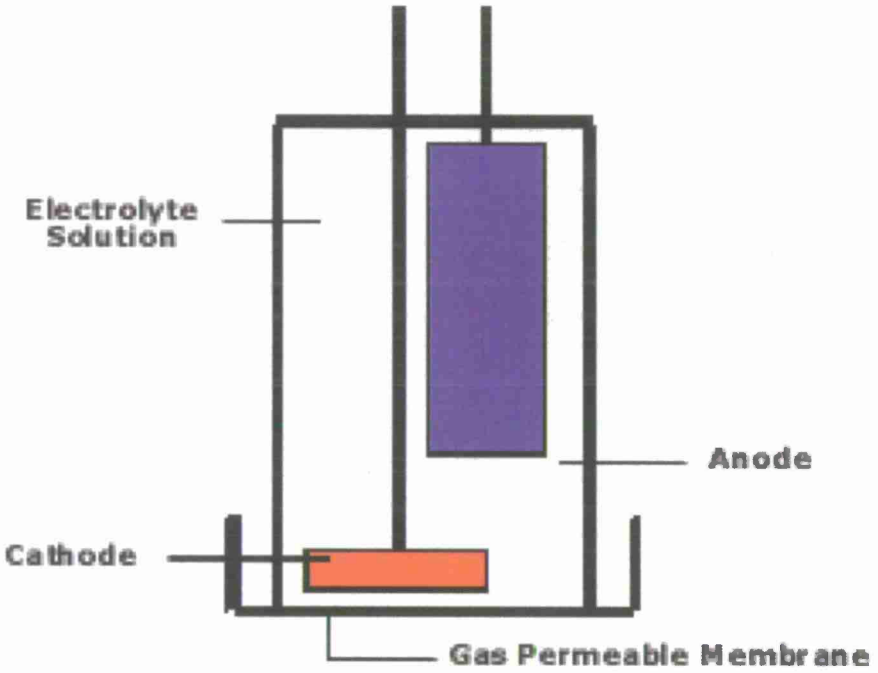
Key West seawater pH as a function of CO2 % in bubbled mixed gas containing 10% H_2 and balance N_2.

Oxygen Concentration

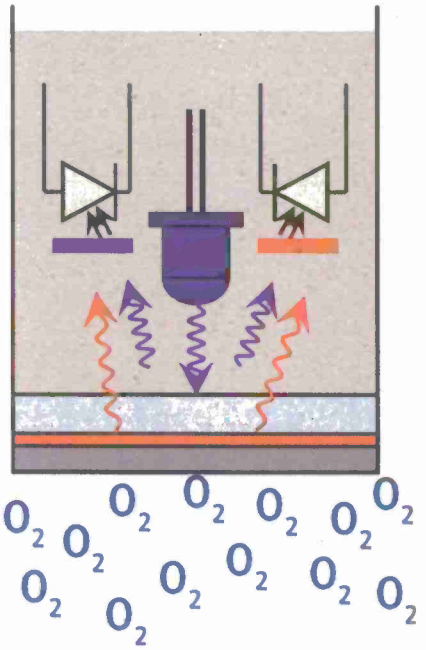


Oxygen Probes

Galvanic
(100 ppb res.)



Optical
(4 ppb res.)



Sensor shaft

Two identical light detectors

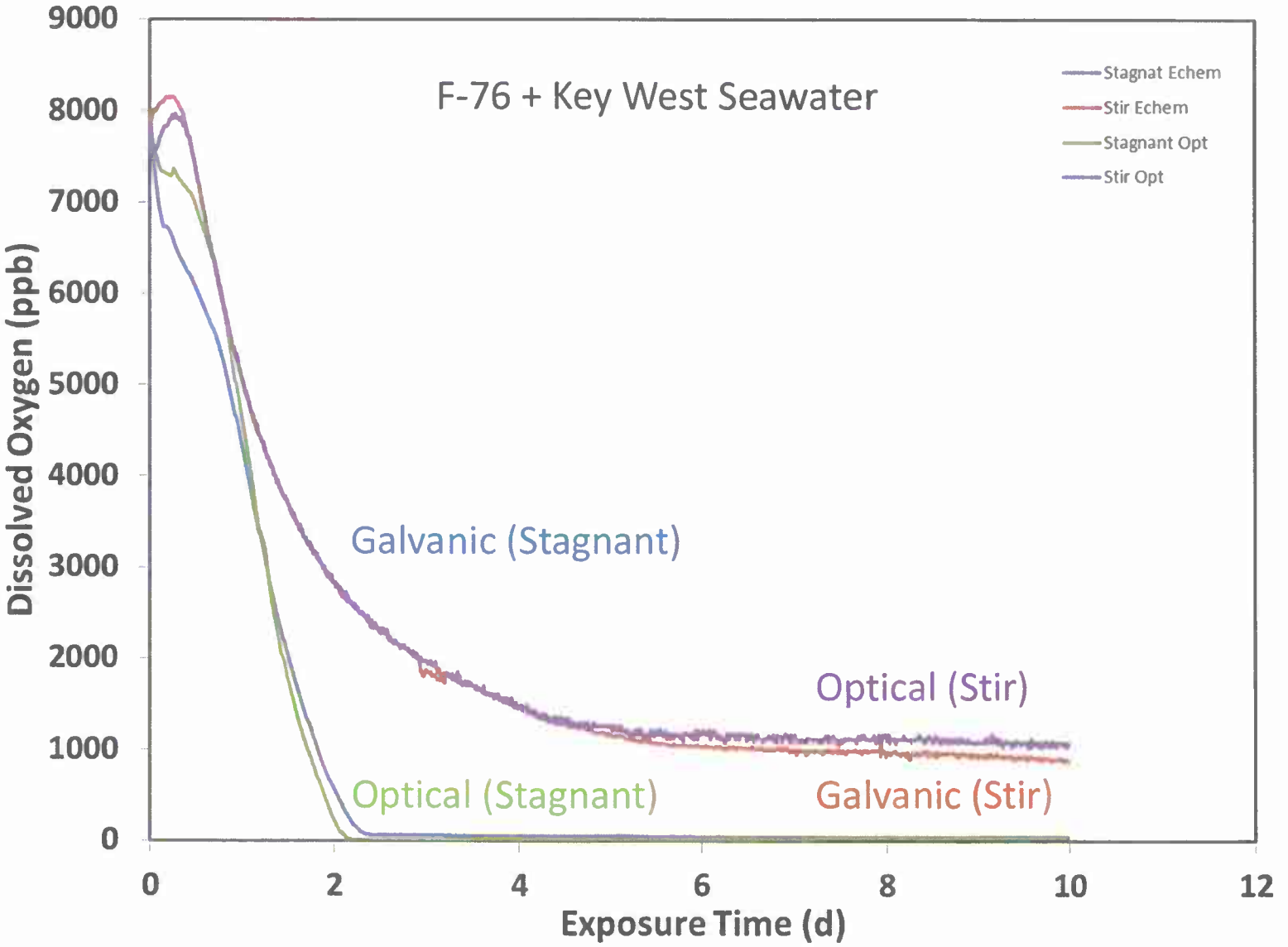
Color filters

Blue LED

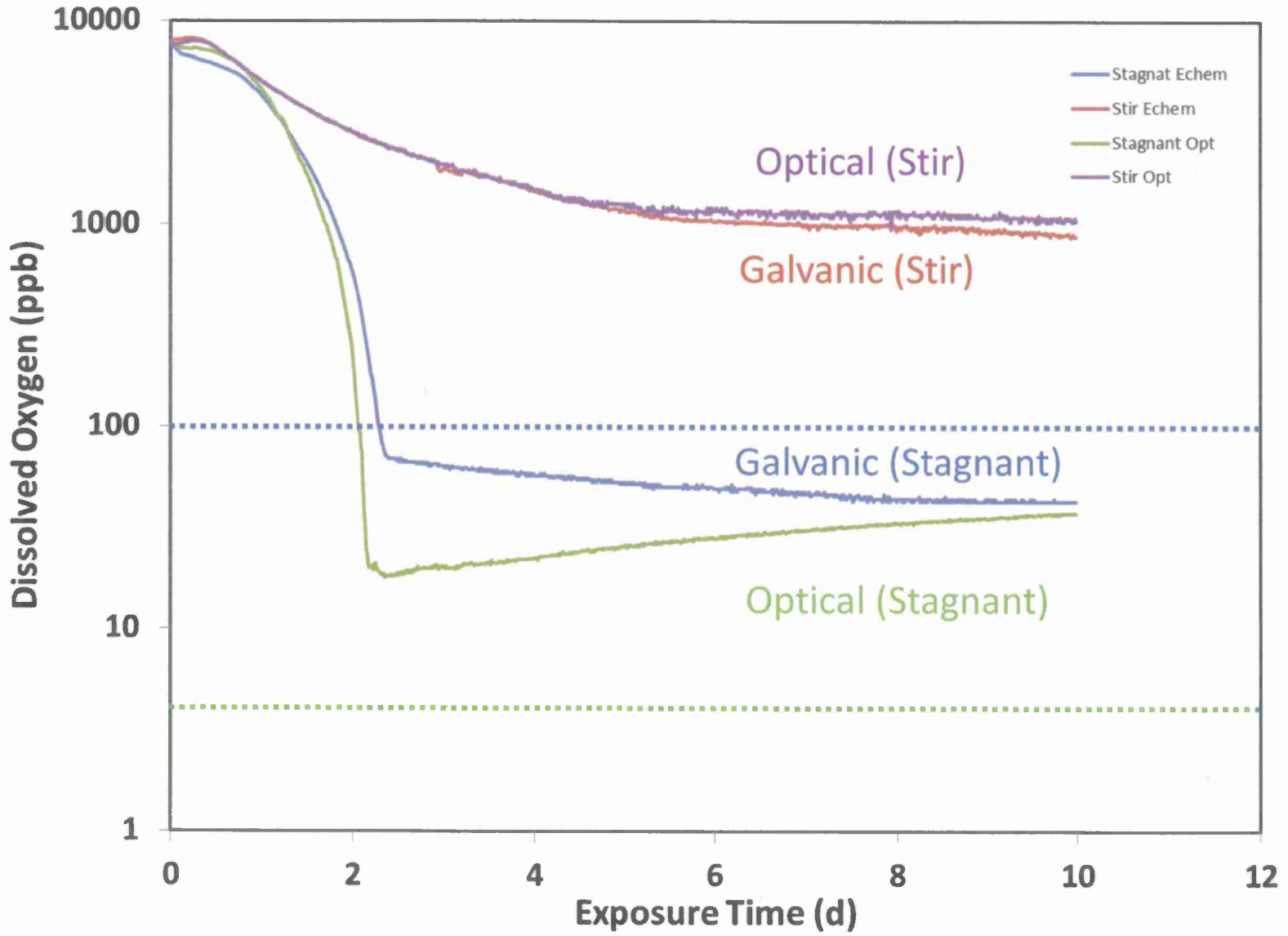
Robust carrier
Luminophore
FDA silicone

Process media with dissolved oxygen O_2

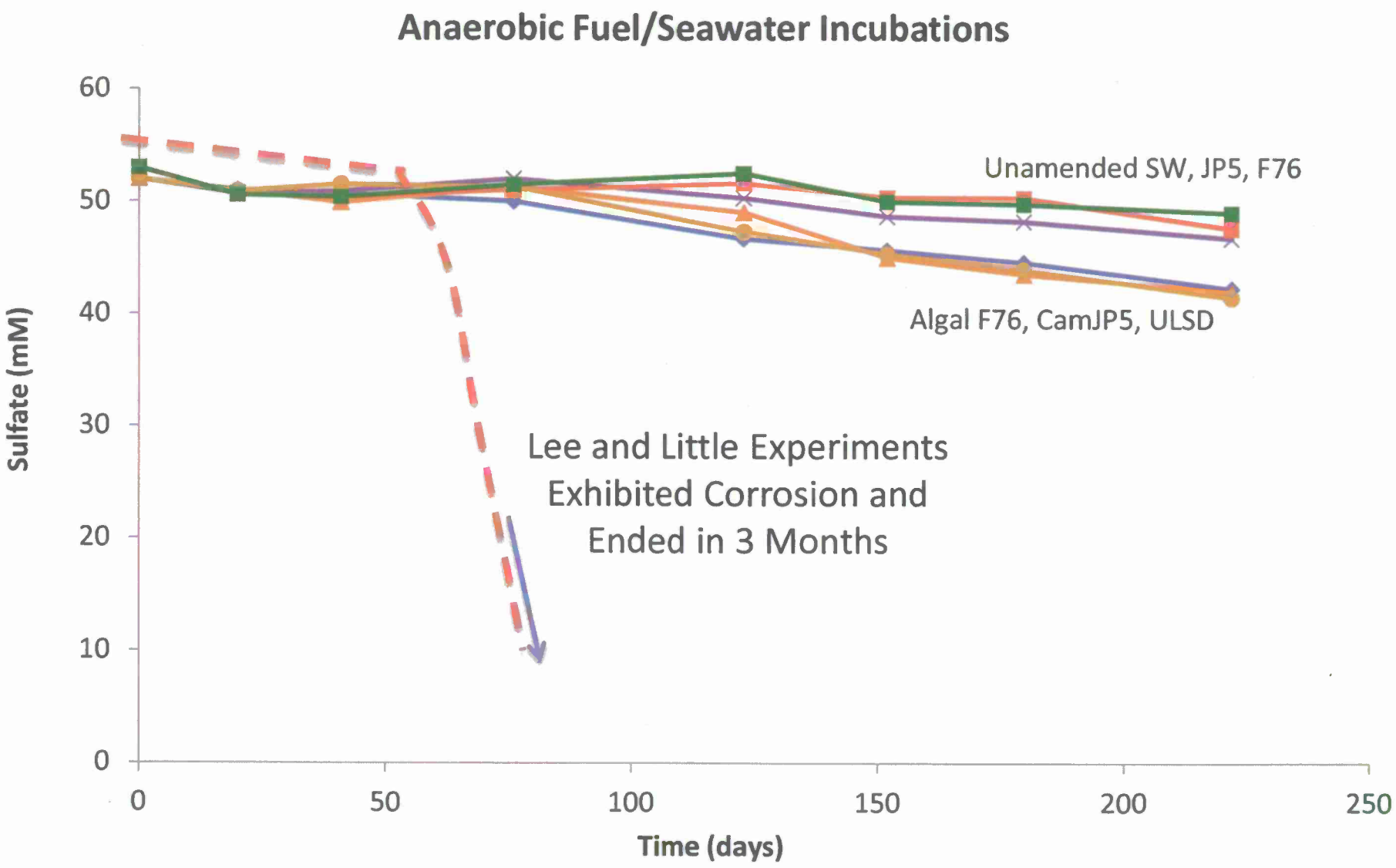
Dissolved Oxygen Measurements



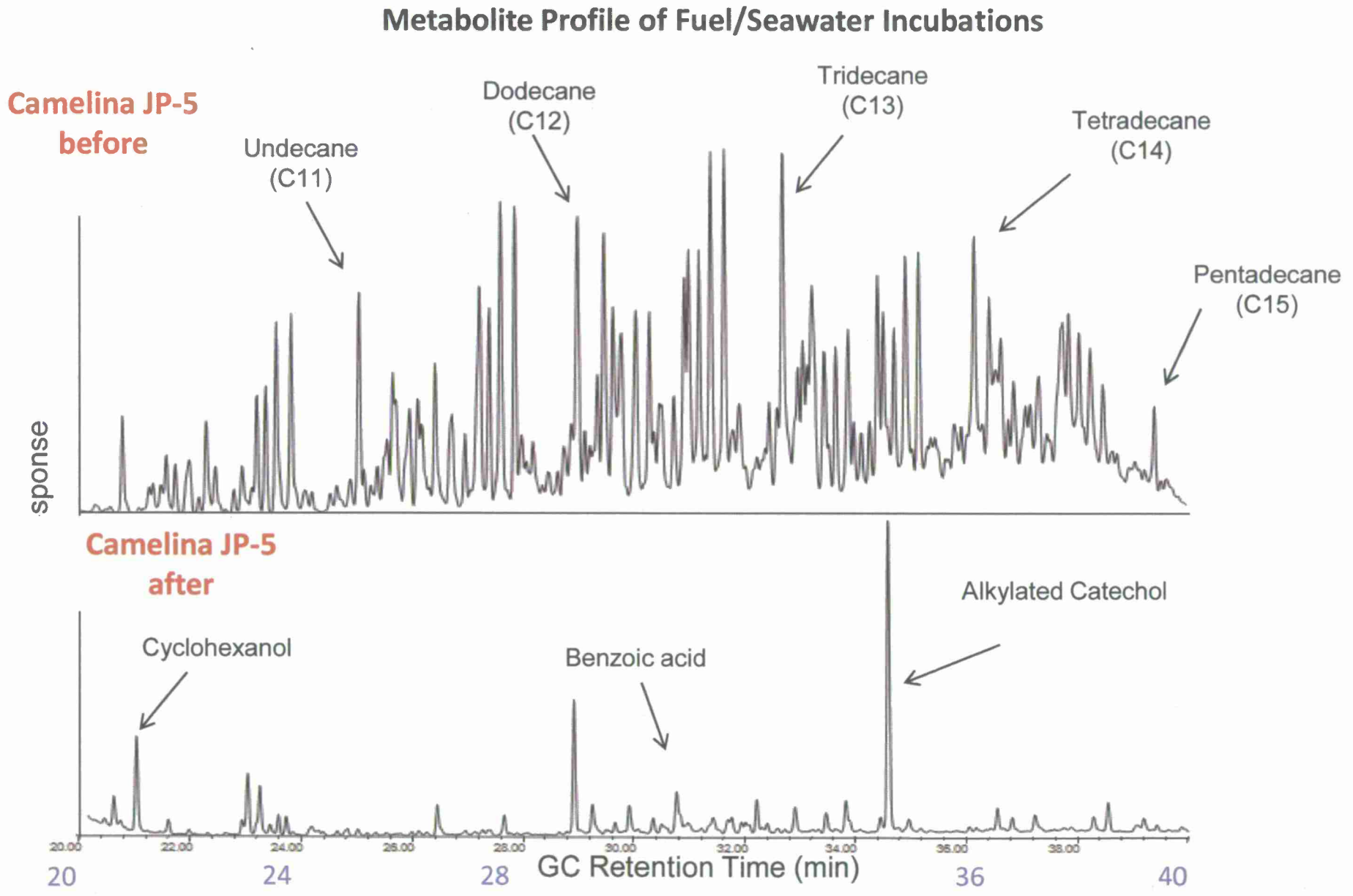
Dissolved Oxygen Measurements



Biocorrosion - ULSD and biofuel blends

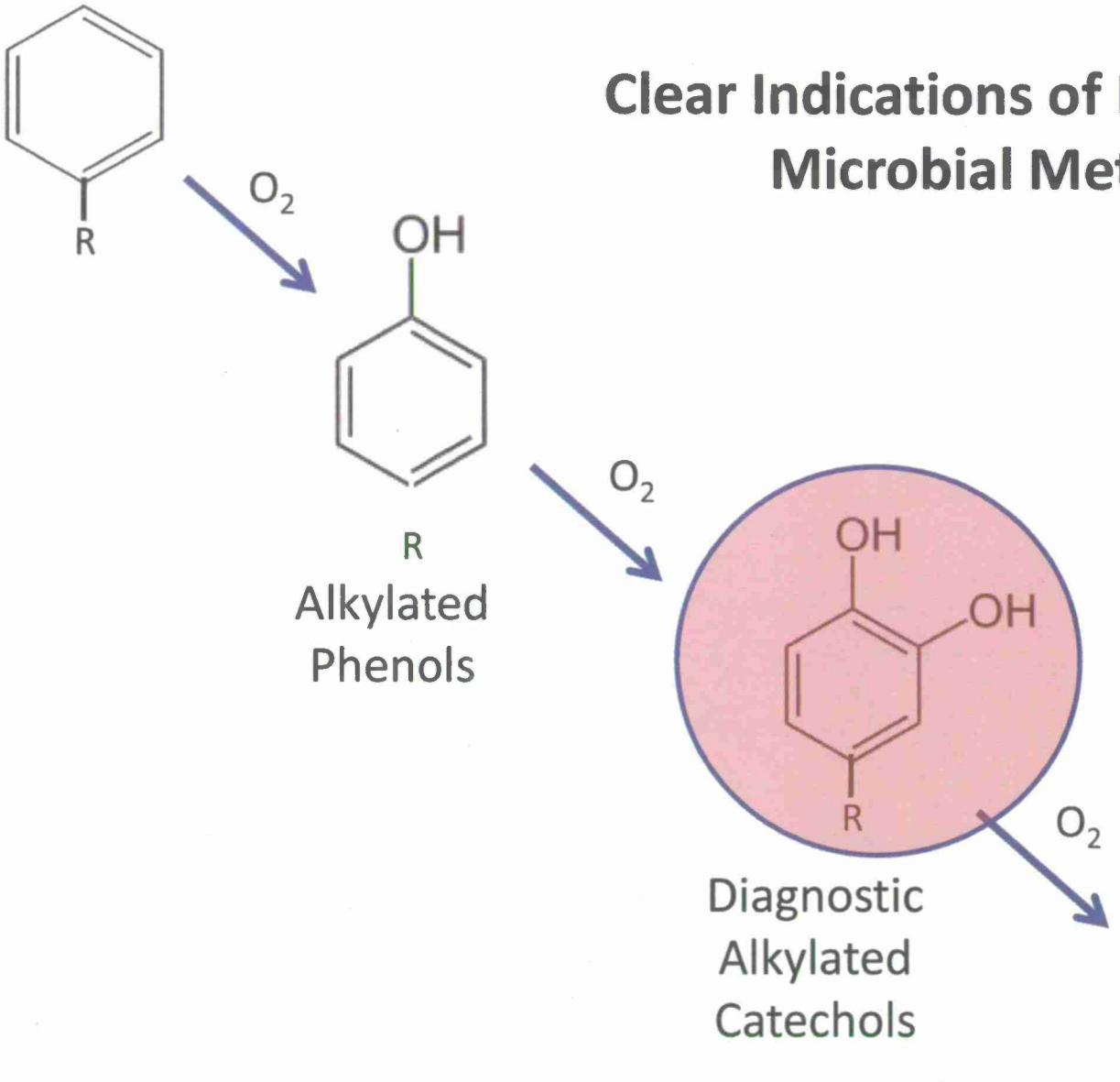


Biocorrosion - ULSD and biofuel blends



Biocorrosion - ULSD and biofuel blends

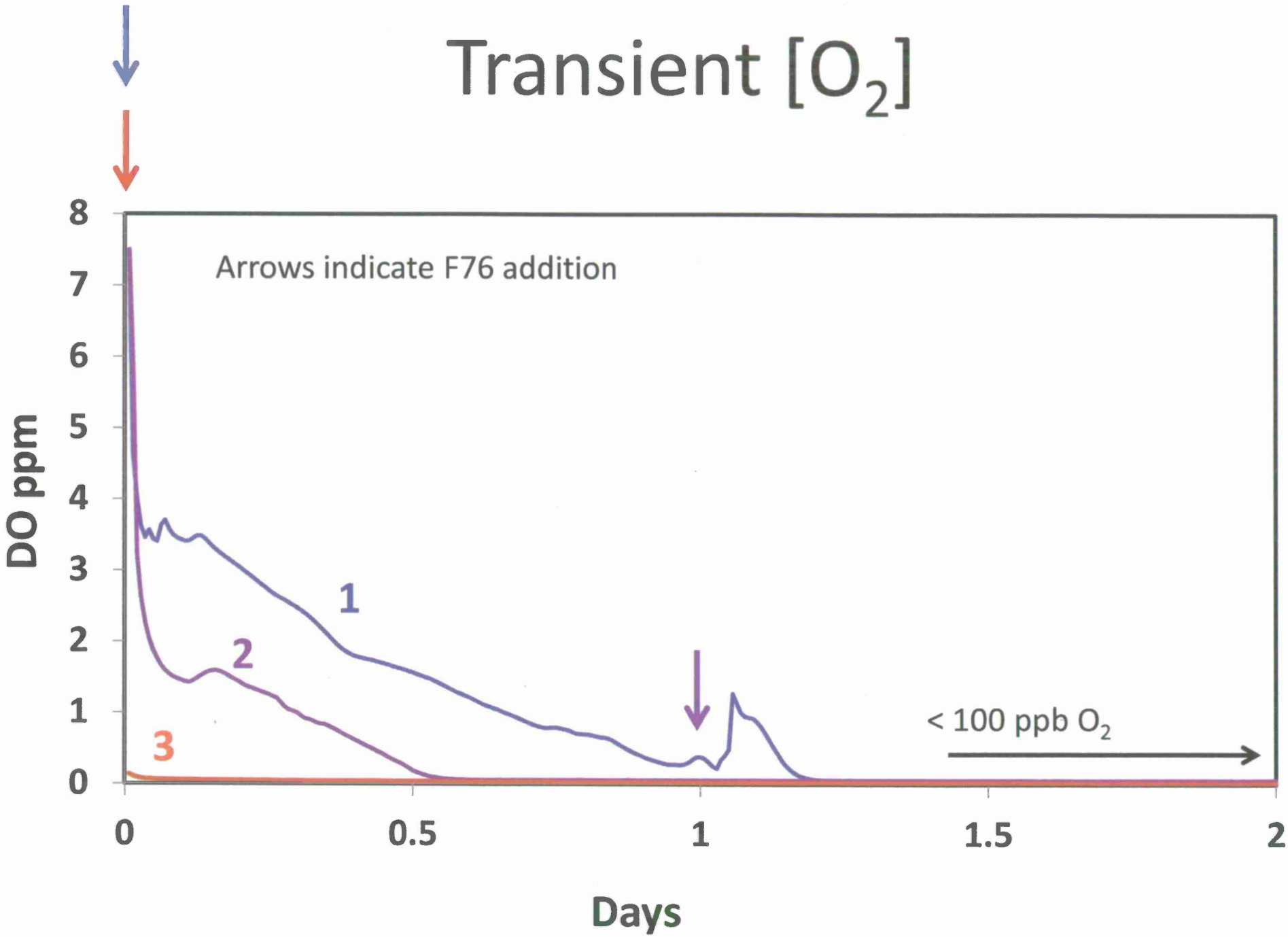
Clear Indications of Initial 'Aerobic' Microbial Metabolism



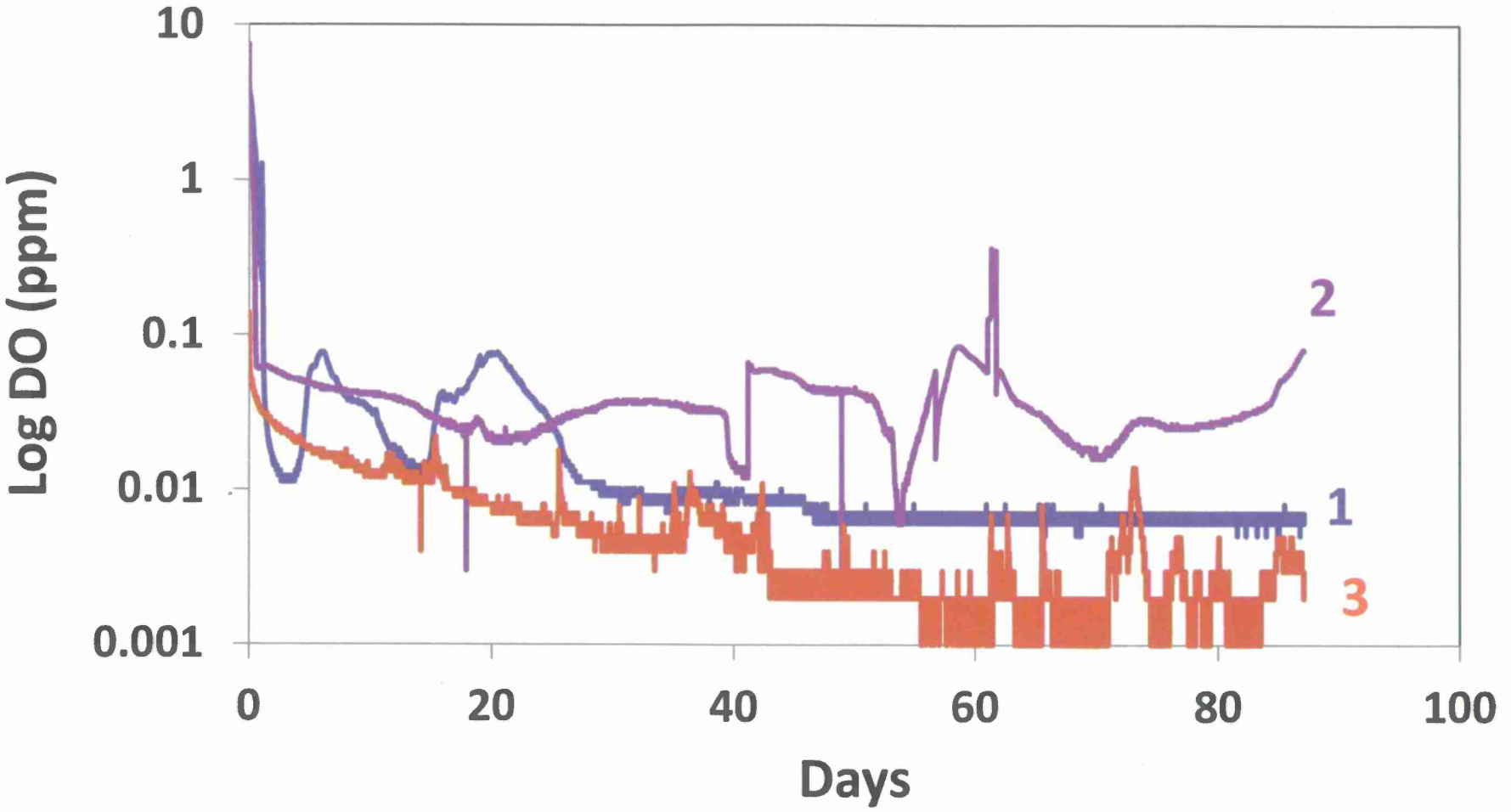
Experimental Conditions

Case	1	2	3
Gas Mixture	0.1% CO_2, 10% H_2, bal N_2	0.1% CO_2, 10% H_2, bal N_2	20% CO_2, 80% N_2
Na_2S Addition	No	No	150 ppm
Seawater [O_2] at Fuel Addition	8 ppm	< 0.1 ppm	0 ppm
Fuel [O_2]	~ 60 ppm	~ 60 ppm	0 ppm

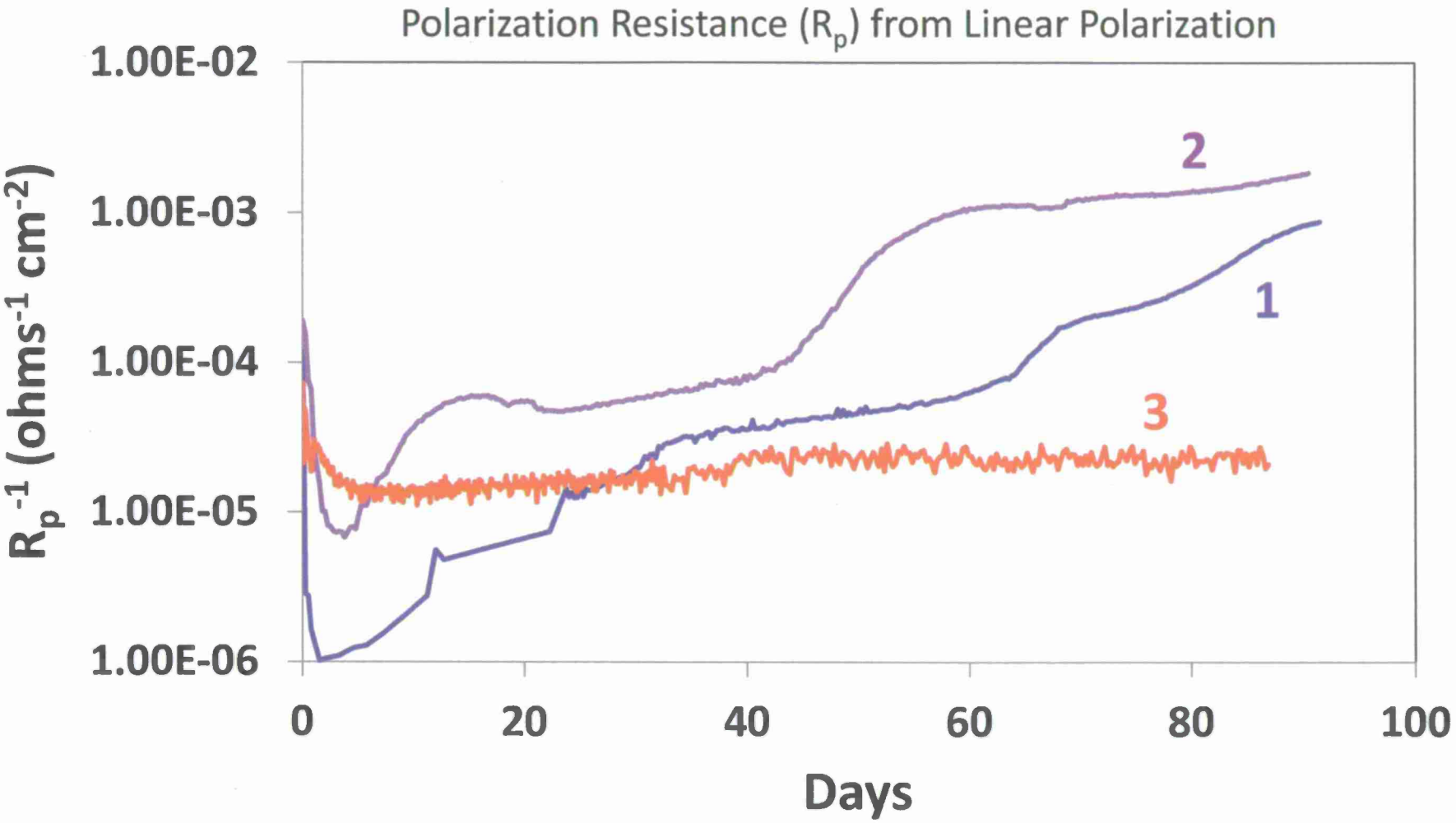
Transient [O_2]

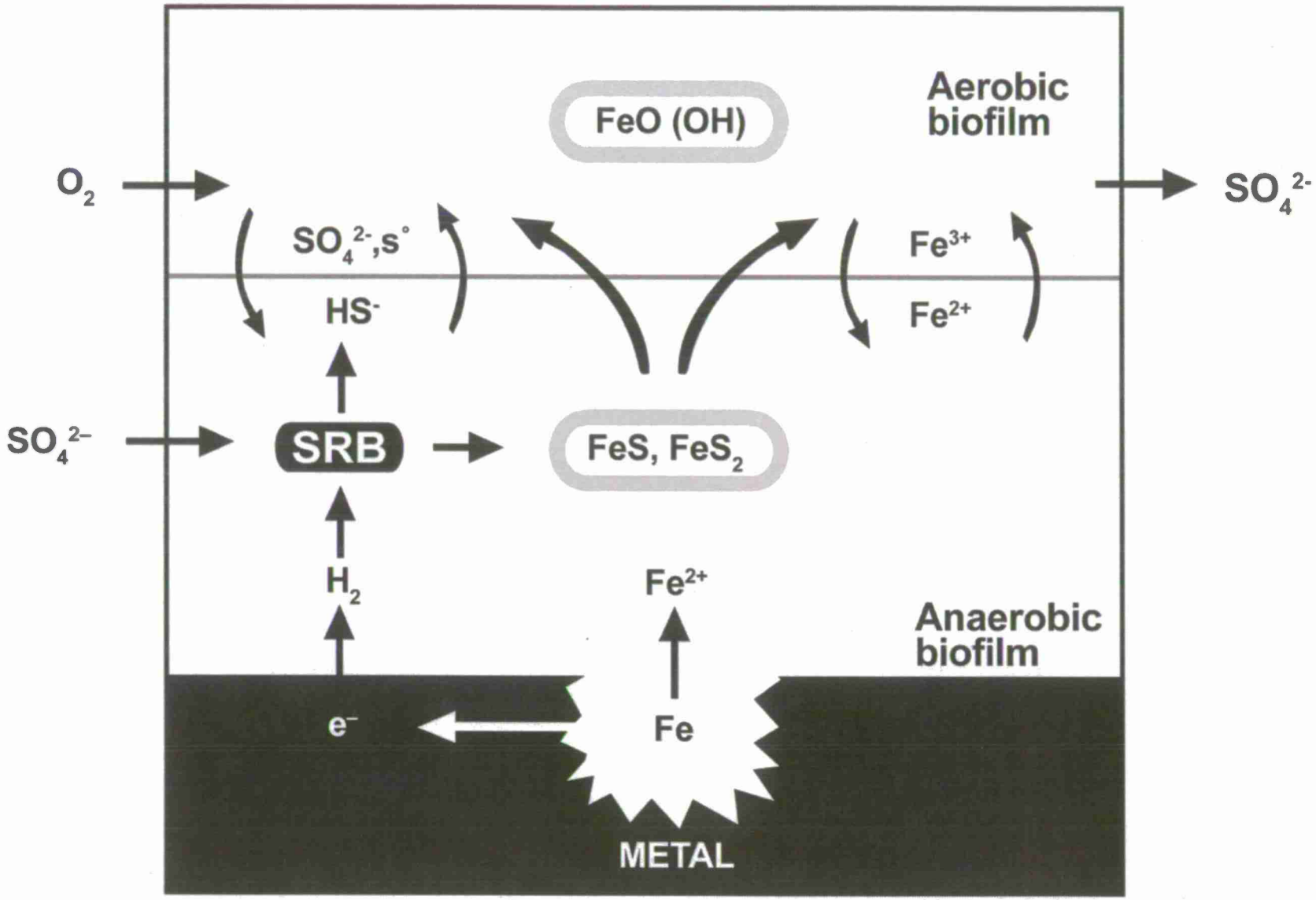


Log DO



Corrosion Rates





Hamilton et al., 2003