Harvesting Energy from the Marine Sediment-Water Interface

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Program Objective

- Develop a power supply that will greatly extend mission duration of low-power marine deployed autonomous instrumentation
- 1 Watt continuous power for 1 year

*a worthwhile milestone towards **near-perpetual** low-power generation*

- Minimize environmental impact
- Durable
- Cost effective
- Wide scope of application

Impact

Power Autonomous Systems

Indefinitely power individual network nodes that require ~ 1 Watt or less continuous power

- CDT
- Hydrophone
- Seismometer
- Transponder

State of Art

- lithium, alkaline, lead-acid batteries

	Lithium	Alkaline	Lead-Acid
size (liter)	0.04	0.04	4.70
weight (kg)	0.09	0.09	10.90
power (mWatt-Year)	8.00	3.00	40.00
liftime (Year)	3.00	2.00	1.00
power density (mWatt-Year/liter)	188.24	70.59	8.51
No. for 1 Watt-Year	125.00	334.00	25.00
size for 1 Watt-Year (liter)	5.30	14.10	118.00
weight for 1 Watt-Year (kg)	11.70	314.00	163.50

State of Art

- lithium, alkaline, lead-acid batteries
- seawater batteries

- Corrosion of a reactive metal anode (Mg, Al)
- reduction of seawater O_2 at inert cathode (C)
- 1-5 Watts continuous power for 1 - 2 years

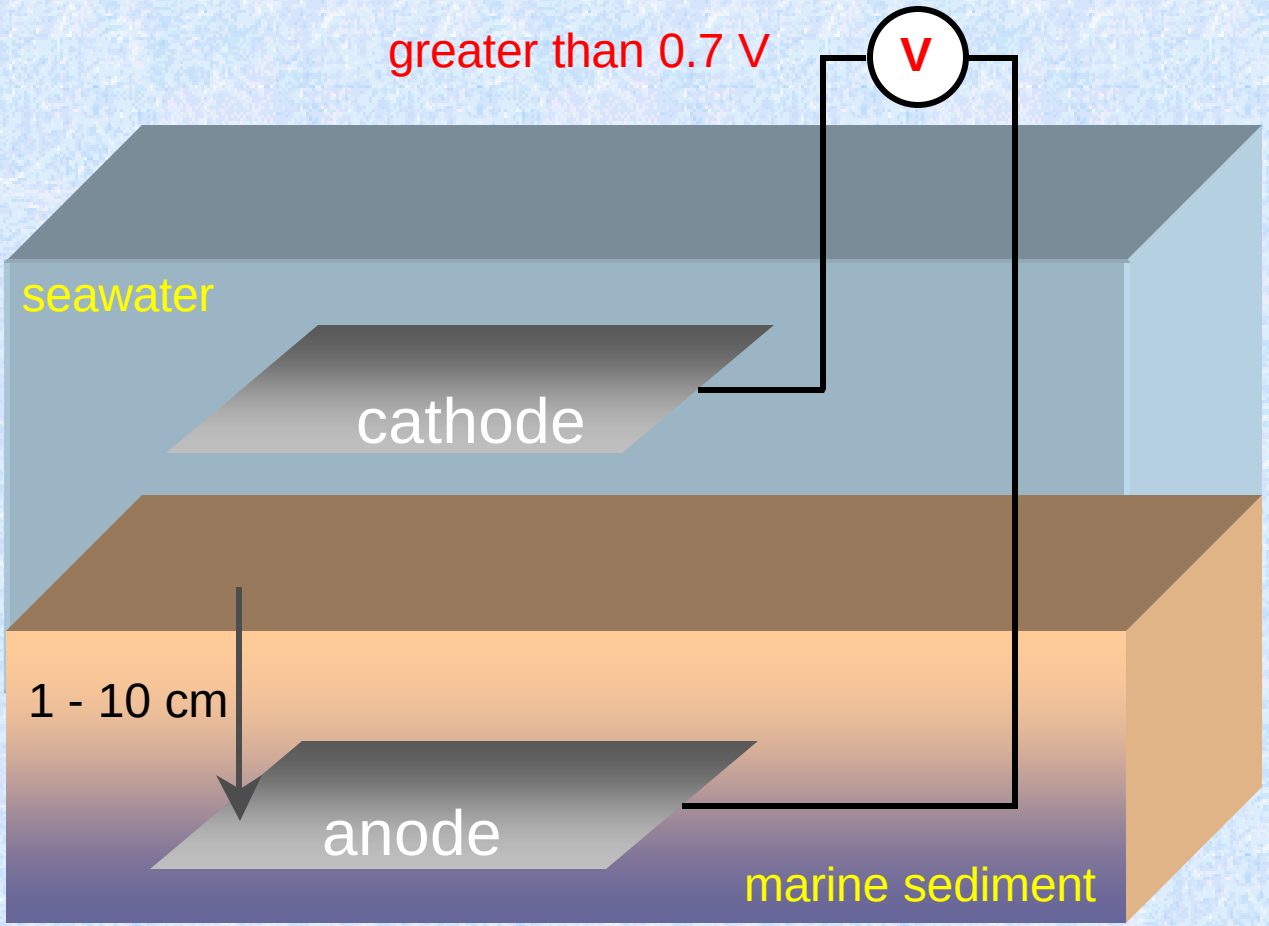
State of Art

- lithium, alkaline, lead-acid batteries
- seawater batteries

Seismometer with internally pressurized battery pack

- Depletion of oxidant and/or reductant limits deployment duration
- Failure under deployment conditions
- Low current at low temperature
- Heavy - Bulky
- Environmental concerns
- Expensive

Approach


greater than 0.7 V
V
seawater
cathode
1 - 10 cm
anode
marine sediment

Background

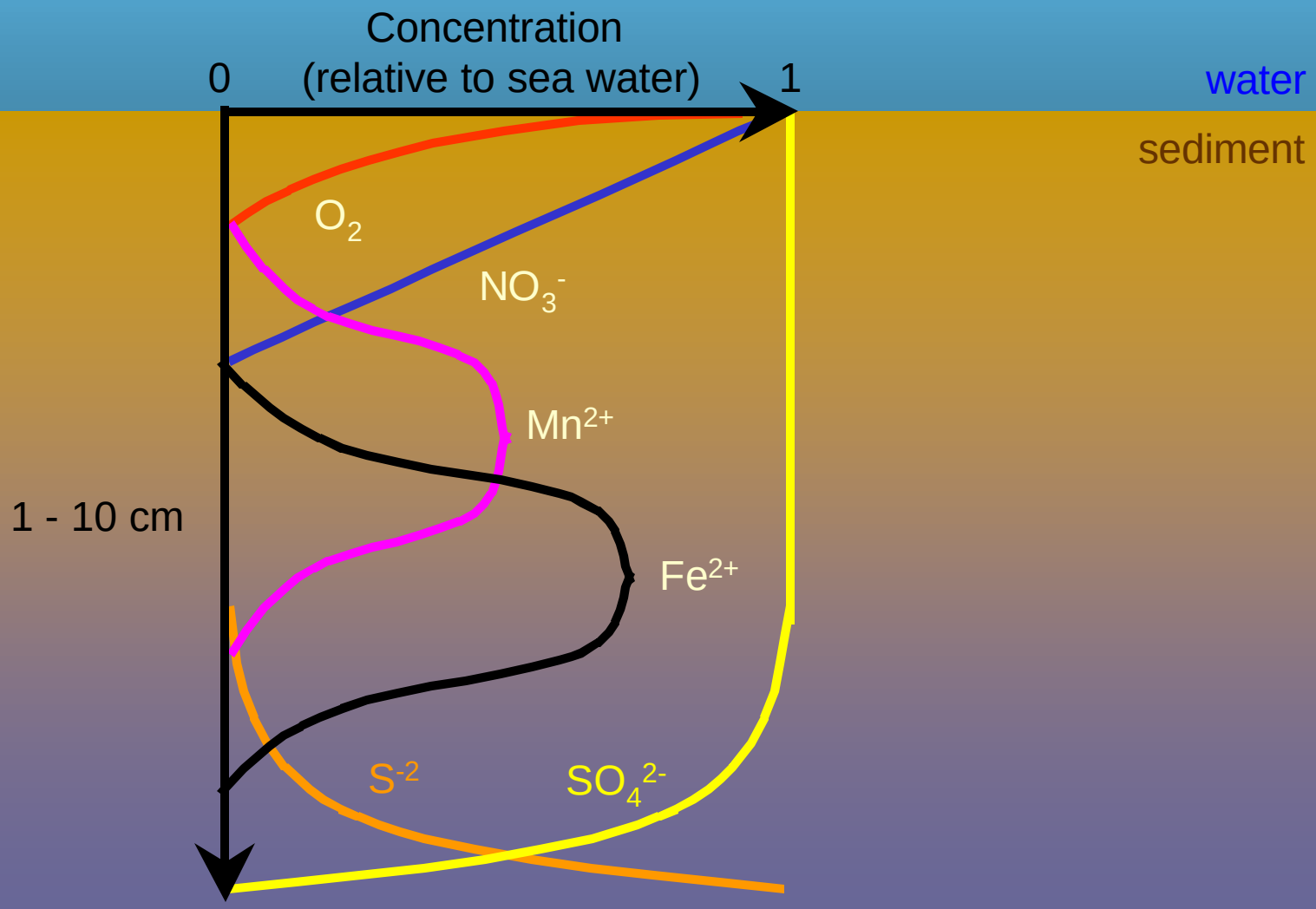
Depth-Dependent Microbial Oxidation of Sediment Organic Matter

Oxidant	Reaction	ΔG^o (kJ/mole $C_6H_{12}O_6$)	
			water
Oxygen:	$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$	-3190	sediment
Manganese	$C_6H_{12}O_6 + MnO_2 \rightarrow Mn^{2+} + CO_2 + H_2O$	-3090	
Nitrate:	$C_6H_{12}O_6 + HNO_3 \rightarrow CO_2 + NH_3 + H_2O$	-2750	
Iron:	$C_6H_{12}O_6 + Fe_2O_3 \rightarrow Fe^{2+} + CO_2 + H_2O$	-1310	
Sulfate:	$C_6H_{12}O_6 + SO_4^{-2} \rightarrow CO_2 + S^{-2} + H_2O$	-380	
Methanogenesis:	$C_6H_{12}O_6 \rightarrow CO_2 + CH_4$	-350	

1 - 10 cm

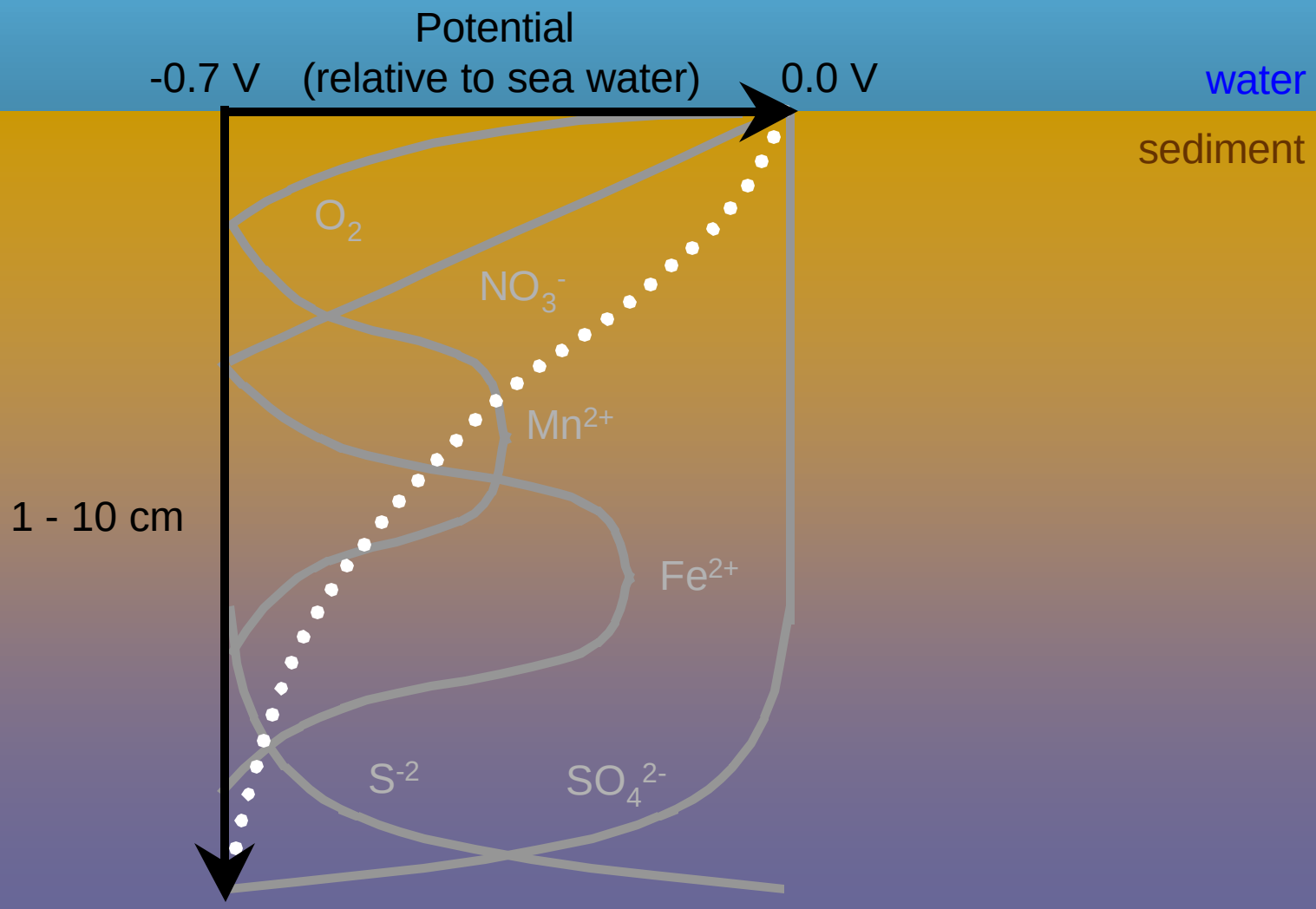
Background

Depth-Dependent Sediment Chemical Gradients



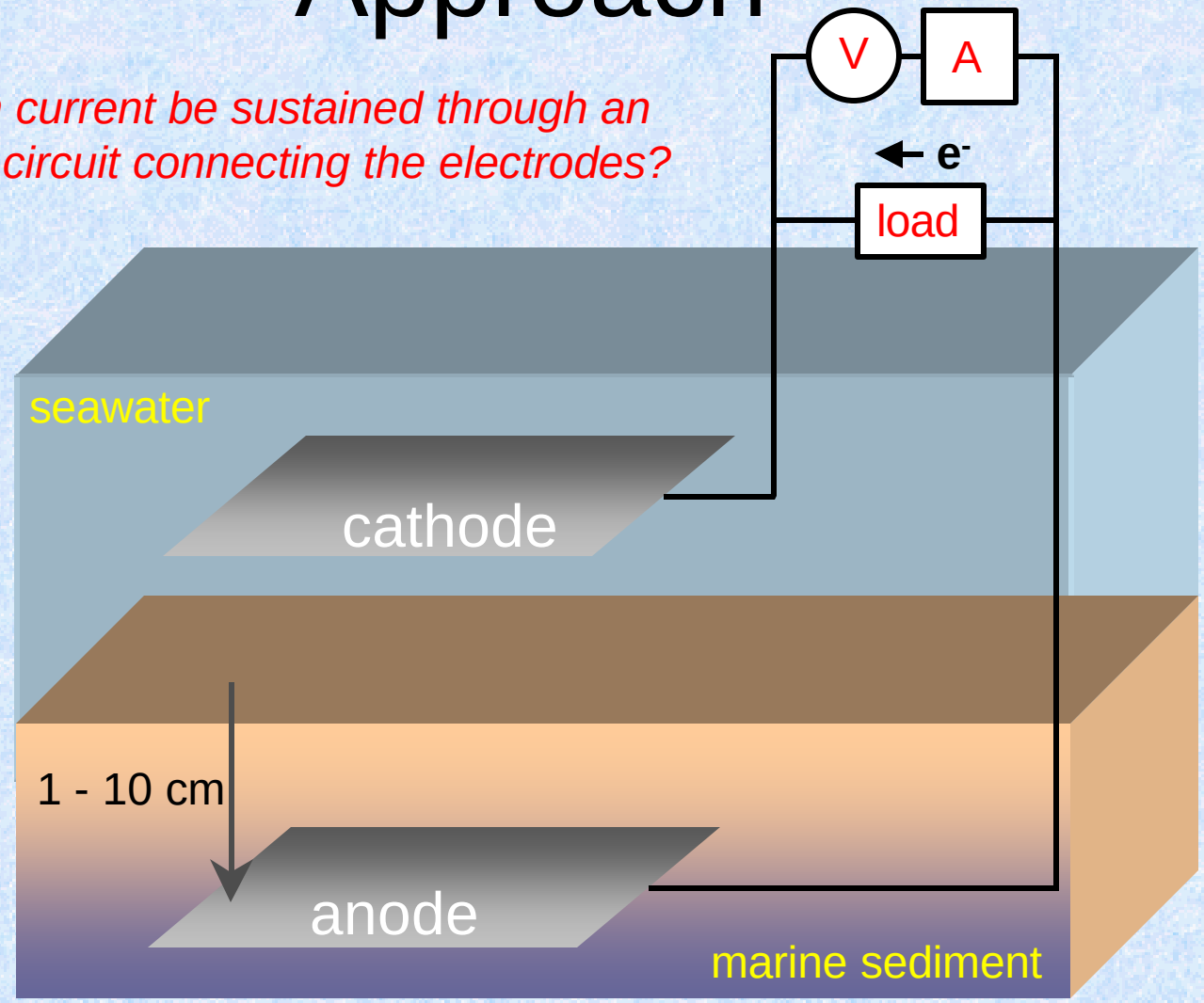
Background

Depth-Dependent Sediment Potential Gradient

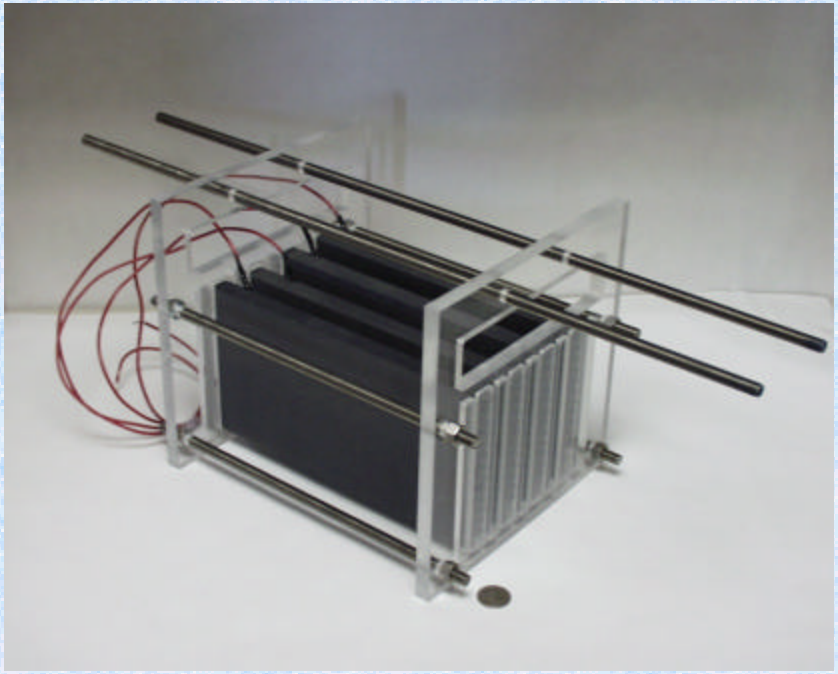


Approach

Can can current be sustained through an external circuit connecting the electrodes?



Approach

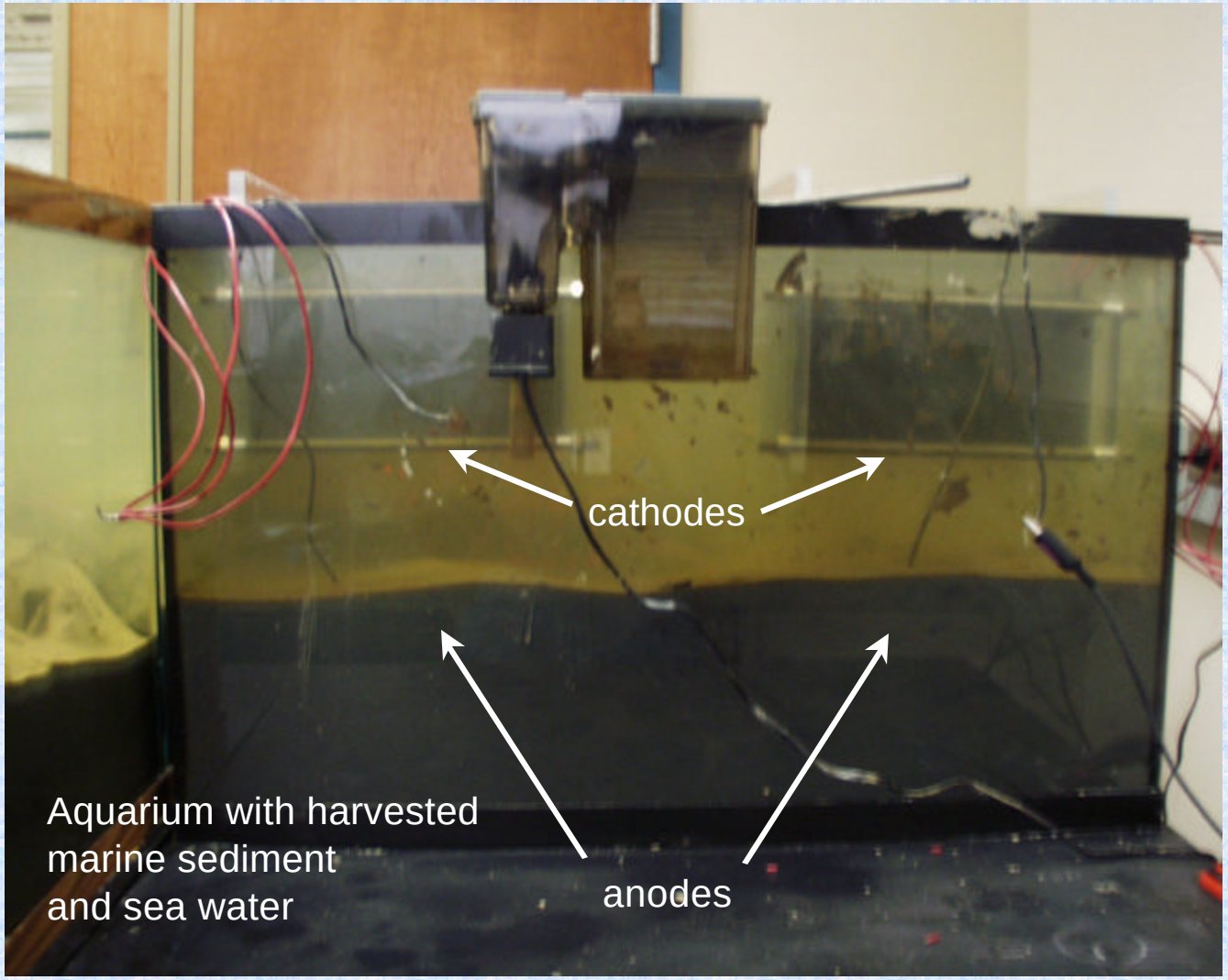


Cathode:
- **Graphite plates**
- **platinum coated Niobium mesh**
- **loosely-packed carbon fiber in fiberglass envelope**

Anode:
- **Graphite plates**
- **platinum coated Niobium mesh**
- **loosely-packed carbon fiber in fiberglass envelope**

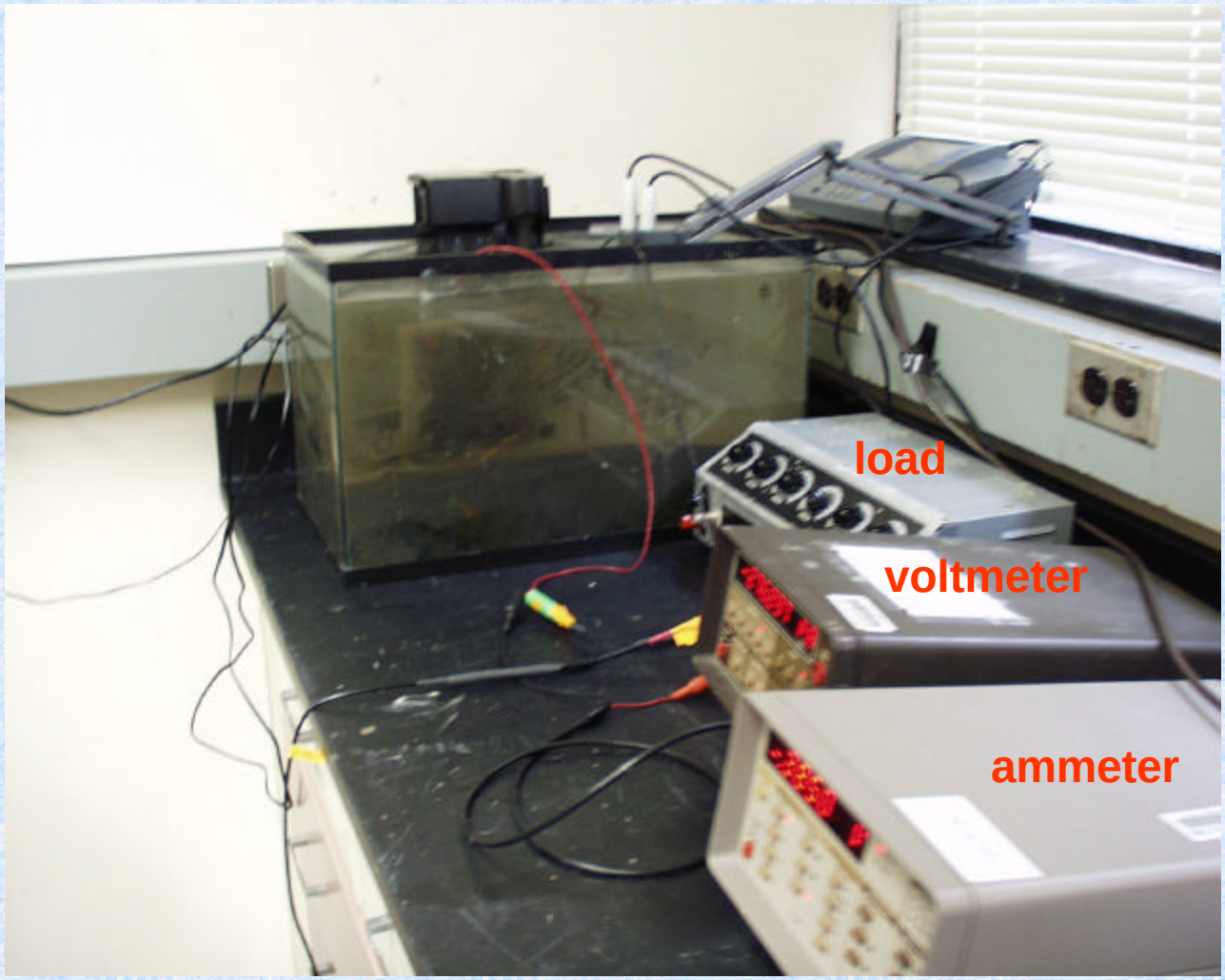
Laboratory Prototypes

Approach

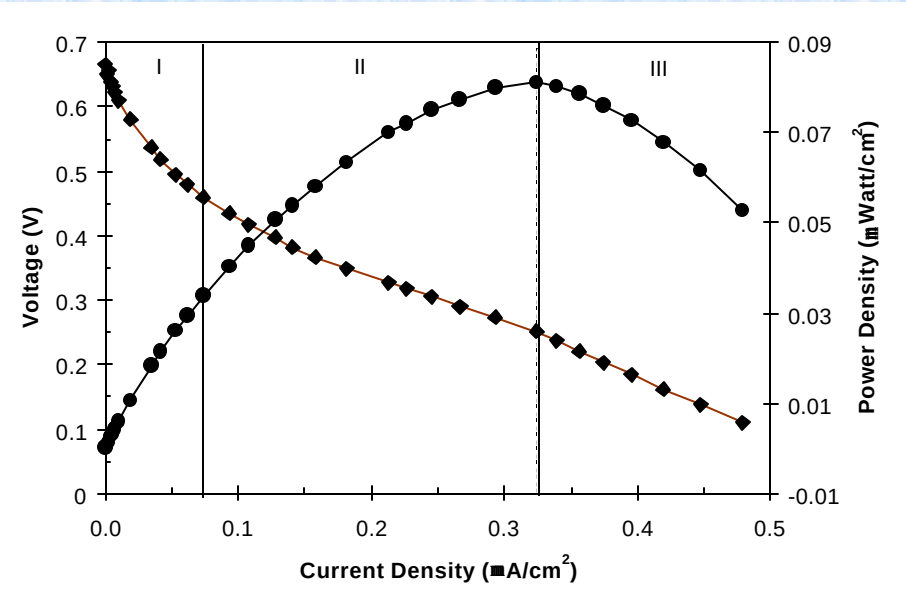


Laboratory Prototypes

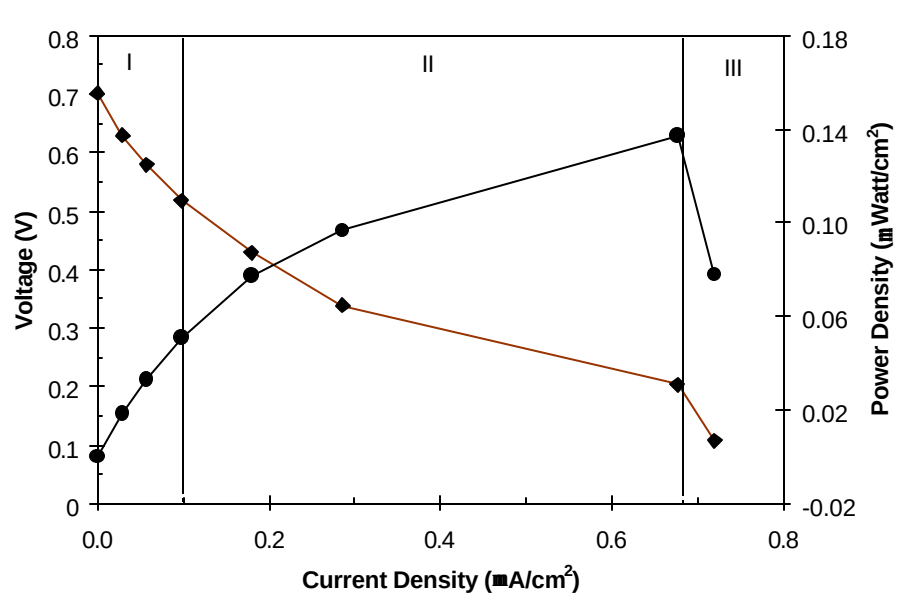
Approach



Voltage and Power Density *Vs*. Current Density

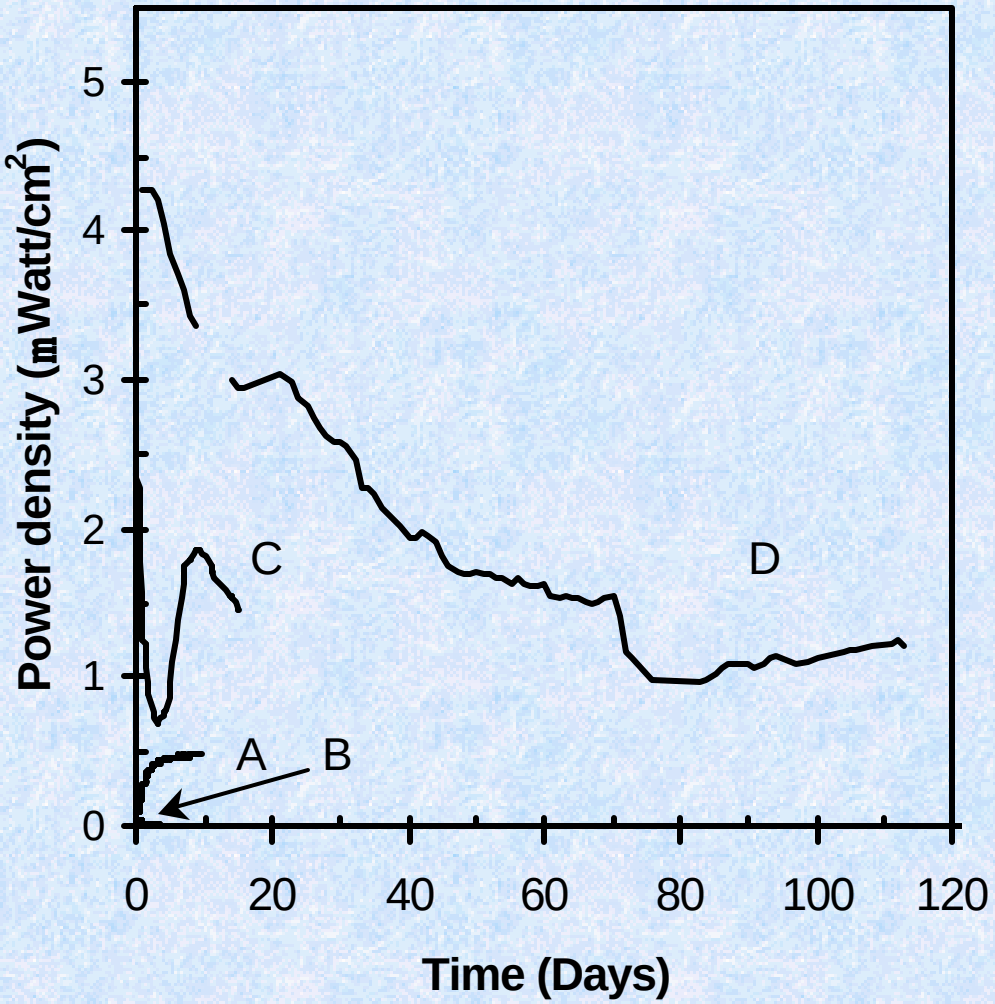
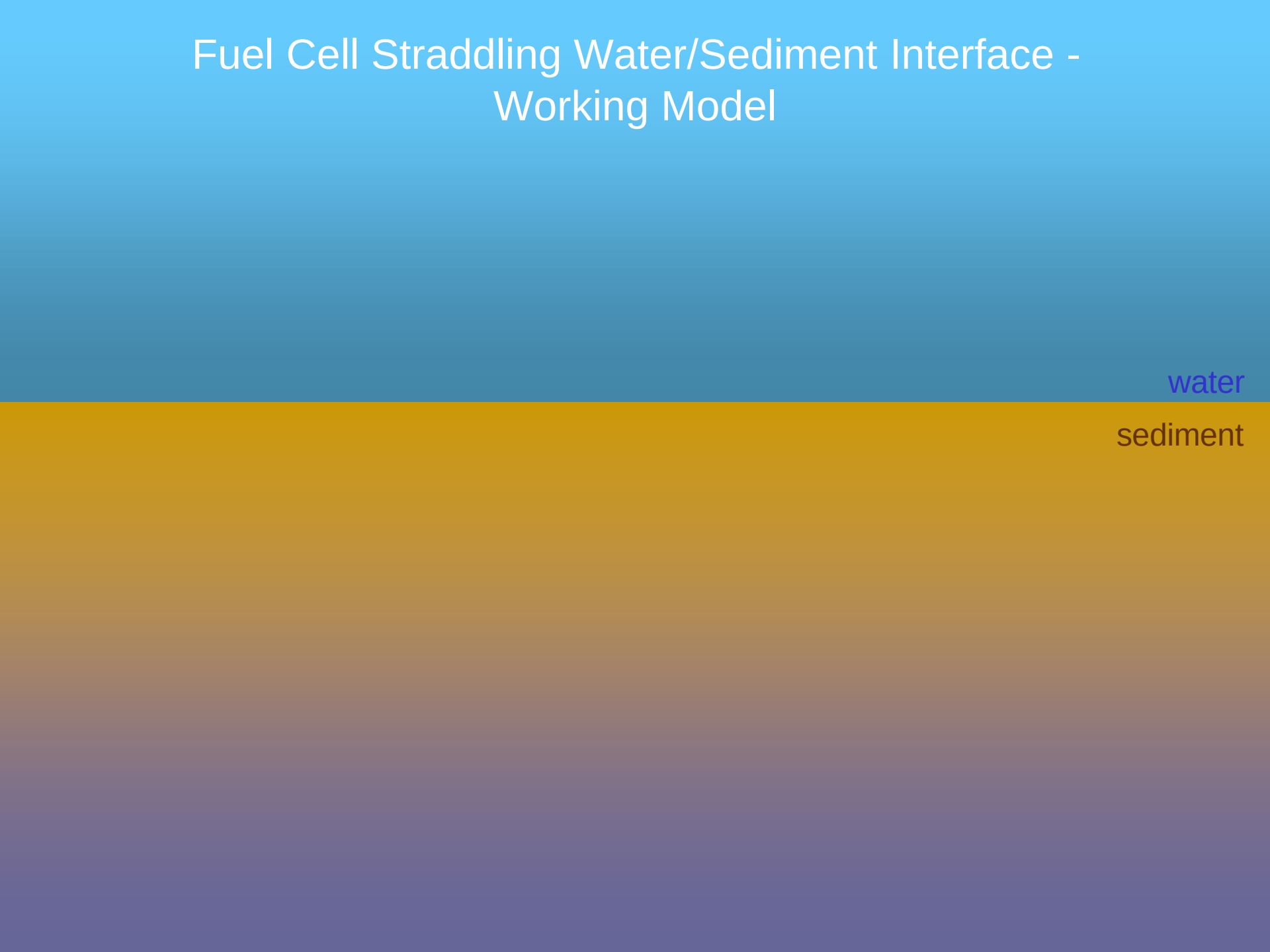


Platinum coated Niobium mesh device in salt-marsh sediment



Platinum coated Niobium mesh device in estuarine sediment

Power *Vs.* time for long-term discharges



Fuel Cell Straddling Water/Sediment Interface - Working Model