



Technology for Inhibiting Methanogenesis during *In Situ* Sediment Treatment

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AquaBlok®
Composite Particle System

Presentation Outline

💧 How do Methanogens Impact Sediment Capping?

- Methanogens are ubiquitous and grow rapidly when stimulated
- Methane induces contaminant migration and can breach caps
- Methanogens can methylate heavy metals (Hg, As, Sn, etc)

💧 Integrated Technologies

- AquaBlok® *In Situ* Sediment Capping Technology
- Engineering designs to control methane and COI migration
- Provect-CH4™ Methanogen Inhibitor
- AquaBlok-CH4™ Antimethanogenic Sediment Cap

💧 Case Study (Example Field Application)

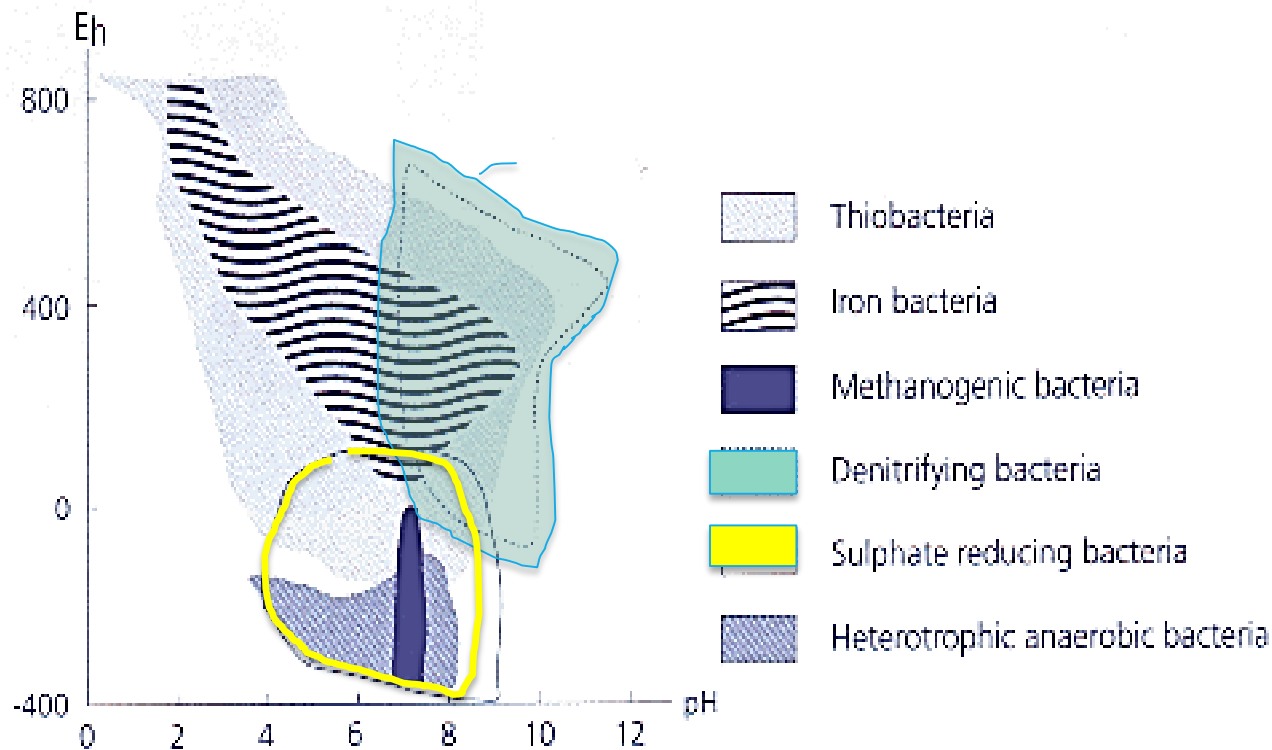
💧 Conclusions

What is a Methanogen?

- Methanogens are microorganisms that produce methane
- Methanogens are Archaea (Woese and Fox, 1977) and hence, from a genetic perspective, *Dehalococcoides ethenogenes* are as different from methanogens as you are.
- Methanogens are often dominant as compared to DHC spp. and acetogens: averaging 2% to 15% of all soil microbes (Bates, *et. al.*, 2011)
 - Even at biostimulated populations of DHC rising to $>10^8$ cells/L Archaea populations can be orders of magnitude greater in number
- Methanogens are important members of synergistic, fickle anaerobic communities = we need some

Idealized Eh pH Ranges for Microbial Growth

Microbe	Doubling Times
Dehalococcoides spp.	24 to 48 hours
Methanogens with cytochromes	10 hours
Methanogens without cytochromes	1 hour



Issues with Methane Generation



- ◆ Typically there is a short term stimulation of methanogenic /microbial activity as a result of disturbing sediments, etc
- ◆ Methane gas ebullition causes cap breaching and induced migration = sheen
- ◆ Can result in the generation of methylmetal(loids)

Biomethylation of Heavy Metals



- With the possible exception of Pb almost all Group IV, V and VI elements can be biomethylated (Bentley and Chasteen, 2002).
- Methylmetal(loids) are usually volatile and more toxic than their inorganic counterparts due to increased water solubility and hydrophobicity (e.g., methylmercury).
- Microorganisms are primarily responsible for the biosynthesis of organo-metals (Challenger, 1945), and the activity of methanogens is a main source of their production (Michalke, *et al.*, 2006).

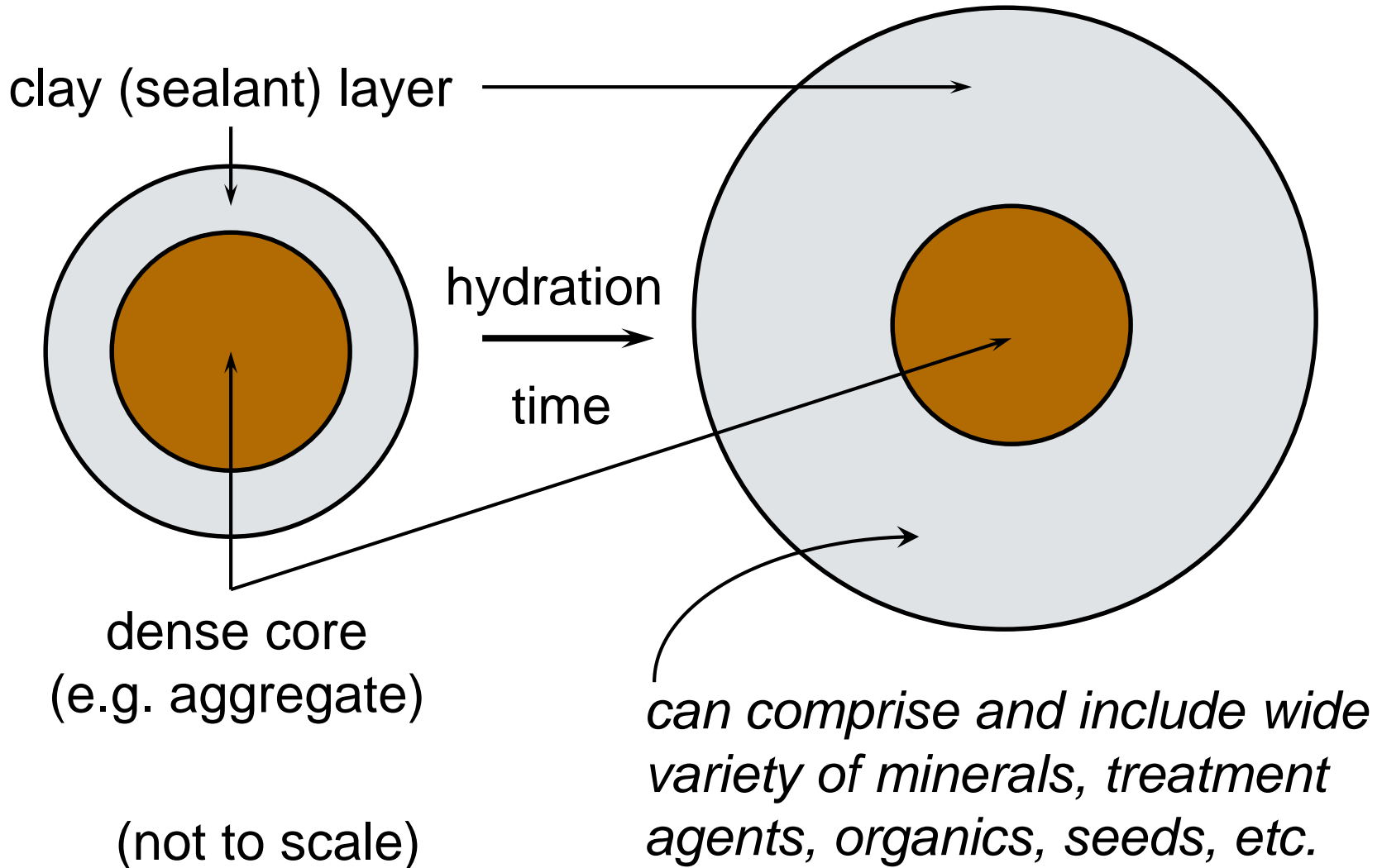
Volatile methylmetal(loids) may produced by Growing Cultures of Methanogens (Archaea).

*** As, Hg, Sn and Pb are of particular interest**

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AquaBlok® *In Situ* Capping Technology



AquaBlok Placement Methods



Basic Product Behavior in Water



Recontamination is Not Due to Flux Through the Cap



***Split-core from Section A
(2.5 yrs after placement)***

New sediment
Deposits

AquaBlok Clean Cap Layer

Discrete boundary

Contaminated Sediment

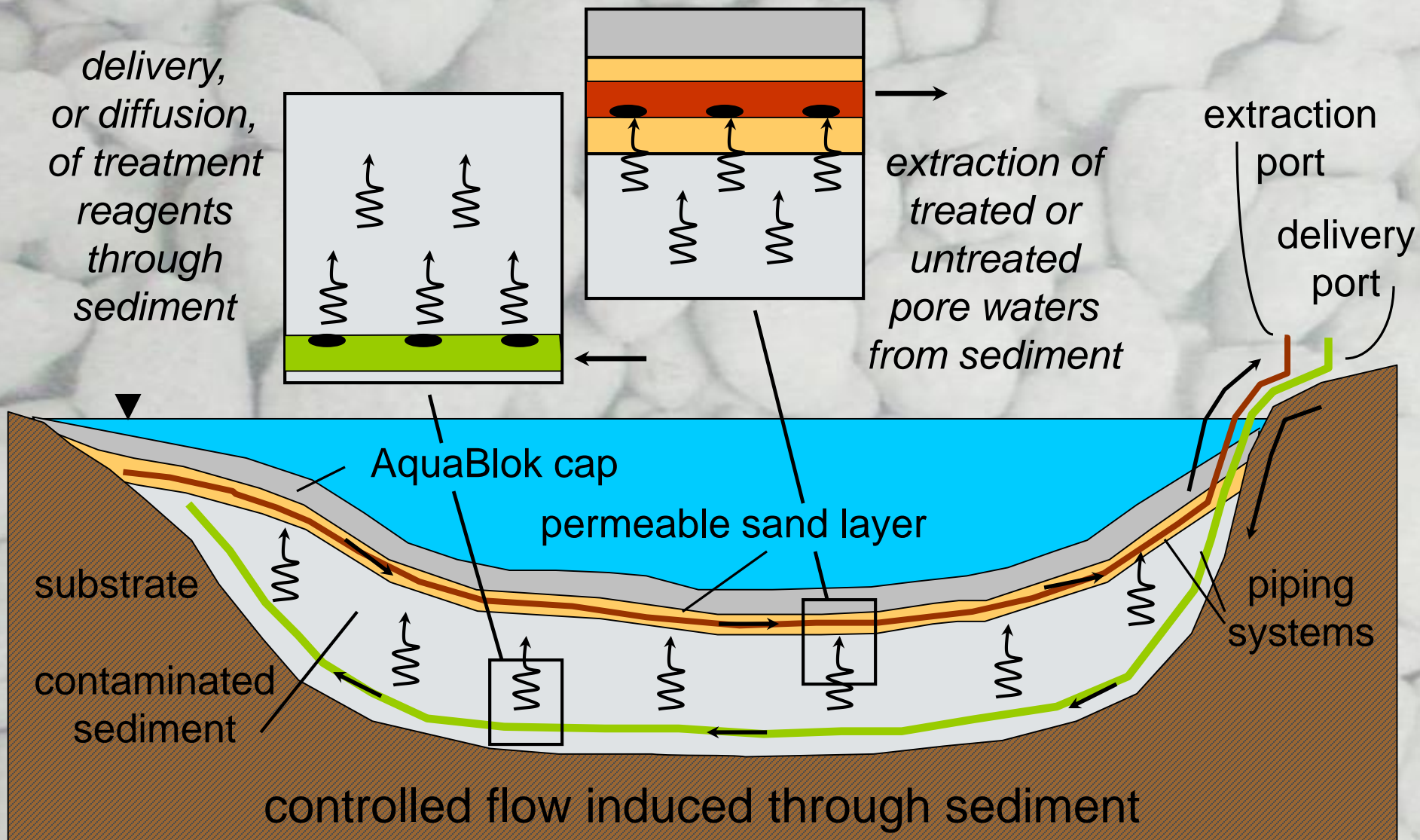


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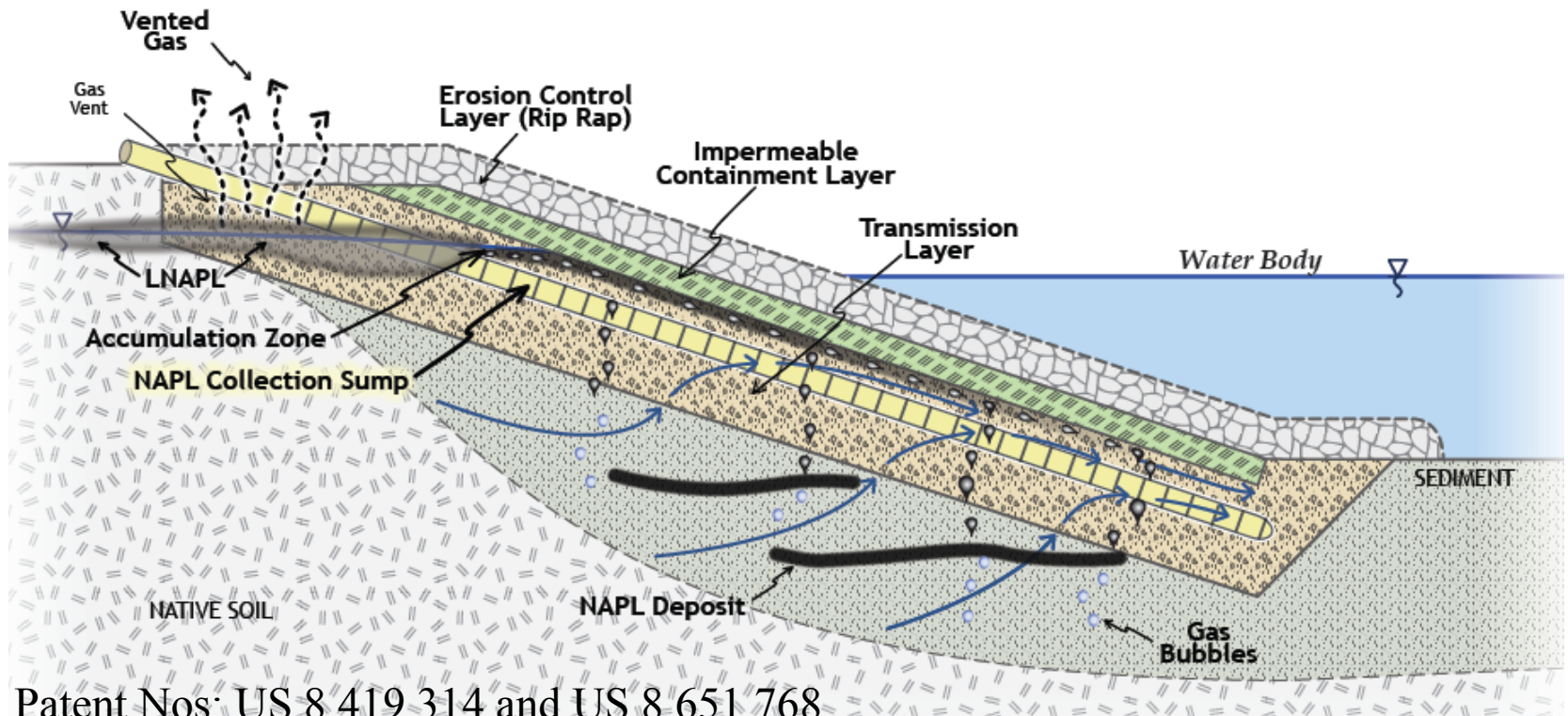
Facilitating *In Situ* Sediment Treatment



(not to scale)

Conceptual Design - NAPL Trapping Cap

A sediment capping system made of geological materials (clay, sand, gravel, boulders) that can be used to capture NAPL permanently and predictably as it migrates from sediments



Patent Nos: US 8,419,314 and US 8,651,768

* NAPL Trapping Cap was designed by TRC

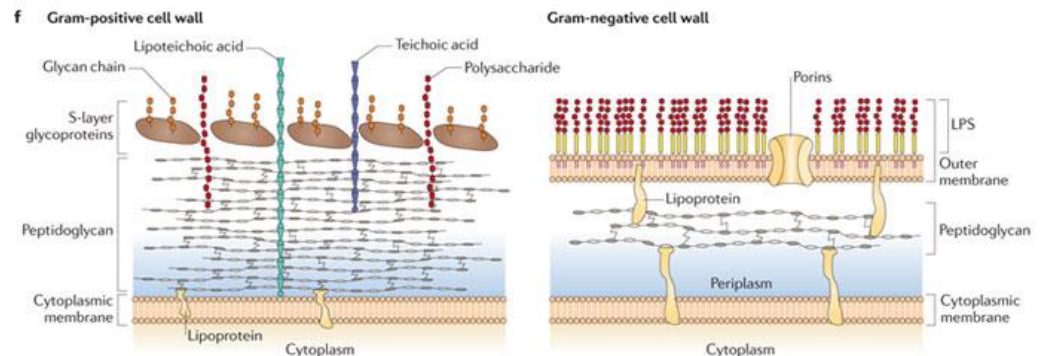
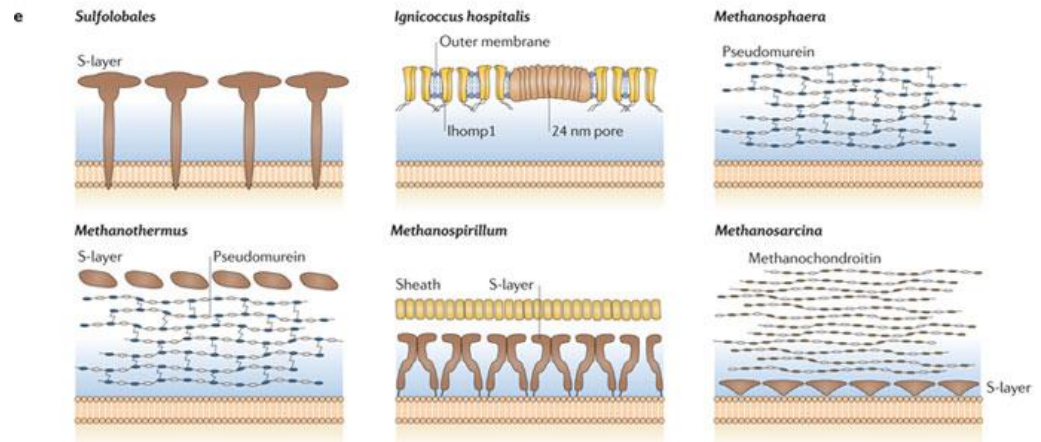
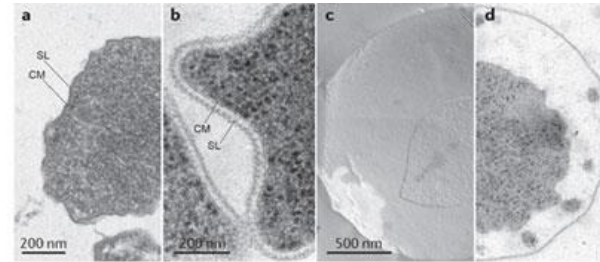
Provect-CH4™ Methane Inhibitor

- ◆ Proprietary combination of Red Yeast Rice (RYR) extract specially prepared for the environmental industry
- ◆ Cold water soluble powder that is safe and easy to handle
- ◆ Packaged and sold in 55.1 lb (25 kg) drums
- ◆ Used as an ERD Supplement; component to ABC-CH4™, Provect-IR™, Provect-IRM™, EZVI-CH4™ and AquaGate-CH4™
- ◆ Multiple patents pending

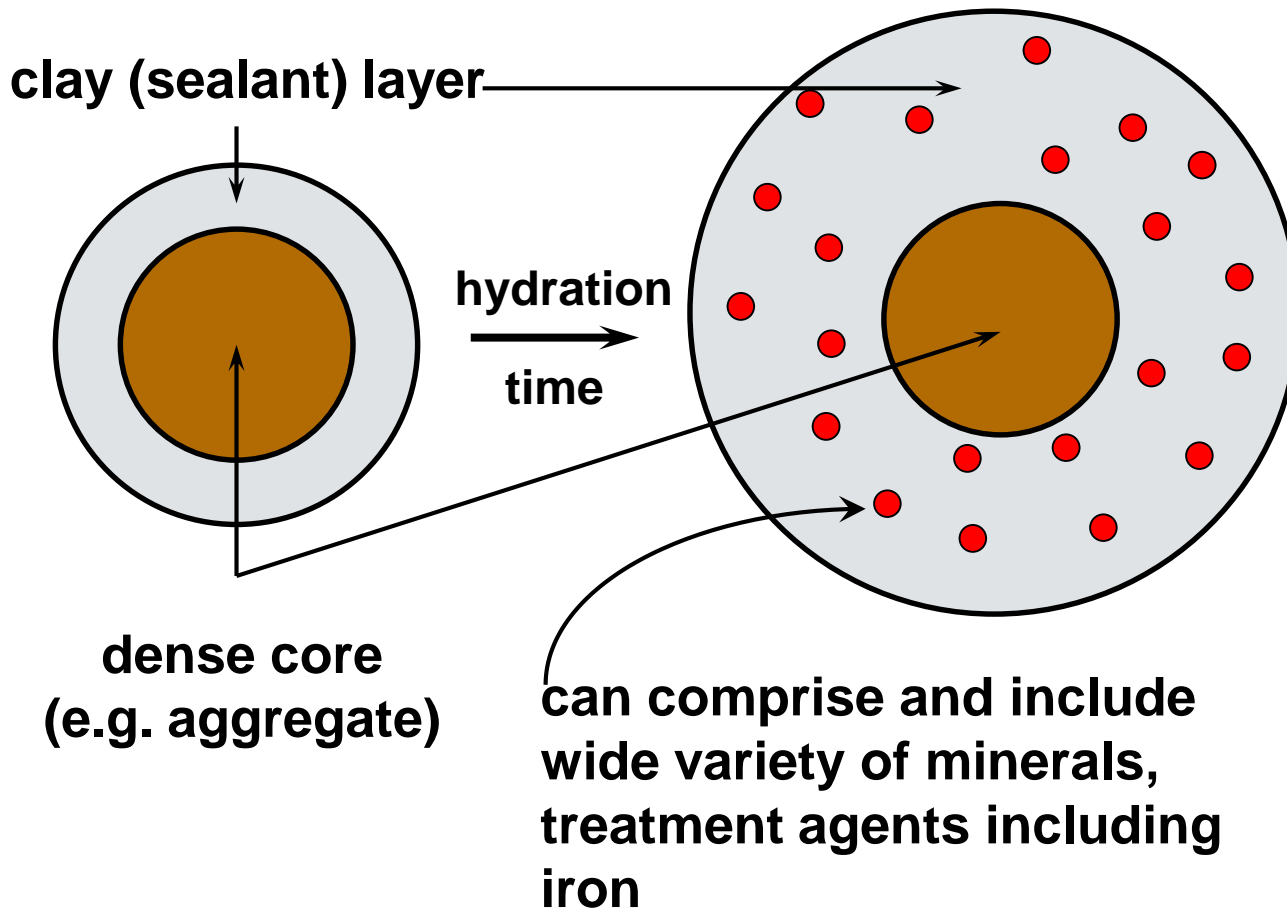


Provect-CH4 will Control Methanogens

- ◆ Bacteria cell walls contain peptidoglycan (murein).
- ◆ Methanogens cell walls contain pseudomurein.
- ◆ Pseudomurein is biosynthesized via activity similar to that of 3-hydroxy-3-methylglutaryl-coenzyme A (HMG-CoA) reductase, which is a key enzyme in the cholesterol biosynthesis pathway in humans (Alberts *et al.*, 1980).

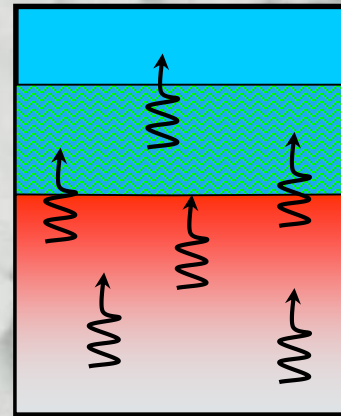


AquaGate-CH4™ Particle

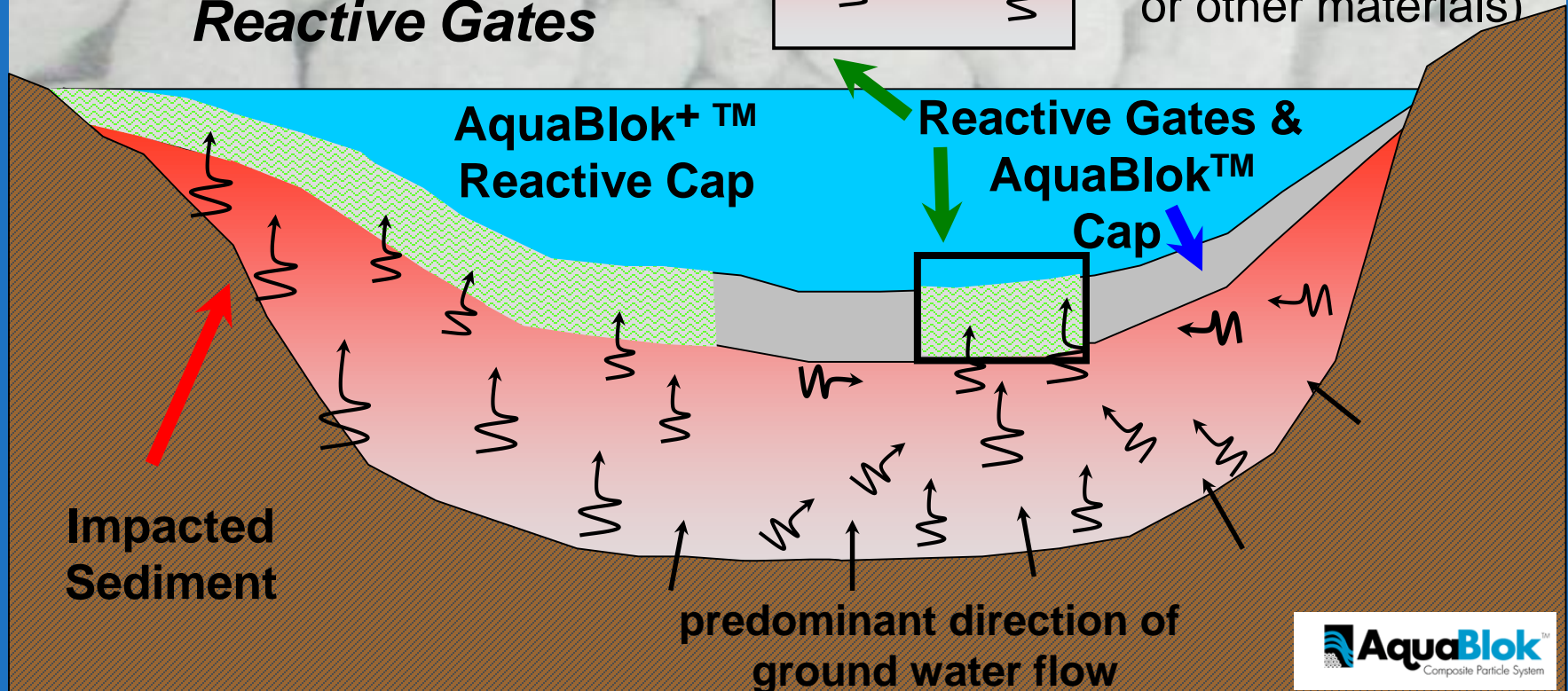


Horizontal Reactive Barrier (hPRB) for *In Situ* Sediment Treatment

Contiguous Reactive Cap or funneling of contaminant-bearing sediment pore waters beneath low-permeability cap through **Reactive Gates**



higher-permeability treatment "gates" (includes reactive medium, ZVI, buffering agents, microbes, or other materials)



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Illegal Gold Mining – Latin America





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A massive gold mining zone in eastern Peru has turned thousands of acres of rain forest into wastelands. This strip of mining in La Pampa is 5 miles wide and 40 miles long.

Jason Beaubien/NPR



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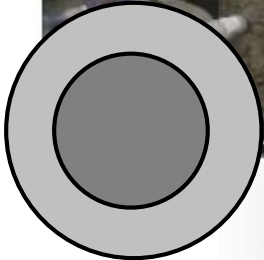
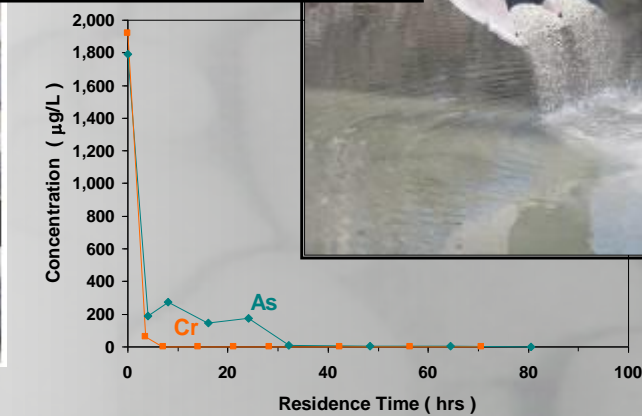
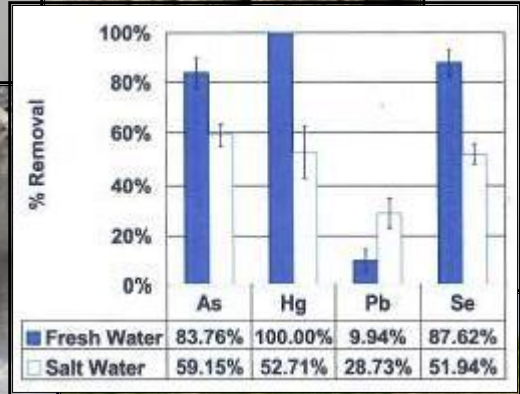
An aerial photo shows the environmental destruction in the wake of illegal gold mining in the Peruvian Amazon.

Courtesy of Gregory Asner, Carnegie Institution for Science

Mercury Contaminated Sediments



In-Situ Treatment & Biological Applications



Reactive AquaGate Materials



Contaminant	Treatment Materials
PAHs, BTEX, PCBs	Activated Carbon, Oxygen Delivery, Rubber
Gasoline	Oxygen Delivery, Nutrients
CVOCs	ZVI*, Provect-IR*, Bimetallic, A/C
Metals, Ammonia	ZVI*, Provect-IRM*, Organic Carbon, Zeolites, Ferric Sulfides, A/C
Acid Mine Drainage	Provect-IRM*, Organic Carbon
Nitrate	Provect-IR*, Organic Carbon
Methane control – all COIs	Provect-CH4™

* Provectus Environmental Products

Case Study - Funnel & Gate Approach



**Site Location: U.S. EPA Region 2
Confidential Site – New York State**

- **Setting/Purpose:** Canal/River (freshwater). MGP Site – PRB and low permeability barrier/cap over contaminated sediments. Site area was approximately 4,000 square feet.
- **Contaminant(s) of Concern:** Coal Tar associated with historic MGP site, including PAH (polynuclear aromatic hydrocarbons) and DNAPL (Dense Non-Aqueous Phase Liquids).
- **AquaBlok Cap Design/Site Area:** Multi-layer design comprised of a one inch basal layer AquaBlok+ORGANOCLAY PRB covered with a hydrated layer (~6 inches in target thickness) of AquaBlok 3070FW. The cap was then armored with a two-inch layer of AASHTO #2 stone.
- **Method of AquaBlok Placement:** Shore-based excavator

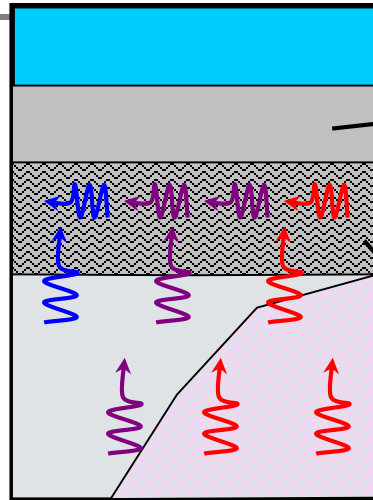


Example of Sheen



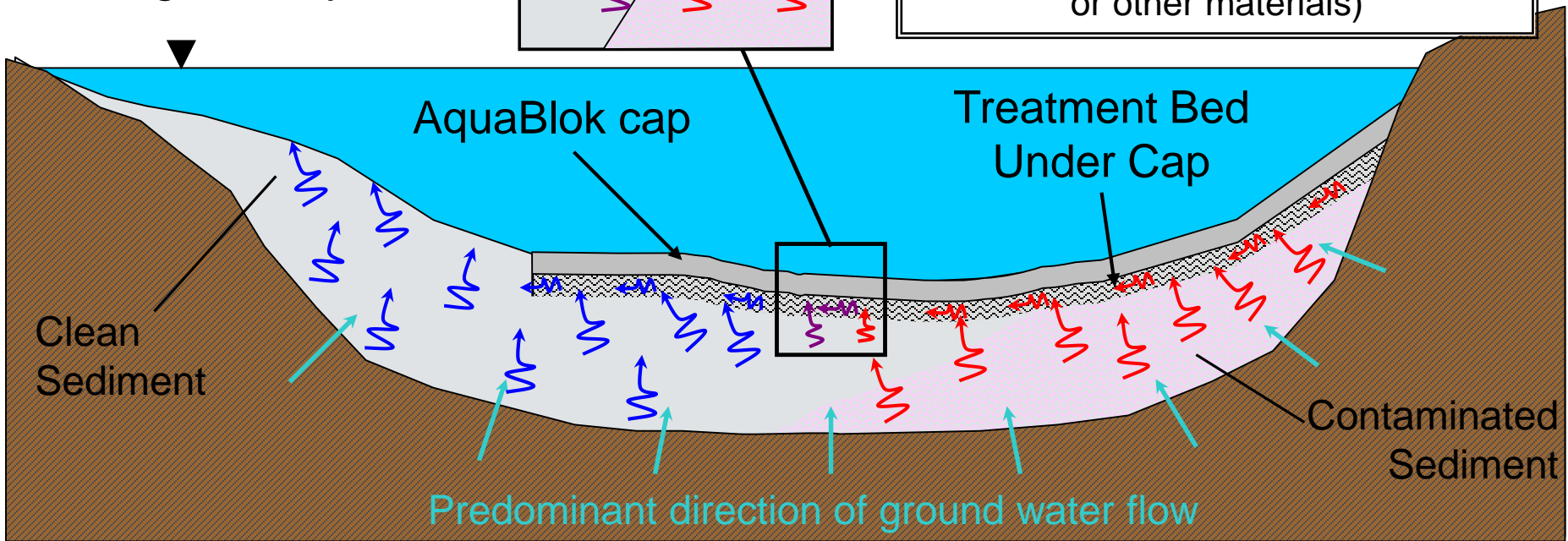
Key Objectives:

- No Localized Breakthrough
- Relatively Long Contact Time for Organoclay



Funneling of Contaminant bearing sediment pore waters are directed beneath a low-permeability cap through a higher-permeability treatment layer that is below the cap

Higher-Permeability Treatment Zone (Gate – includes organoclay or other materials)



Placement of Low-Permeability Cover Layer & Armor Stone



Completed AquaBlok Cap with Armor Stone



AquaBlok Cap Following Spring



Summary

- A variety of treatment materials are available to effectively reduce bioavailability of contaminants in sediments.
- Funnel and reactive gate technology provides:
 - isolation of contaminated sediment
 - treatment of contaminated sediment pore water
 - better protection of uncontaminated water bodies and aquifers than sediment removal or non-reactive caps
- Technology is applicable to:
 - contaminated sediments
 - contaminated groundwater discharging into water bodies
 - contaminated water bodies recharging groundwater
 - wide range of contaminants

Cost Factors

- **Location**
- **Size of Area**
- **Desired Thickness of (hydrated) Layer**
- **Contaminant Capping/Treatment Strategy**
- **Sediment Layer Thickness / Consolidation**
- **Energy Level of Site**
- **Access to Installation Area**
- **Slopes/Stabilization**

Order of Magnitude Cost:

Std. AquaBlok: \$1.50 – 4.50 / SF for Material & Installation
 \$110 – 250 / US Ton (Based on 85lb/CF Bulk Density)

Positions Available....

- 💧 Hydrogeologists
- 💧 Geologists
- 💧 Engineers
- 💧 Microbiologists
- 💧 Environmental Scientists
- 💧 Business Development
- 💧 Sales & Marketing



A Career – not just a job

Microsoft..... Google..... Provectus