

# Overview of Acid Sulfate Conditions, Weathering Processes and Effects

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## Objectives for Today

- **1. Understand the nature and occurrence of acid sulfate materials in Virginia and the Fredericksburg region.**
- **2. Relate S form and content to the potential for a given material to pose soil, water quality and materials damage hazards.**
- **3. Recommend appropriate remedial strategies and methods to protect soil, local waters and materials (concrete and metal) from acid-S attack.**

Active pyrite depositional environment in high C and sulfate input tidal marsh.

Common in reduced estuarine sediments.

Also found in a wide range of hydrothermally altered and /or volcanic igneous & metamorphic rock environments.



Fe-oxides on sediments are reduced microbially and this releases alkalinity to the system.

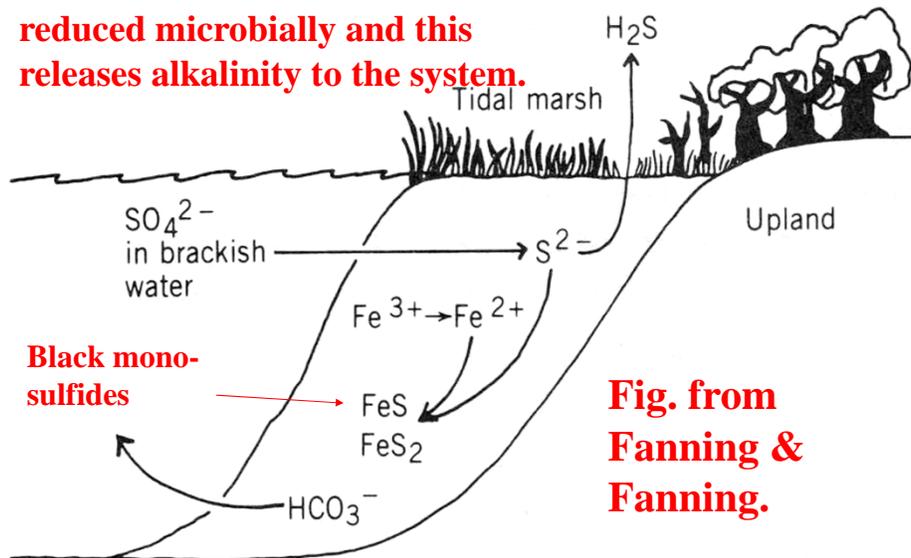


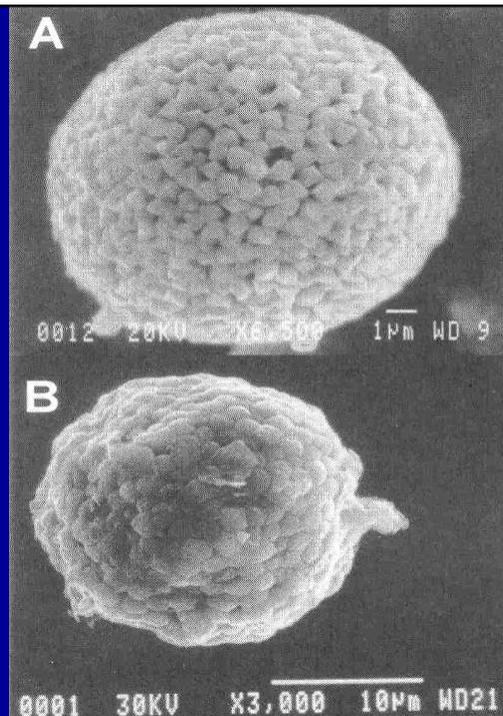
Fig. from Fanning & Fanning.

Figure 10.1 Diagram illustrating sulfidization.



**Framboidal pyrite forms from Fanning et al. (2002). Finely divided framboidal pyrite is much more reactive than larger and more crystalline forms.**

**Also occurs in other sizes/forms in sediments and rocks.**



## “Simple” Pyrite Oxidation

(Singer & Stumm 1970; Nordstrom, 1982)



(Direct oxidation; relatively slow)



(Oxidation by  $\text{Fe}^{\text{III}}$ ; very fast under  $\text{pH} < 4.5$ ) (4)

Common end salts:  $\rightarrow \text{KFe}_3(\text{SO}_4)_2(\text{OH})_6$  (jarosite)  
 $\rightarrow \text{NaFe}_3(\text{SO}_4)_2(\text{OH})_6$  (natrojarosite)

Summing it up all up:



1 mole of pyrite produces 2 moles of sulfuric acid

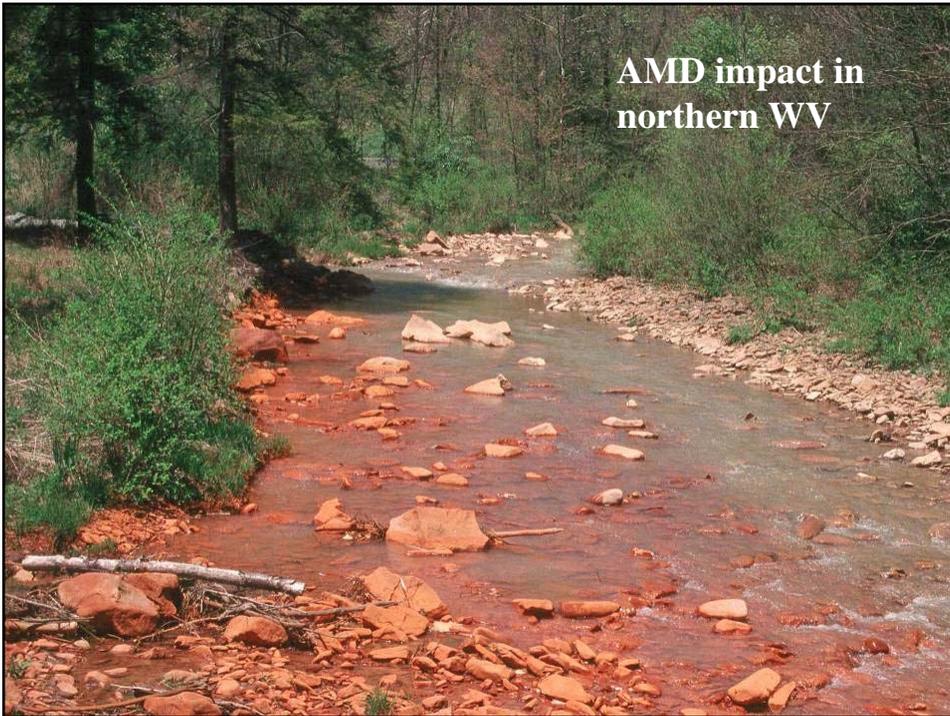
Or **1% pyritic S** in a soil or sediment will generate acidity to require addition of:

- **32 tons of lime per acre 6 inches deep** (tons of agricultural lime per thousand dry tons soil).
- **~ 32 x 50 lb bags of lime per 1000 square feet** incorporated to 6 inches.

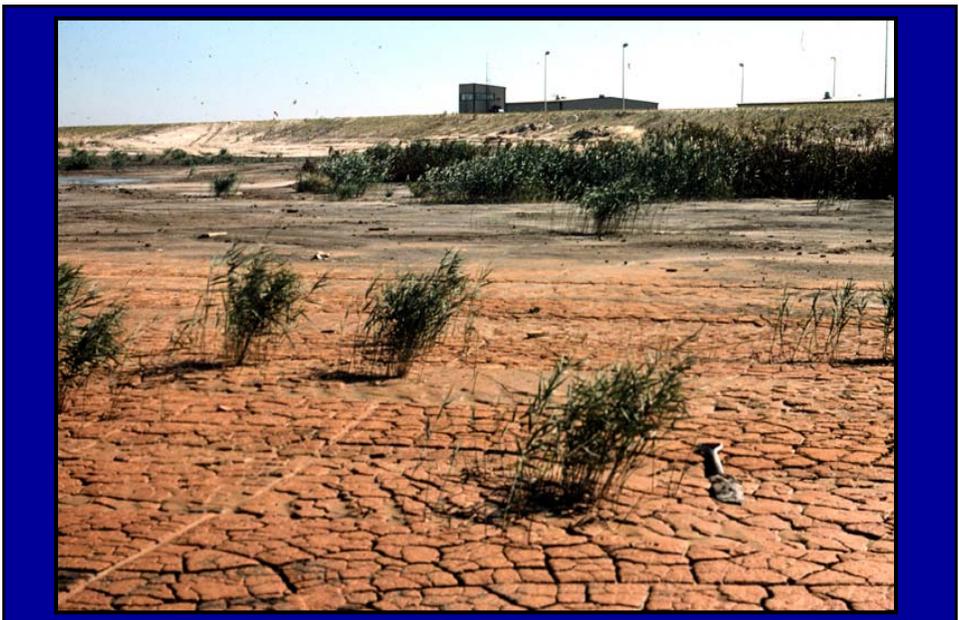
**Acid sulfate coal mine spoils  
exposed in SW Virginia. These  
were over 30 years old.**



**AMD impact in  
northern WV**



**Acid sulfate materials from dredging in Queensland mangrove area.**



**Phragmites reeds begin to invade acid sulfate soil in sulfidic dredge materials at Hart-Miller Island (MD)**

**Acidic, high S Pb/Zn smelter slag site in Katowice Poland in 1994. Materials were 3 to 10% total-Zn, > 1000 ppm water soluble Zn, and > 90 ppm water soluble Cd.**



**Revegetated metal slags in Poland after 10 years.**

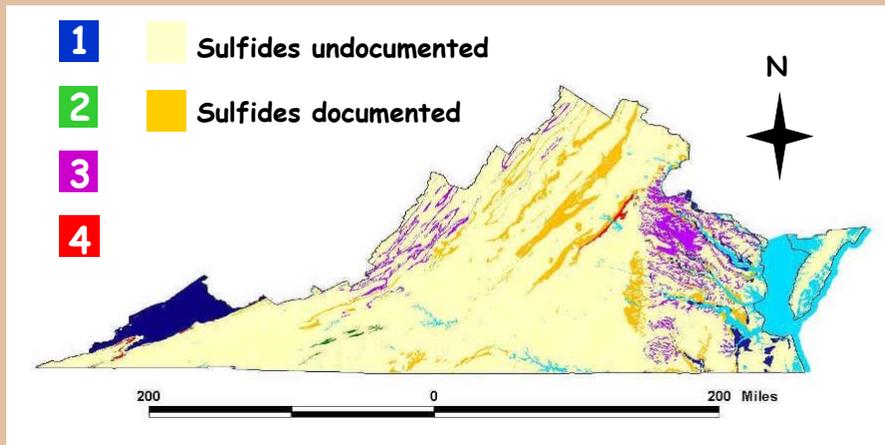


**More on  
remediation  
later!**



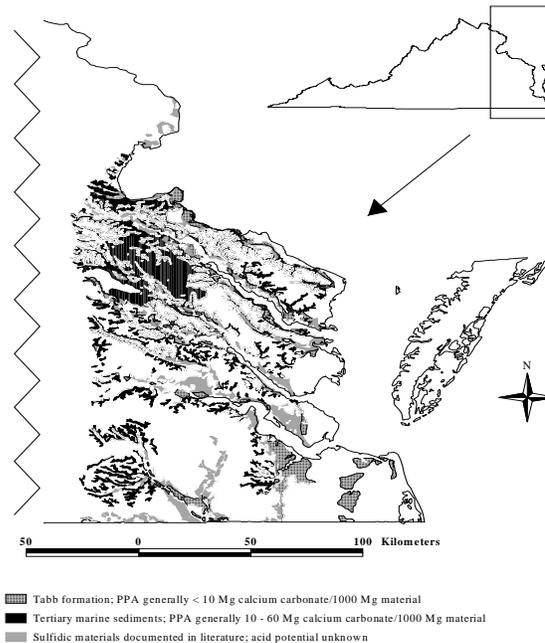
Enough of the world view; why are we talking about this today in Fredericksburg?

### Compiling a state-wide sulfide hazard map for Virginia: the final map. Orndorff 2001



**Extent of acid-sulfate forming materials in Virginia Coastal Plain of Virginia that are within excavation depths (5 to 20 m). The darker shaded tertiary aged marine sediments are the most extensive and damaging.**

**However, a belt of Piedmont materials just to the west of Fredricksburg and Stafford is actually much more problematic!**

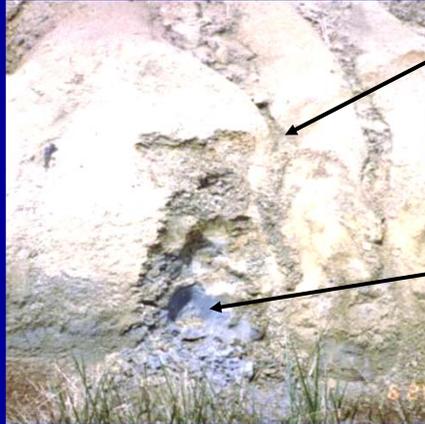


## **What are acid sulfate soils?**

**Soils formed from the weathering of sulfide-bearing parent materials, which results in extremely low pH (commonly < 3.0), soluble metals and precipitation of sulfate salts.**

- **Sulfidic materials** contain sulfides
- **Sulfuricization** refers to the oxidation processes
- **Post-sulfuricization soils** remain strongly acidic for decades, but can actually increase up to ~ pH 3.8 to 4.2 over extended periods of time

## Typical young acid-sulfate weathering profile



Overlying oxidized material is typically a light yellowish brown with pH ~ 3. The yellowish salt here is jarosite.

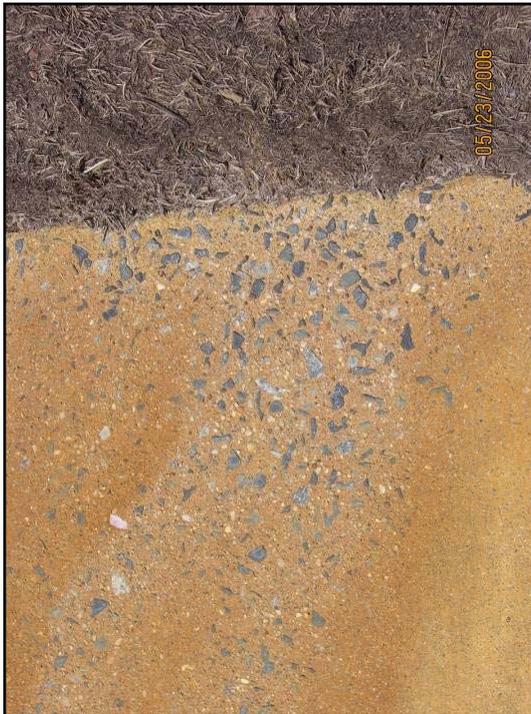
Underlying reduced material is typically drab blue or gray, with pH > 5.5. May be pH 7-8.



Red Fe-stains  
Bare/dead vegetation  
White and/or yellow salts



**Second round of sod placed over pH 2.5 soils at Great Oaks.**

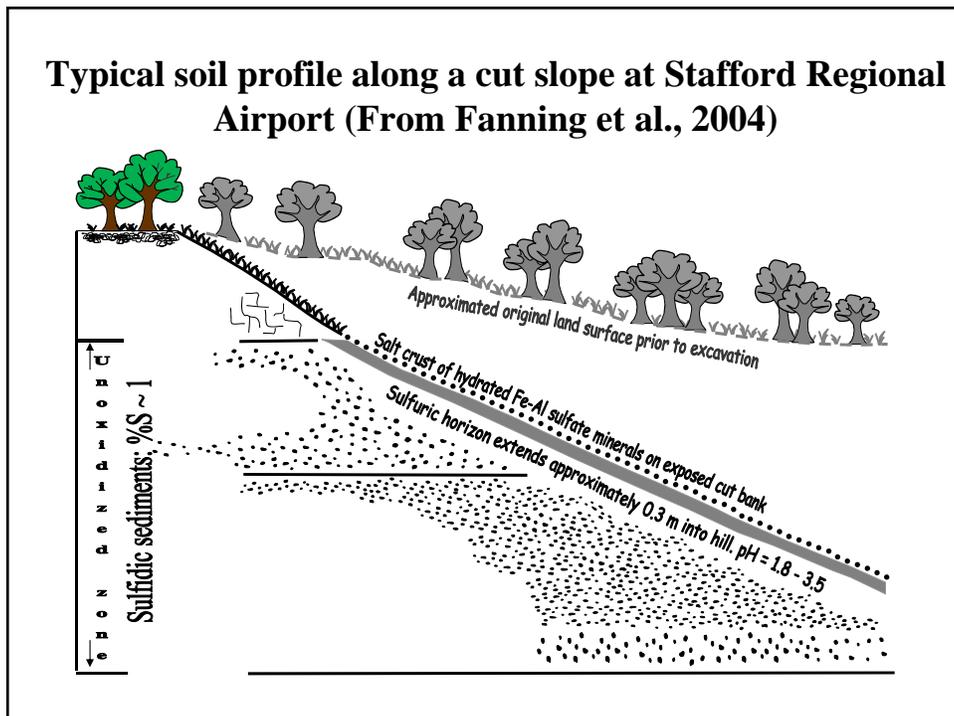


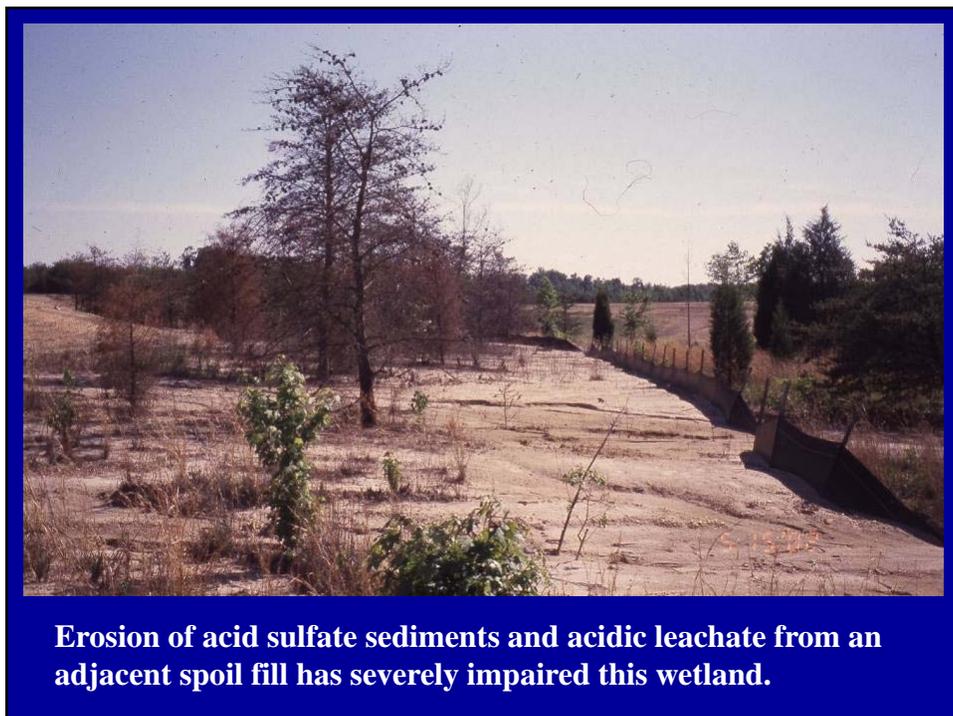
**Cement being stripped out of concrete; leaving aggregate exposed.**



## The “wake up call”: Stafford Airport Project

- Approximately 400 acre cut-and-fill site was initiated in 1998 and supposedly completed in the fall of 2001.
- Site was inadvertently excavated through lower Tertiary sulfidic sediments which contain up to 2% pyritic-S.
- Average soil pH was less than 4.0; many areas were less than 3.0; some were 1.8!
- **Important:** We have no native vegetation adapted to the combination of  $\text{pH} < 3.8$  coupled with high salts!







## **Acid Attack on Concrete**

- (1) Direct dissolution of cementitious materials due to their high solubility in acids,
- (2) formation and expansion of highly hydrated Ca-sulfates like ettringite under moderate to high pH,
- (3) formation and expansion of hydrated Ca-Si-sulfates like thaumasite, and
- (4) formation of complex Fe-hydroxy sulfates which may also infiltrate the concrete structure leading to significant swell and matrix shatter.



**Compiling a state-wide sulfide hazard map for  
Virginia: Devonian black shales.**



Inside the culvert at Clifton Forge.

## **Acid-S Attack on Metal**

**Direct dissolution of metals at  
low pH.**

**Salt induced corrosion.**



## Compiling a state-wide sulfide hazard map for Virginia: Tertiary marine sediments.

Within 5 years, erosion has removed over 30 cm of sediment...



...and the guardrail is severely corroded.

## Sulfate Minerals -- Expansive

### Ettringite



### Thaumasite



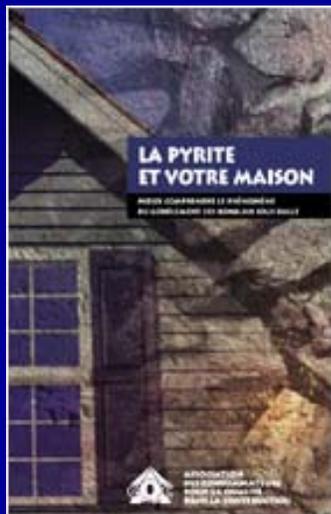
## Expansive pyritic shales

Sulfides may convert to sulfate minerals that occupy several times more volume.

The forces exerted by this expansive crystal growth may result in heaving which affects overlying structures.

Heaving also may result in slope instability and landslides along roadcuts.

## Expansive pyritic shales are notably problematic around Montreal, Canada



A Canadian consumers group (ACQC) publishes this pamphlet to promote public awareness of expansive pyritic shales. According to this group about 10,000 houses in eastern Canada are thought to be affected by pyrite oxidation.



Cracks in basement floor due to sulfide/sulfate-induced shale heave.



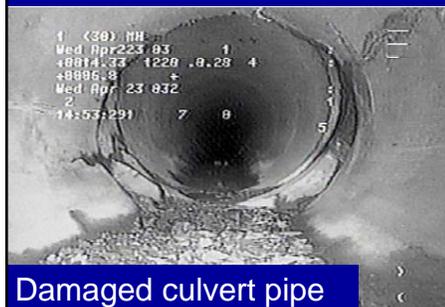
Pavement surface distortion



Displaced curb and gutter above culvert

### Sulfide-induced shale heaving in Bristol, VA

Pictures from report to VDOT by Thomas E. Freeman P.E., available online



Damaged culvert pipe



Shale borrow site

## Remediation Options?

- Recognize and avoid it first!
- Sample it and run appropriate lab analyses
- Add lime to offset potential acidity. May need lots of lime!
- Add organics like composted yardwaste or om biosolids
- Place it *quickly* below the permanent water table
- Keep groundwater out of it
- Apply protective coatings to concrete and metal
- More later on this!



**Remediated yard, summer 2006**

**Neighbor's yard, Summer 2006**

