ACID SULFATE SOILS OF THE U.S. MID-ATLANTIC/CHESAPEAKE BAY REGION

Tour July 6-8, 2006

For 18th World Congress of Soil Science

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Table of Contents

OVERALL INTRODUCTION

First, some comments on various items in the guidebook. In part I, various writings are provided as background information for the tour and for general education purposes. Some of these are like extended introductions to the trip. The first and longest of these, by me, Rabenhorst and Sullivan is a history of the recognition of acid sulfate soils and the development of information about them, which comes down to the region of the trip. A second document, by Martin Rabenhorst, pertains to sub-aqueous soils. This topic should be of interest because we will consider sub-aqueous soils, particularly at the first stop, and many tour participants may not be well versed in concepts about these soils that have only been developed in the last few years. The third document, by Charles Hanner, Jim Brewer and Susan Davis of USDA NRCS, pertains to the geologic and geographic background of the Mid-Atlantic region going back to when, before continental drift, the region may have been connected to what is now North Africa. A fourth document, by John Wah and Jonathan Burns pertains to the cultural history of the region -- this document is not slated much at acid sulfate soils, but I thought that people visiting this region would like to be briefed on the occupation of this region by humans going back to the earliest Native Americans.

Part II of the guidebook provides information on the soils to be examined at each of the 9 official stops of the tour, plus a little information on some unofficial (not numbered) stops that we hope to make if there is sufficient time. The tour will examine tidal marsh and sub-aqueous soils at Stops 1 and 2, which are potential acid sulfate soils. Active acid sulfate soils in uplands will be examined at Stops 3, 5, 6 and in dredged materials at Stop 9. Post-active acid sulfate soils will be examined at Stop 4. At Stop 7, at Prince William Forest Park in VA, we had hoped to be able to visit the site of an old pyrite mine. Unfortunately, to see the site of the old mine and associated spoil -- some of which laid un-vegetated for about 80 years because of the severe acid sulfate soil conditions – we would have to walk about 45 minute to the site and 45 minutes back. I decided that we shouldn't do that. Instead we will have lunch at the park at the Turkey Run Education Center where there will be the opportunity to learn about the mining and the reclamation from a Power Point presentation provided by the park that we plan to run while we eat.

A variety of different soils, including non-acid sulfate soils, as monoliths will be available for viewing at Stop 8 when we visit the University of Maryland Soil Monoliths Collection in H. J. Patterson Hall on the campus in College Park, MD. Here we will also hear about acid sulfate soils problems on the campus itself and we hope also to be able (time-permitting) to examine an exposure of pyrite-containing lignite exposed in an eroding cliff face along the Paint Branch Creek that we think is representative of some of the geologic materials that underlie the University.

This tour has been planned and worked on for several years after it started to be conceived at the 5th international acid sulfate soils conference in Australia in 2002. Efforts began in earnest after Leigh Sullivan came to Maryland in the spring of 2004 and he, with Maryland graduate student Cary Coppock and I drove to Maryland's Eastern Shore and met with Jim Brewer, NRCS soil scientist there, and others to begin to plan the stops in that region. Leigh and I also spent a day with Susan Davis, NRCS soil scientist on Maryland's Western Shore, in the area commonly referred to by Marylander's as Southern Maryland, to look at some exposures there, one of which, Stop 3, will be visited on our tour.

I was fortunate to work with Lee Daniels and Zenah Orndorff of Virginia Tech on some acid sulfate soil exposures along the I-95 corridor in Virginia, particularly at the new Stafford County Regional Airport (Stop 5), where a huge area of active acid sulfate soils developed on exposures made in the building of the airport at the beginning of the 21st century, which we reported on at the 5th international conference in 2002. The Virginia folks informed me and helped to gather information on other sites along I-95. I already knew of the old pyrite mine site at Prince William Forest Park (Stop 7). Unfortunately the pyrite mine site/spoil, which has been reclaimed in the last few years, has turned out to be too far of a walk for the tour to visit, but we will hear about it when we stop at the park for our lunch on Saturday, July 8. The National Park Service personnel at the park have been very helpful in facilitating our visit to the park.

My colleagues and several departmental graduate students at the University of Maryland have been very helpful in planning and in gathering information on the stops to be visited on the trip and in preparing stuff for this guidebook. We have benefited greatly from having Dr. Rabenhorst be able to devote time to help prepare for the trip and to be able to come along for most of the tour with graduate students from the university to help with explanations etc. In this regard we benefited from the cancellation of other pre- and post-conference tours because Marty has been Co-Chair of the overall 18th WCSS tours committee. The cancellation of the other tours has permitted Marty to have more time for us. Graduate student Philip Zurheide has been especially instrumental in all kinds of help, to the extent that he has become an official leader of the tour. Other students and former students have helped as well, even to helping to gather the words for some soil songs for us to sing along the way when we get bored on the long drives between stops.

We were encouraged by the WCSS tours committee to get WRB classifications for soils to be examined on the tour. We were very fortunate that Otto Spaargaren in the Netherlands was able to give us such a fast turn around to provide WRB classifications based on the information that we sent to him. These classifications, along with *Soil Taxonomy* classifications are provided, sometimes with additional comments on the classifications, for all the official stops of the trip.

I hope that participants enjoy this trip and learn a lot about soils and environmental issues. I apologize for the long distances that we must travel in such a short time, but it seemed to be the only way we could show the things that we wanted to show in the time available. We thank tour participants for your support, without it we would not have been able to have this tour. We ask everyone on the tour to be careful to protect your health and that of your fellow tour participants and tour leaders and others that we encounter along the way. The weather is likely to be hot and humid. Drink plenty of water and use sun screen and other protective measures as deemed advisable.
Delvin (Del) S. Fanning, June 26, 2006. Slight modifications, 8/15/06, DSF.

SOME HISTORY OF THE RECOGNITION OF AND THE DEVELOPMENT OF KNOWLEDGE ABOUT ACID SULFATE SOILS -- INTERNATIONALLY, AND IN THE U.S. (ESPECIALLY IN MARYLAND AND IN NEARBY STATES)

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The purpose of this section is to put the topic of acid sulfate soils in perspective for the field tour (July 6-8, 2006) that will examine some acid sulfate soils in the Mid-Atlantic/Chesapeake Bay region of the U.S. in connection with the World Congress of Soil Science (July 9-15) in Philadelphia, PA, where there will also be a symposium during the morning of July 10, 2006 on acid sulfate soils and their management organized by Leigh Sullivan, current Chair of the International Acid Sulfate Soils Working Group.

By and large, there has been little recognition of acid sulfate soils in the United States by the international community of soil scientists, including many in the U.S. This tour hopes to demonstrate that acid sulfate soils are extensive in the U.S., especially if these soils are defined to include naturally occurring post-active acid sulfate soils. Although this tour is confined to the Mid-Atlantic/Chesapeake Bay region, similar kinds of things could be demonstrated in other parts of the country, although there is no other coastal inland sea comparable to the Chesapeake Bay.

EARLY AND PRESENT INTERNATIONAL (BEYOND U.S.) RECOGNITION OF ACID SULFATE SOILS

Pons (1973) for the first (1972) international acid sulfate soils symposium (Dost, 1973) gave a historical summary of the recognition of acid sulfate soils in the Netherlands and Northern Europe. He noted that such soils were recognized in the Netherlands by Linnaeus in the 18th century, who called them *argilla vitriolacea* meaning “clay with sulfuric acid”. They subsequently were recognized in northern Europe with terms such as *cat clay* (Dutch *Kattekleigronden*) or *Maibolt* (for hayfields under the influence of an evil spirit or the devil) or *Gifterde* (for poison earth) in Germany (Pons, 1973; Benzler, 1973). The term acid sulfate soils came into use for the first international acid sulfate soils symposium in 1972. The term caught on quickly with soil scientists who deal with these soils and has been heavily used in subsequent years. Usually these soils were recognized in Europe for tidal marsh soils and for land reclaimed from the sea (polders and associated soils) that had accumulated sulfide minerals during the deposition of the soil/sediments through the reduction of sulfate from sea water by the overall process that may be referred to as sulfidization (Fanning and Fanning, 1989; Fanning et al., 2002), or pyritization (Rickard, 1973).

Pons (1973) also provided a broad definition of acid sulfate soils as all soils in which sulfuric acid may be produced, is being produced, or has been produced in amounts that have a lasting effect on main soil characteristics. This definition includes potential, active, and post-active acid sulfate soils, three broad genetic kinds that continue to be recognized (e.g. Fanning, 2002).

Pons and others from the Netherlands organized, with strong local support in each case, three more international acid sulfate soils symposia. These were held in tropical regions. In each case, the symposium proceedings were published by ILRI (the International Land Reclamation Institute, Wageningen, The Netherlands). The second (Bangkok) symposium was held in Thailand and Malaysia in 1981 (Dost and van Breemen, 1982). The third (Dakar) symposium was held in 1986 in West Africa with field trips in Senegal, Gambia, and Guiné Bissau (Dost, 1988). The fourth was held in Vietnam in 1992 (Dent and van Mensvoort, 1993). These symposia emphasized acid sulfate soils developed in recent coastal (tidal) sediments and measures for their reclamation and management. However, they also contained some reports pertaining to acid sulfate soils in other environments. In some cases social impacts of the soils were also considered.

There were plans after the symposium in Vietnam for a fifth international symposium to be held in Indonesia, where much collaborative work and research on acid sulfate soils between the Dutch and Indonesian workers took place (e.g. AARD and LAWOO, 1990), but this symposium never took place because of political difficulties. ILRI also published a book by David Dent (Dent, 1986) that summarized much of the existing knowledge and literature on acid sulfate soils. This book again emphasized coastal acid sulfate soils.

In the late 1990's, and in the 21st century, vigorous acid sulfate soils research and education programs have developed in Australia, where up until 1990 acid sulfate soils had previously been recognized by only a few soil scientists such as Pat Walker (1963). Since the early 1990's acid sulfate soil materials have been described in Australia using a variety of approaches depending on whether the purpose of the description is for soil classification, general communication, or management, as summarized below.

> **For classification**. In 1996 Ray Isbell in the Australian Soil Classification adapted the USDA *Soil Taxonomy* approach for the definition of acid sulfate soil materials for rigorous soil classification purposes. The Australian Soil Classification (Isbell, 1996); and the more recent 2002 edition (Isbell, 2002) divides acid sulfate soil materials into *sulfidic* and *sulfuric* along similar lines to that currently used by *Soil Taxonomy*. For example, an incubation technique is used for the determination of *sulfidic materials*.
>
> **For communication with lay audiences**. In Australia presently, the two acid sulfate soil taxonomic terms, sulfidic and sulfuric, have been 'translated' into: *potential acid sulfate soil materials*, and *actual acid sulfate soil materials*, respectively for general communication purposes with land managers. The term *actual acid sulfate soil materials* generally corresponds to the *sulfuric horizon* as used in the USA.
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> Previously in Australia, and still there today for the purpose of extension to the public a simple definition of acid sulfate soils has been employed by some agencies (e.g. http://www.agric.nsw.gov.au/reader/10742), simply that they are soils that contain iron sulfides. Fanning (2002) has pointed out that "this

> definition calls attention to the minerals that cause acid sulfate soils to become acid, however, it neglects to consider that how acidic the soils become depends on the balance between acid forming substances (mainly iron sulfides) and the substances (minerals) that neutralize acidity, most commonly calcium carbonate minerals. This simpler definition also does not recognize the genetic distinction among the potential, active, and post-active stages of development of acid sulfate soils". Fanning (2002) has also noted that Australians, for practical purposes such as in the web site noted above, have tended to use the terms potential acid sulfate soils and active acid sulfate soils differently than elsewhere. These terms have been used for soil materials from the un-oxidized vs. the actively oxidizing parts of the profiles of acid sulfate soils, roughly synonymous with (but less technically defined than) the terms *sulfidic materials* vs. the *sulfuric horizon* of *Soil Taxonomy* (Soil Survey Staff, 1999, 2003), such that potential acid sulfate soils and active acid sulfate soils can exist in the same soil profile if it is one that has been opened to surface oxidation. These definitions seem to have worked well for educating the public about the hazards and management of acid sulfate soils in coastal parts of Australia, even if they do ignore the grander vision of soil as an organized natural body as promoted in *Soil Taxonomy* and in soil science textbooks such as Fanning and Fanning (1989).
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> **For management**. Since 1998 for acid sulfate soil management purposes, the reduced inorganic sulfur content (also called the oxidizable sulfur content and consisting mainly of pyritic sulfur) has been recommended in Australia as the soil property that should initially be used to estimate the potential acidity risk upon disturbance of a soil material and to trigger the need for the preparation of a detailed Acid Sulfate Soil Management Plan for the site containing that soil material (Stone et al., 1998). The reduced inorganic sulfur content action criteria depend on factors such as soil texture and are as low as 0.03 %S. If the need for an Acid Sulfate Soil Management Plan is triggered by the presence of soil materials with reduced inorganic sulfur contents greater than the action criteria then an acid/base accounting approach is used within the management plan to estimate the degree of environmental risk associated with disturbance of these materials and to quantify required liming rates (Sullivan et al., 2001; Ahern et al., 2004).

A recent development in acid sulfate soil science and management in Australia has been the recognition that *monosulfidic materials* are widespread in both coastal and inland acid sulfate soil environments (e.g. Bush and Sullivan, 1997; Bush et al., 2000, 2004; Sullivan et al., 2002a and b). Monosulfides can accumulate rapidly in soil materials, are highly reactive, and can decompose rapidly (e.g. within minutes) (Sullivan et al., 2002a; Burton et al., 2006). Monosulfidic soil materials have the ability to affect surrounding environments favorably by immobilizing potential metal pollutants (e.g. Simpson et al., 1998), or detrimentally via their ability to cause severe deoxygenation and acidification upon mobilization in water bodies (Sullivan et al., 2002a) and the consequent release of metals upon acidification (Burton et al., 2006). The recognition of the occurrence and importance of monosulfides in soil materials led in 2005 to the inclusion of *monosulfidic* *materials* as a distinguishing property within mapping units of the Australian National Atlas of Acid Sulfate Soils which is currently being prepared by Rob Fitzpatrick (Stage 1 of the atlas is currently available on the web at <www.asris.csiro.au>).

Australian soil scientists took the leadership to hold a fifth international acid sulfate soils conference (the term symposium was abandoned) in 2002 at Tweed Heads, New South Wales, with field trips in coastal areas of New South Wales and Queensland . Qualifying papers from this conference were published in 2004 in a special issue (Vol. 42, Numbers 5 and 6) of the Australian Journal of Soil Research, which was totally devoted to acid sulfate soils and papers presented at this fifth international conference.

RECOGNITION OF ACID SULFATE SOILS IN THE UNITED STATES

Development of Concepts for the Classification of Acid Sulfate Soils in *Soil Taxonomy*

Acid sulfate soils, under the name of cat clays, were recognized in the U.S. in the 1950's and 60's. Charles Kellogg, Assistant Administrator of the USDA SCS (Soil Conservation Service) invited C. H. Edelman, Dutch Soil Scientist at the University of Wageningen, and J M. van Staveren, drainage engineer with ILRI, to come to the United States from the Netherlands for a tour with USDA SCS personnel of marsh soils along the Gulf of Mexico and the Atlantic Coasts, from Texas to New Jersey -- to compare them with marsh soils in the Netherlands and to judge the potential of these soils in the U.S. to be reclaimed for agricultural and other uses. Edelman and van Staveren's (1958) report, published in the Journal of Soil and Water Conservation, recognized that many of the marsh soils along the Atlantic Coast had cat clay characteristics, whereas the marsh soils along the Gulf Coast did not acidify severely enough to qualify for the cat clay term in their estimation. They also pointed out that the marsh soils in the U.S. generally did not contain lime (natural calcium carbonate or it equivalent) to the extent of those in the Netherlands. They recognized 4 broad groups of marsh soils in the U.S. in terms of their suitability for drainage and reclamation with the most restrictive being *cat clay* soils. For these soils they recommended that no attempt to reclaim them should be made and that they be allocated for wildlife refuges.

Fleming and Alexander (1961), workers at the SCS soil survey laboratory of that time in Beltsville, MD, published results of characterization studies of some drained (inside dikes) and un-drained marsh soils from along a tidal river in Colleton County, South Carolina. They used the term *cat clay* for these soils with reference to usage of that term in the Netherlands for such soils. Previously-unoxidized samples from these soils greatly acidified upon drying for periods of 1 and 4 weeks. Those already drained (inside dike) under field conditions already had such low pH's (and the presence of jarosite) that they had a *sulfuric horizon* as that term is now defined in *Soil Taxonomy*. Two of these profiles/pedons were subsequently used to demonstrate the concepts of *sulfidic materials* and the *sulfuric horizon* and the great groups of *Sulfaquents* and *Sulfaquepts* in *Soil Taxonomy* (Soil Survey Staff, 1975). See page 568 of that publication for Pedon 42 for the description and data for a *Sulfaquept* (*sulfuric horizon* present) and page 569 for

Pedon 43 for the *Sulfaquent* -- with *sulfidic materials* without an overlying *sulfuric horizon*. Another example of early recognition of presumed acid sulfate soils, without the application of the classification terms, in the U.S was the finding of such soils in the San Francisco Bay area of California (Grass et al., 1962).

The terms *sulfidic materials* and the *sulfuric horizon* were first officially recognized, as were the great groups *Sulfaquents* and *Sulfaquepts*, in *Soil Taxonomy* in the Soil Survey Staff (1975) publication. However, those involved in the development of *Soil Taxonomy* were previously aware of such soils. In the Seventh Approximation (Soil Survey Staff, 1960) the term *n*-value, that has been called Index of Squishiness (Fanning and Fanning, 1989), was already defined (although slightly differently mathematically than at present), relying on the Dutch definition of this term as developed by Pons and Zonneveld (1965). In regard to the great group of *Hydraquents* that contained the soft squishy soil materials with high *n*-value, thus low bearing capacity, Soil Survey Staff (1960, page 108), stated that "it is in this class that many of the undrained cat clays belong". Now such soils with *sulfidic materials* and high *n*-value at shallow depth are classified in *Soil Taxonomy* in the *Typic Sulfaquents* subgroup (Soil Survey Staff, 1999; Soil Survey Staff, 2003), although the *Hydraquents* still exist for those soils that don't have *sulfidic materials* at a shallow enough depth for *Sulfaquents* and a class of *Hydraquentic Sulfaquepts* has been defined, which is what a *Typic Sulfaquent* would be expected to develop into if it was drained and developed a *sulfuric horizon* with soft (high *n*-value) sediments in that horizon or beneath at a shallow enough depth. Draft versions of *Soil Taxonomy* (Soil Survey Staff, 1970) contained definitions of *sulfidic materials* and the *sulfuric horizon* about as they appeared in the later official version (Soil Survey Staff, 1975) five years later.

Although little is written about these matters with which Fanning is familiar, there is no doubt that Guy Smith and others involved in the initial development of the concepts of *sulfidic materials* and the *sulfuric horizon* for *Soil Taxonomy* relied heavily upon the Dutch work on acid sulfate soils and the concepts of potential and active acid sulfate soils that these properties were designed to encompass and classify. Van Breemen (1982) from the Netherlands made strong suggestions for the revision of the initial concepts of these properties at an SSSA acid sulfate weathering symposium in 1979. He proposed the pH drop on incubation way of recognizing *sulfidic materials*, instead of the original definition based on the relative contents of S and calcium carbonate equivalent that is still the WRB (http://www.fao.org/ag/ag1/ag11/wrb/doc/wrb2006final.pdf) definition of their *sulphidic materials*. The *sulfuric horizon* was redefined because of the lack of jarosite in some low pH acid sulfate situations and other matters. Van Breemen suggested that the presence of 0.05 percent or more water soluble sulfate be used as an additional criterion to show when pH's of 3.5 or less are caused by active acid sulfate effects and jarosite is not present.

Building upon van Breemen's suggestions, Fanning and Witty (1993) revised the definitions of *sulfidic materials* and the *sulfuric horizon* and the classes of acid sulfate soils in *Soil Taxonomy* and got them accepted for the classification system as part of the ICOMAQ Committee (chaired by Johann Bouma of the Netherlands) revisions to *Soil* Taxonomy in 1992. They added the criterion of underlying *sulfidic materials* for recognizing a *sulfuric horizon* for cases where jarosite is not present, but the pH is sufficiently low (3.5 or less as measured in water at a 1:1 ratio of soil material to water) and they added a thickness criterion of 15 cm or more. They also dropped the color criteria for recognizing jarosite in the field because they found jarosite (identified by X-ray diffraction) with chromas lower than specified in the old *sulfuric horizon* definition. These revisions first appeared in the fifth edition of Keys to Soil Taxonomy (Soil Survey Staff, 1992).

Some Highlights of the Recognition of and Studies of Acid Sulfate Soils at the University of Maryland (also at Virginia Tech)

Upland Acid Sulfate Soils. Although the term acid sulfate soils was not applied at first, upland acid sulfate soils were recognized on athletic fields at the University of Maryland by Dr. Ed Strickling of the Department of Agronomy in the 1960's. In land shaping and the deposition of spoil for the baseball field (Shipley Field), soil materials containing sulfide minerals (undoubtedly pyrite) were deposited or exposed at or near the surface of the field to such an extent that turf grass could not be established in a number of places. Dr. Strickling, who had already had success in the 1950s in establishing grass and in reshaping the football field (Byrd Stadium) was requested to see if he could do something to establish grass on the baseball field where previously other agronomists and/or horticulturalists had not succeeded with "normal" agronomic/horticultural practices. He found that the soils of the field where grass wouldn't grow were extremely or ultra acid (pH less than 3.5) and he experimented by applying increasing levels of lime to given small areas (e.g. 1 square foot, but incorporated to his depth of interest) to find out how much lime would be required to raise the pH to a desirable level for establishing turf grass. His recommended liming rate from these experiments was 25 tons per acre of ground limestone for a 6 inch (15 cm) layer. To make sure that the pH was raised to a sufficient depth (18 inches or 45cm in his estimation) 75 tons per acre (168 Mg/ha) was added and mixed into the soil of the field to the 18 inch depth with a road grader. The treatment succeeded and grass grew successfully and Ed was thanked by the university with free football tickets to the University football games for a few years for his advice.

University acid sulfate soils experts now think that the bulk if not all of the university is underlain at some depth by *sulfidic materials*, although sulfide-bearing layers are not as uniform as with the Tertiary and Upper Cretaceous glauconitic sulfide-bearing soil materials that occur farther to the east in Prince George's and Anne Arundel Counties. The sulfide-bearing soil materials in the vicinity of the university are Cretaceous geologic materials that contain thin strata of lignite. This lignite typically contains seams of fine-grained, but macroscopic, pyrite that has the typical metallic luster of "fools gold". We hope to show tour participants an example natural exposure of such materials with such lignite and associated pyrite and other acid sulfate features where the Paint Branch Creek has eroded into a steep bank/cliff off Metzerott Road and behind the Comfort Inn on U.S. Rt. 1 in North College Park when the tour comes to the University on Saturday afternoon, July 8.

After Strickling's success in improving plant-growth characteristics of the acid sulfate exposures on the University athletic fields, the standard recommended rate of ground limestone addition to active acid sulfate soils that were occasionally encountered in samples that homeowners and others sent to the University Soil Testing Laboratory (a lab operated by the Cooperative Extension Service and unfortunately recently disbanded because of lessened state/federal financial support) became 25 tons per acre. Samples from such exposures (usually made by deep disturbance of soils of suburban and other "developments") were recognized by the testing laboratory personnel from very low pH's, commonly 3 or less, often accompanied by high soil electrical conductivity.

Ed has also noted that concrete corrosion problems, presumably from acid sulfate effects, were also noted in the east end of the football (Byrd) stadium on the campus, which required extensive renovation. This was after the problems in establishing turf on the baseball field were encountered.

As upland acid sulfate soil exposures were repeatedly encountered in the Coastal Plain and elsewhere in the state of Maryland (e.g. associated with surface mining of coal from Paleozoic rocks in the western part of the state), research into the nature of these soils and the geologic formations with which they were associated was done. Dan Wagner included a section on these soils in his M.S. thesis (Wagner, 1976) and he went on to do his Ph.D. dissertation on these soils and associated post-active acid sulfate soils (Wagner, 1982). A major publication out of some of Dan's and associated work was the Wagner et al. (1982) chapter in the SSSA Acid Sulfate Weathering publication (Kittrick et al., 1982). From a practical point of view, it is important, with upland soils that have *sulfidic materials* in the un-oxidized zone beneath them, to know the depth at which the *sulfidic materials* occur. In his M. S. thesis, graduate student Terry Valladares (1998) observed that the depth to sulfides in the Cretaceous sediments generally ranged between 2 m and 12 m (and sometimes to greater depths in some of the Tertiary deposits) with greater depths to sulfides occurring where there was a higher degree of geomorphic landscape dissection. He also demonstrated that the depth to sulfidic materials could be modeled based upon a simple geomorphometric parameter called point relief (the difference in elevation between the point of interest and the hydrologic base point in the landscape unit) (Rabenhorst and Valladares, 2005).

In spite of some efforts to warn people in communities in the Mid-Atlantic region and elsewhere about the hazards of exposing *sulfidic materials* in construction and other land disturbance projects, upland active acid sulfate soil exposures have continued to come into being, as will be illustrated at several stops on the present tour (e.g. at the Stafford County, VA, Regional Airport, Fanning et al., 2004). Also, it has been found that in several places in New Jersey and in other states in the region, clayey *sulfidic materials* have been and continue to be used to cap landfills (Kargbo et al., 1993; Fanning and Burch, 1997; Fanning et al., 2002) in spite of some warnings by U.S. EPA (Kargbo, 1993) about the potential dangers of this practice. In the last two years (2004-2006) acid sulfate soils educational symposia aimed at engineers and other land evaluators and managers, as well as at soil scientists, have been held in Maryland and Virginia by MAPSS and VAPSS and University of Maryland and Virginia Tech soil scientists.

However, so far no strict laws or regulations have been developed in any of the states of the region to control soil disturbances that might give rise to active acid sulfate exposures – like what have been developed in Queensland and New South Wales in Australia. Undoubtedly exposures will continue to be made in the Mid-Atlantic and in other regions of the U.S. and the world until sound regulations are developed and enforced.

Studies of acid sulfate soils and reclamation strategies for them have also proceeded at Virginia Tech, Blacksburg, VA, where much work, not described here, has been done over many years on soils brought into existence by surface mining, primarily for coal in the Appalachian Mountains. W. L. (Lee) Daniels as well as scientists at other universities in the region (e.g. West Virginia, Kentucky, Ohio State) have conducted much research on "mine soils" and on AMD (acid mine drainage). More recently, in connection with highway construction in Virginia, it was found that active acid sulfate soils have been brought into existence at constructions sites throughout much of the state. To help to avoid these occurrences in the future, information was collected on the acid sulfate hazards associated with various geologic formations from throughout the state by Zenah Orndorff for her Ph.D dissertation (Orndorff, 2001). Recently Daniels and Orndorff have become involved with the recognition and reclamation of active acid sulfate soils in the Coastal Plain and Piedmont, as well as in the Appalachian Mountains regions of VA (and other parts of the country and the world – e.g. work by Dr. Daniels in mining areas in Poland). They have also conducted research related to ARD (acid rock drainage) (Daniels and Orndorff, 2003).

Three examples of this work, to be seen on this field trip, include 1) The Mine Road site by Garrisonville in Stafford County, VA (Stop 6), 2) the previously mentioned Stafford Regional Airport (SRAP) (Stop 5), and 3) the extra stop at the Great Oaks subdivision in Fredericksburg, VA. When notified of a possible acid sulfate site, current standard protocol by Virginia Tech is to conduct a field investigation, procure soil and drainage samples, complete laboratory analyses, and develop a reclamation prescription based on sample characteristics and site specific conditions. The prescriptions are largely based on values for potential peroxide acidity (PPA) – a procedure used to predict liming requirements based on the total acidity produced after complete oxidation of a sample by hydrogen peroxide (Barnhisel and Harrison, 1976). Two points that are strongly emphasized are that the lime must be thoroughly incorporated to at least 6 inches and that seeding should be completed only during established planting dates in the fall or spring. Fertilization needs also are addressed, and incorporation of organic amendments or topsoil covers is typically recommended but is not always essential for reclamation success. (Note – this paragraph contributed by Zenah Orndorff, Virginia Tech University)

Tidal Marsh Soils. In the 1970's work began in Maryland to improve the classification and mapping of tidal marsh soils, which are extensive in counties surrounding the Chesapeake Bay. Previously these soils were recognized only as generalized mapping units called tidal marsh (e.g. Miller, 1967). These efforts took place in work that led to the M.S. thesis by Bob Darmody (1975) and other publications (Darmody and Foss, 1979a; Darmody and Foss, 1979b). It was found that the tidal marsh soils contained high quantities of S and it was realized that these soils were potential acid sulfate soils. An important distinction by Darmody was the recognition of three broad geomorphic groups of tidal marsh soils. The <u>submerged upland type</u> was found to be the most extensive kind around the Chesapeake Bay where sea level is slowly rising relative to the land surface, where firm buried soils, typically under a peaty cover, have evidence that they were once above sea level – e.g. the presence of buried argillic horizons (Stolt and Rabenhorst, 1991). <u>Estuarine tidal marsh soils</u> were recognized along tidal rivers in soft sediments deposited in the rivers. <u>Coastal tidal marsh soils</u> were recognized in/over typically sandy deposits associated with the barrier beach islands etc. along the Atlantic Coast.

As part of Darmody's work, university workers searched for improved and more rapid ways of doing soil sulfur analyses. X-ray spectroscopic methods were developed that were thought to be very good until they were tested on some National Bureau of Standards samples. After that it was realized that the X-ray spectroscopic response from a given quantity of S was highly dependent on the form of S present in the sample (pyritic vs. organic vs. various sulfates) as well as upon particle size. However, a whiff-test field test based on the intensity of hydrogen sulfide odor that emanated from the marsh soils proved to be quite useful and it correlated with the level of S in the soils as measured by X-ray spectroscopy for the marsh soils (Darmody et al., 1977).

Briefly, the whiff levels recognized were:

3. The odor of H_2S is detected when one is just walking over the marsh.
2. The odor is only detected as one starts to dig or auger a hole in the marsh.
1. The odor is only detected when one brings some of the soil material close to the nose.
0.5. The odor is not detected until the nose gets dirty as the material is brought closer and closer.
0. No odor is detected regardless …

The whiff-test did not work with the upland S bearing deposits because new H_2S is generally not being actively generated in the upland situations -- as it is in the marsh environment where sulfidization is fed by sea water sulfate.

Subsequently Snow (1981) developed accurate X-ray spectroscopic S analytical methods for total S by chemical treatments that converted all forms of the S in a sample to a sulfate form. Snow also developed methods for measuring various forms of S in soil samples. These methods have not continued to be applied for S and other analyses of acid sulfate soils in our University of Maryland programs because of their time-consuming nature and because of changes in personnel and personal preferences, and also now because an X-ray spectroscopy instrument is no longer available.

<u>Acid sulfate soils in dredged materials</u>. In the early 1980's, Fanning and others at the University of Maryland became involved in a large amount of research on acid sulfate soils developed in DM (dredged materials), at first at the behest of MPA (Maryland Port Administration) -- which contracted workers in the Agronomy and Horticulture

Departments to examine soils developed in DM from Baltimore Harbor that contained high levels of heavy metals (Zn, Cd, Cu, Ni etc.). This work was in part to learn about the bio-availability of the heavy metals, but also to learn about the ability of these soils to produce agronomic and horticultural crops. This work went on for several years, although MPA only financially supported the work for about 2 years. The work led to multiple theses, dissertations, papers and chapters in books as well as to some unpublished reports. Much of this work was reviewed by Fanning and Burch (2000).

Some of the work again related to quantities of lime needed to sufficiently raise the pH for the growth of crops and to the value of some waste materials as liming agents (e.g. Offiah and Fanning, 1994). Other work has pertained to the selection of plant species for use in reclamation efforts (McMullen, 1984). Fanning became attracted to the use of *Phragmites australis*, which tends to naturally invade upon active acid sulfate soils in DM as a monoculture, in a reclamation strategy called “letting nature run its course”. In writings about the reclamation of acid sulfate soils in DM, Fanning and Burch (2000) and Fanning et al. (2002) promoted the “let nature take its course” strategy -- with the idea that after a period of some decades for the sulfides in the upper part of the soils to oxidize away etc., the Phragmites could be gotten rid of by herbicides or by other means and the land managed like a non-acid sulfate soil after neutralization of acidity to the extent needed for the crop or other plants that it would be desired to promote following the Phragmites. Fanning has repeatedly threatened, and aspired, to start a **Phriends of Phragmites Society** to promote wise uses and a better understanding of this generally unpopular, but potentially useful, plant. Professor Pons told Fanning in 1986, when he and his wife Nadia visited Maryland after they and Fanning became friends at the 3rd international acid sulfate soils symposium in West Africa, “**Promote Phragmites”**. In the Netherlands, phragmites are planted on new polders for a short period to hasten the ripening of the initially soft soils/sediments after the building of dikes to turn the sea bottom into cropland. In the future Fanning hopes to become more energetic in promoting Phragmites. Participants of this tour will be offered an opportunity to become members of **Phriends of Phragmites.**

Returning to the heavy metals issues, we at Maryland have learned (e.g. El-Desoky, 1989; Fanning et al., 1988; Fanning and Fanning, 1989, pages 310-311) that Baltimore Harbor DM are high compared to most other soils and compared to tidal marsh soils in the state other than those close to Baltimore (Griffin et al., 1989; Griffin and Rabenhorst, 1989) in heavy metals and that the bulk of these metals in the raw (unoxidized) DM are present in the materials as sulfides. Upon oxidation and active sulfuricization the metals are mobilized as metal sulfates and move with the water that passes through the soils, although they can be illuviated deeper in the soils if they encounter sufficiently reducing conditions. The association of heavy metals with sulfides and glauconite (a micaceous silicate mineral that forms under marine conditions) in upland soils and sediments of Tertiary and Cretaceous age was also documented (Rabenhorst and Fanning, 1989).

Recently acid sulfate soils in dredged materials were examined in Somerset County, MD (Demas et al., 2004), where dredged materials were shown to have been deposited in diked containment structures directly on the surface of tidal marsh soils over a period of many years going back to at least the 1940’s. Leachates from some of these soils were shown to have penetrated beneath the dikes and to have formed ironstone on beaches by the tidal Pocomoke River outside of the dikes. Some of the active acid sulfate soils, in materials deposited 60 or more years prior to examination, were shown to have developed to an early post-active stage of development so as to qualify for placement into the *Sulfic Endoaquepts* subgroup by *Soil Taxonomy*. Soils in more recently deposited DM in the same area were active acid sulfate soils that classified as *Typic Sulfaquepts*. Some documentation was provided in the paper that drainage waters from these soils, particularly following long dry periods, may have contributed to lesions on fish and fish kills in the Pocomoke River Sound near the DM deposition site that previously have been linked to the dinoflagellate *Pfisteria piscidia*.

A relatively new reclamation strategy using dredged materials is to restore tidal marshes that are or have been eroded away using dredged materials contained at sea level. Some of this has been done on an experimental basis at the Black Water Wildlife Refuge close to Stop 2 of the tour. Workers in our programs have not been directly involved in this work, although Dr. Needelman has become involved to study the rate of carbon sequestration in such marshes.

Overall and Continuing Studies. Rabenhorst and his students and colleagues have in recent years made many advances in studies of acid sulfate soils. One important advance has been to learn how rapidly iron sulfides can form in our tidal marsh soils when the ingredients to form them are present. In “burial studies”, it has been learned that if an iron (hydr)oxide bearing soil material is buried in a tidal marsh soil in a porous container that the iron (hydr)oxides in the outer portion of the buried soil material are rapidly (noticeably within a matter of months) converted to iron mono- and di-sulfides, with framboids forming in less than two years (Rabenhorst, 1990). These studies have demonstrated that one limitation to the accumulation of iron sulfides in our peaty tidal marsh soils is the supply of iron providing minerals (Rabenhorst and James, 1992).

Work by graduate students Joey Shaw and Mark Magness demonstrated that the processes of sulfidization could be optimized in constructed wetlands in order to remediate metal contaminated acid waters flowing from mining sites (Rabenhorst et al., 1992, 1993; Magness, 1996). In Magness’ laboratory scale wetland mesocosms designed to treat acid mine drainage, both pyrite and greigite were shown to form within one year as well as more labile monosulfides.

Other studies (e.g. Haering et al., 1989; Hussein and Rabenhorst, 1999) have shown that large quantities of the S in the organic soil materials in our tidal marsh soils occur in organic form and that organic soil materials of tidal marsh soils are resistant to and/or are slow to drop sufficiently in pH during incubation to be recognized as *sulfidic materials* in spite of the presence of large amounts of total (and Cr-reducible) S in the soil materials. This may relate in part to the buffering of the pH by the organic soil materials.

The presence of *sulfidic materials* in most subaqueous soils, sufficient to cause them to qualify for Sulf great groups by *Soil Taxonomy*, in spite of rather low levels of total S present (in sandy sediments), is a recent interesting finding as demonstrated by data collected by Cary Coppock for his M.S. thesis as shown in other parts of this tour guidebook – see information for Stop 1 of the tour.

Studies by Hussein and Rabenhorst (1999) employing what has been termed the chrono-continuum approach (Rabenhorst, 1997) have provided information on the rate at which organic soil materials (Hussein et al., 2004) and S accumulate in tidal marsh soils that are slowly becoming progressively more submerged in sea water.

As work has gone on, Maryland workers have written other chapters etc. on the recognition of acid sulfate soils and sulfide- and sulfate-bearing soil materials based on soil color (Fanning et al., 1993) and on the minerals found in acid sulfate soils (Fanning et al., 2002). Information about the processes involved in the formation of acid sulfate soils has been summarized under what are called the gross processes of sulfidization and sulfuricization (Fanning and Fanning, 1989; Fanning et al., 2002). These processes were recognized (Fanning and Fanning, 1989) at a similar level in regard to soil genesis as other gross processes such as podzolization, calcification, and salinization.

At present, one of our big interests in regard to post-active acid sulfate soils is in dating the time of formation of jarosite that occurs in some of these presumably old soils. We think this should be possible based on success in doing this by Vasconcelos (at the University of Queensland in Australia) by argon isotope dating techniques for certain landscapes in Queensland (e.g. Vasconcelos and Conroy, 2003). To do this for situations in Maryland,such as for Site 4 of the tour, it will be necessary to purify this old jarosite from other minerals in the same samples, such as glauconite, that are undoubtedly much older than the jarosite, that contain the same isotopes. Our efforts to do this are underway as will be discussed on the trip and in the paper by Fanning et al. (2006) on post-active acid sulfate soils at the World Congress of Soil Science in Philadelphia on July 10, 2006. Graduate student Philip Zurheide, one of the leaders of the field trip, has recently succeeded to purify jarosite from a small vug in a profile of a post-active acid sulfate soil at SERC, to be examined at Stop 4 of the tour. Although only a small quantity has been purified (about 40mg) we are hoping that we can convince Dr. Vasconcelos at the University of Queensland to try to date the material for us.

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Developments in the Concept of Subaqueous Pedogenesis

Martin C. Rabenhorst

The Context

Terrestrial materials deposited in sedimentary environments permanently covered with water have traditionally been assigned to the realm of sedimentary geology. Over the last 50 years or so, there have been several suggestions that these subaqueous materials be included in soil taxonomic systems (Muckenhausen, 1965; Ponnamperuma, 1972). Objections have primarily focused upon the idea that these subaqueous sediments are not, in fact, soils. The ruling dogma at that time made the primary requirement of soil its ability to support the growth of plants. In the first edition of Soil Taxonomy (Soil Survey Staff, 1975), for example, soils were defined as "the collection of natural bodies on the earth's surface, in places modified or even made by man of earthy materials, containing living matter and supporting or capable of supporting plants out-of-doors." Thus, the essential absence of higher plants in many subaqueous environments excluded them from the pedologic realm. A secondary issue was related to defining the boundaries of soil. The first edition of Soil Taxonomy (1975) stated that the upper limit of soils is ".... air or shallow water. At its margins it grades into deep water or to barren areas of rock or ice." Thus, these materials were additionally excluded from being soil by their permanent saturation beneath deep water. Over the 25 years that spanned the development of the 2nd edition of Soil Taxonomy (Soil Survey Staff, 1999) an evolution continued in the thinking of pedologists which allowed a distancing of themselves from their agricultural roots and a loosening of the link in the definition of soils to the growth of plants. Rather, they began to emphasize what had already become deeply entrenched as the foundation to the Taxonomy itself, namely the formation of pedogenic horizons resulting from those generalized processes described by Simonson (1959). For example, based upon such work as that of Jim Bockheim (1990, 1997) and Iain Campbell (Campbell and Claridge, 1987) in Antarctica, where higher plants are not able to grow because of the harsh cold climate, pedogenic soil horizons were observed forming as a result of additions, losses, transfers and transformations. The idea that these areas should be recognized as soils was gaining support among the pedologic community, even though they were not capable of supporting the growth of higher plants.

In the early 1990's as NRCS soil scientist George P. Demas was updating the Worcester County, MD soil survey on the shores of the Atlantic Ocean, the stars were already beginning to align to permit a change in the definition and concept of soil. The area of Worcester County included some 8,000 ha of coastal marshland that had been last mapped in the miscellaneous land type called *Tidal Marsh*. Following the same approach used in the update of Dorchester County, MD it was concluded that these marsh areas would be correlated into soil series that had been established for this purpose. Most of these soils were mapped in consociations of series that were classified as Sulfihemists and Sulfaquents. The story goes that as George was at one point standing on the edge of the marsh he was mapping, and looking down into the tidal water of Sinepuxent Bay, he posed the question "Why should we stop here?" He began to consider that such submersed aquatic vegetation as Eelgrass (*Zostera marina*) and Widgeongrass (*Ruppia* *maritima*) were rooted in these substrates and, as he began to closely examine them, he began to observe what could be construed as pedogenic horizons.

George's earliest efforts to gain acceptance of the idea that these shallow water substrates should be considered soils met with mixed reviews. For example, George reported that he was unsuccessful in his attempts to convince Dr. Roy W. Simonson of the merits of this idea during one or more conversations they shared (Demas, personal communication). Nevertheless, he would not be dissuaded and proceeded to publish his first conceptual paper on this idea in Soil Survey Horizons (1993) where he titled his paper "Submerged soils: a new frontier in soil survey." Over the next two years, George was able to convince me that this topic was worth pursuing as a focus of his PhD dissertation, and more importantly, he was able to convince several senior individuals in USDA that this was worth their providing George "release time" and a graduate school fellowship to explore these ideas. Thus, he began his doctoral studies at the University of Maryland in 1995, where we were able to piece together the support needed for equipment and supplies through a grant from the Maryland Agricultural Experiment Station.

Specific Contributions of Demas and Colleagues

The work that was undertaken during the late 1990's resulted in six primary accomplishments or findings.

1. By joining a research grade fathometer with a real time Geographic Positioning System (GPS) (at the same time during which we were recording tide levels to permit correction) we were able to develop a high quality bathymetric Digital Elevation Model (DEM) for shallow water estuaries. This development of bathymetric DEMs, when joined to aerial photography, permitted the identification of subaqueous landforms in a manner analogous to the sub-aerial landforms that soil scientists had been studying for most of the last century (Demas and Rabenhorst, 1998).

2. Examination of the collected cores (using a variety of coring techniques including vibracoring, Macaulay auger for soft materials, and the traditional bucket auger) demonstrated that soil horizons could be recognized and that they appeared to have formed as a result of the generalized processes of additions, losses, transfers, and transformations (Demas and Rabenhorst, 1999). These soils could therefore be classified according to Soil Taxonomy[1].

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[1] Most subaqueous soils are classified in current *Soil Taxonomy* as Aquents or as Histosols. There is a proposal under development (led by Dr. Mark Stolt at the University of Rhode Island) to include a new suborder of Entisols (and possibly Histosols) called Wassents (Wassists) to accommodate subaqueous soils. A draft version of the great groups of Wassents is provided later in this document.

3. It was observed that similar soils occurred or formed on similar landforms. Therefore, it was possible to utilize a “soil-landscape” paradigm for the mapping of soils in the subaqueous environment, as is usually done in the sub-aerial environment.

4. Specific soil-landscape relationships were beginning to be documented for the coastal lagoons of the Mid-Atlantic USA.

5. A framework or foundation for understanding the genesis of subaqueous soils (SAS) was established.

6. Proposals were made that led to the first official soil series (six of them - Demas, Trappe, Whittington, Tizzard, Southpoint, Sinepuxent) that were established for SAS (Note that one of these soils was renamed Demas, in honor of the late George P. Demas, whose untimely death in 1999 came as a heavy blow to all who knew and worked with him).

Soil Genesis in Subaqueous Environments

In considering the genesis of SAS, similarities to processes and factors described by Jenny (1941) were recognized, but significant differences were also noted. The generalized model for estuarine sediments (Se) of Folder (1972) was noted where he described their origin as being derived from source geology (G), bathymetry (B), and hydrologic condition (H) (flow regime).

$$Se = f\,(G, H, B)$$

In 2001, a new state factor equation for the formation of SAS was proposed (Demas and Rabenhorst, 2001).

$$Ss = f\,(C, O, B, F, P, T, W, E)$$

In this equation, which preserves and modifies some of Jenny’s and Folgers’ concepts and adds some new ideas, Ss is subaqueous soil, C is climatic (temperature) regime, O is organisms, B is bathymetry, F is flow regime, P is parent material, T is time, W is water column attributes, and E is catastrophic events.

Climatic regime (C), was not included in Folger’s equation, and does not include precipitation as in Jenny’s model. The climatic component in this model primarily represents temperature. Temperature, for example, will affect the rate of organic matter decomposition (and other biogeochemical reactions).

Organisms (O) was also not included by Folger, and represents the role that biota play in subaqueous pedogenesis. As an example, the burrowing of benthic organisms (essentially irrigating their burrows with oxygenated water) often contribute to the development of light colored, surface horizons (some thin oxidized zones may be the result of diffusion of oxygen from the water column rather than biotic influences).

Bathymetry and flow regime (B and F) replace relief (R) in Jenny’s equation. The catena concept per se is not applicable in a permanently submersed environment. The role is somewhat different than simply relief or topography as normally considered in soils. Bathymetry contributes to the effects of internal and wind generated waves on the subaqueous soil surface. Flow regime helps to shape underwater topography and accounts for differences in the energies associated with currents and tides. Together, these two factors (B, F) essentially play the same genetic role as relief does in subaerial soil environments.

Parent material (P) was a factor in both the equations of Folger and Jenny and explains the effect of the source material on subaqueous soil profile attributes. For example, SAS that form in areas where they receive barrier island washover materials are predictably sandy textured.

Time (T) of course represents the amount of time available for the expression of subaqueous soil attributes.

A term for water column attributes (W) was not included in either Jenny's or Folger's equations, and has been added to include variations in the chemical composition of the water column that could have an impact on subaqueous soil characteristics. Those subaqueous soil profiles developed in freshwater regions or fresh portions of estuaries will likely be significantly different than those formed in more saline or brackish environments. Similarly, the dissolved oxygen levels in the water column could dramatically impact the formation or the thickness of light-colored surface horizons

The possibility of catastrophic events (E) is included in this equation to account for the possibility that subaqueous soil profiles may be dramatically impacted by major storm events or other uncontrollable or unknown factors. The effects of storms or modest hurricanes, however, do not seem to cause wholesale alterations to large areas of SAS.

More Recent Developments and Studies

Around the beginning of the last decade, Mike Bradley and Mark Stolt began subqueous investigations in Ninigret Pond, a coastal lagoon in Rhode Island, Southern New England USA. Mike found that the bathymetric map that he constructed was essentially the same as a map created from data collected by NOAA (National Oceanic and Atmospheric Administration) 40 years prior suggesting that many of the subaqueous landforms change very little with time (Stolt and Bradley, 2002). Most of the change in the landscape was occurring in the tidal delta areas near the inlet to the coastal lagoon. In addition, the works in Ninigret Pond led to more formal descriptions of the soil-landscape relationships for the coastal lagoons in Southern New England (Bradley and Stolt, 2003) and the beginning of the adoption of a set of terms for consistent use in naming subaqueous landforms (http://nesoil.com/sas/glossary.htm). Bradley also attempted to begin to develop some ecological interpretations for SAS in particular, interpretations for eelgrass (*Zostera marina*) restoration. He found that for areas having the same water quality certain soil types were more likely to hold denser eelgrass than others. These data suggested that certain soils should be more successful in restoration of eelgrass (Bradley and Stolt, 2006).

A number of other studies followed the work done by George Demas and Mike Bradley. Cary Coppock began work in Rehoboth Bay, Delaware which was significantly larger (3,300 ha) than subaqueous areas previously studied. Several students under the advisement of Dr. Laurie Osher began studying SAS in Taunton Bay, Maine. This included work by her graduate students Chris Flannagan and Jennifer Jesperson. Jesperson's work was focused on the carbon sequestration and storage in subaqueous soils. Under the guidance of Dr. Mary Collins at the University of Florida, Larry T. Ellis completed his doctoral research studying the interactions of sea grasses in SAS, and K.C. Fischler and Thomas J. Saunders are both currently conducting SAS research in Florida. In 2002, Danielle Balduff began studying the SAS in Chincoteague Bay in Maryland which is an 18,000 ha coastal lagoon located behind the Assateague barrier island. In Rhode Island, Maggie Payne has been studying the effects of water column attributes (water quality) on SAS morphology and chemistry. Information from several of these projects will be reported at the World Congress, and a symposium on SAS is being planned for the annual meeting of the Soil Sci. Soc. of America in Indianapolis this November.

Proposed Modifications to Soil Taxonomy

Wassents

Over the last two years, Dr. Mark Stolt at the University of Rhode Island has been working with a group of interested colleagues to propose taxa to highlight SAS in Soil Taxonomy. Because most subaqueous soils are Entisols, he has focused on the taxonomy of this order. He has proposed the term Wassents as a suborder for subaqueous Entisols. These are defined as Entisols that have a positive water potential at the soil surface for 90% of each day. If approved these soils will be the first suborder to key out under Entisols. The formative element Wass is derived from the German word "Wasser" for water.

Key to Great Groups

LAA. Wassents that have, in all horizons within 100 cm of the mineral soil surface, an electrical conductivity of <0.2 dS/m in a 1:5 by volume mixture of soil and water[2]. **Frasiwassents**

LAB. Other Wassents that have less than 35 percent (by volume) rock fragments and a texture of loamy fine sand or coarser in all layers within the particle-size control section. **Psammowassents**

LAC. Other Wassents that have sulfidic materials within 50 cm of the mineral soil surface. **Sulfiwassents**

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[2] This criterion for electrical conductivity (EC) at <0.2 dS/m in a 1:5 by volume mixture of soil and water has not yet been finalized. The intention of this criterion is to distinguish between freshwater Wassents and those that have formed under brackish or more saline environments.

LAD. Other Wassents that have, in all horizons at a depth between 20 and 50 cm below the mineral soil surface, both an *n* value of more than 0.7 and 8 percent or more clay in the fine earth fraction. **Hydrowassents**

LAE. Other Wassents that have *either* 0.2 percent or more organic carbon of Holocene age at a depth of 125 cm below the mineral soil surface *or* an irregular decrease in content of organic carbon from a depth of 25 cm to a depth of 125 cm or to a densic, lithic, or paralithic contact if shallower. **Fluviwassents**

LAF. Other Wassents. **Haplowassents**

One example from the Key to Subgroups

Sulfiwassents

LAAA. Sulfiwassents that have a lithic contact within 100 cm of the mineral soil surface. **Lithic Sulfiwassents**

LAAB. Other Sulfiwassents that have, in some horizons at a depth between 20 and 50 cm below the mineral soil surface, *either or both*: 1. An *n* value of 0.7 or less; *or* 2. Less than 8 percent clay in the fine-earth fraction. **Haplic Sulfiwassents**

LAAC. Other Sulfiwassents that have a buried layer of organic soil materials, 20 cm or more thick, that has its upper boundary within 100 cm of the mineral soil surface. **Thapto-Histic Sulfiwassents**

LAAD. Other Sulfiwassents that have *either* 0.2 percent or more organic carbon of Holocene age at a depth of 125 cm below the mineral soil surface *or* an irregular decrease in content of organic carbon from a depth of 25 cm to a depth of 125 cm or to a densic, lithic, or paralithic contact if shallower. **Fluvic Sulfiwassents**

LAAE. Other Sulfiwassents that have a chroma of 3 or more in 40% or more of the matrix of one or more horizons between a depth of 15 and 100 cm from the soil surface. **Aeric Sulfiwassents**

LAAF. Other Sulfiwassents. **Typic Sulfiwassents**

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Formation and General Geology of the Mid Atlantic Coastal Plain

By: Charlie Hanner, Susan Davis, and James Brewer
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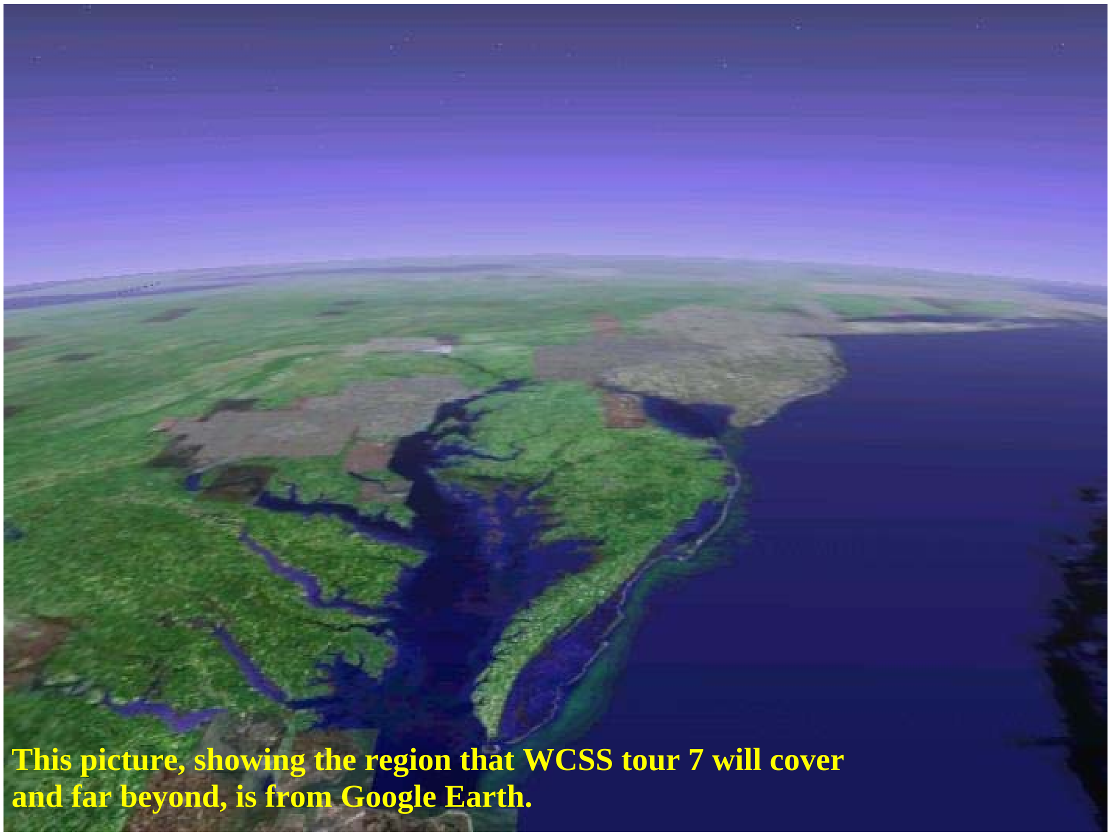
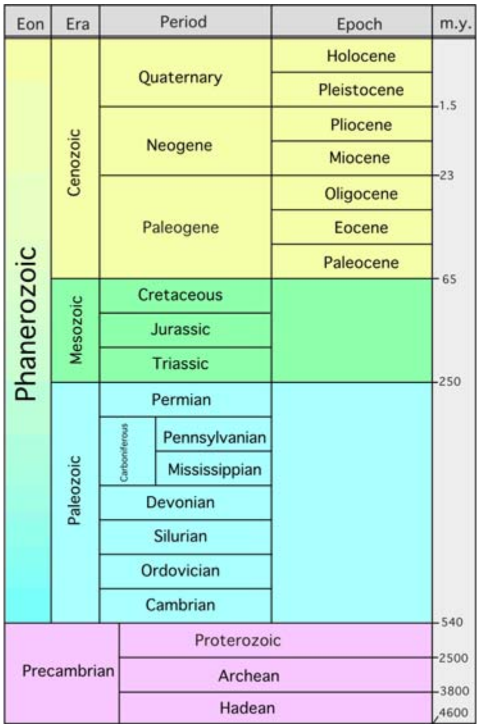


This picture, showing the region that WCSS tour 7 will cover and far beyond, is from Google Earth.

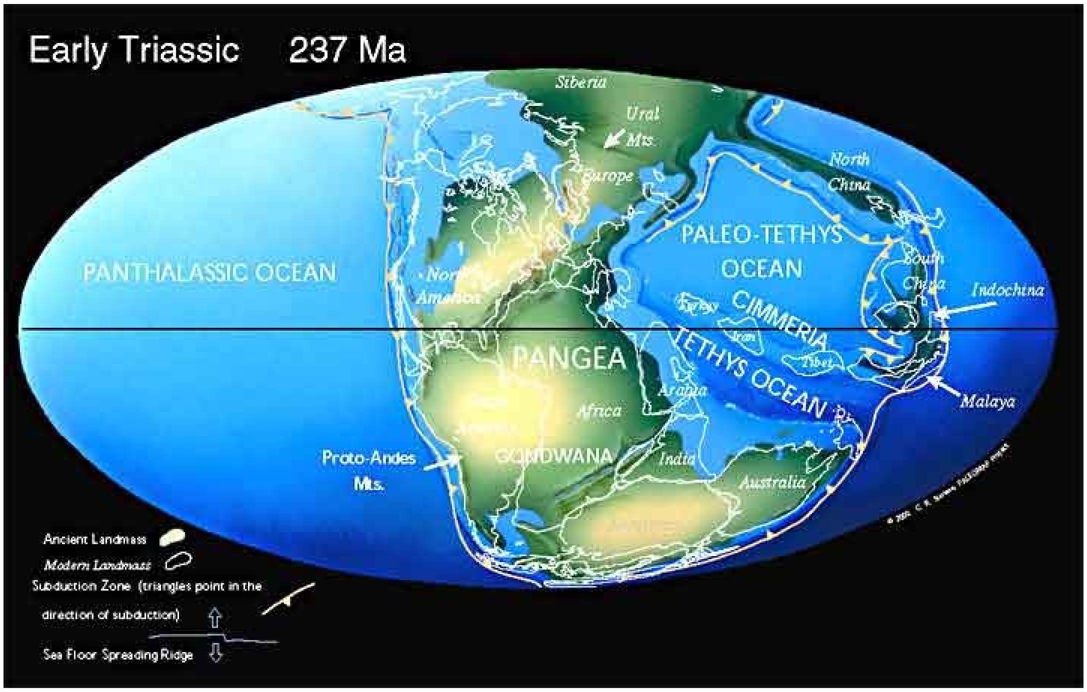
The Mid Atlantic Coastal Plain is a physiographic province along with the Piedmont Province and the mountain provinces of Blue Ridge, Valley and Ridge and Appalachian Plateau. The Mid Atlantic Coastal Plain is composed of the States of Delaware, New Jersey, and portions of Maryland and Virginia. The boundary between the Atlantic Coastal Plain and the Piedmont is known as the Fall Line. The Fall Line is the transitional zone where the more ancient harder rock of the Piedmont upland makes contact with the more easily eroded sands, silts and clays of Coastal Plain sediments. This erosional scarp, the site of many waterfalls, hence the term “Fall Line”, hosted flume and water-wheel powered industries in colonial times and thus helped determine the location of such major cities as Philadelphia, Baltimore, Washington, and Richmond, which tend to occur at the upstream head of the navigable rivers and bays of the region. In Maryland the Fall Line roughly follows an imaginary line linking the cities of Wilmington (Delaware), Baltimore, MD and Washington, D.C. East of the Chesapeake Bay lies the Delmarva region. Delmarva is a peninsula of land consisting of the State of Delaware and the Eastern Shores of Maryland and Virginia. It is bordered by the Delaware Bay to the northeast, the Chesapeake Bay to the west and south, and the Atlantic Ocean to the east.



Eon	Era	Period	Epoch	m.y.
Phanerozoic	Cenozoic	Quaternary	Holocene	
			Pleistocene	1.5
		Neogene	Pliocene	
			Miocene	23
		Paleogene	Oligocene	
			Eocene	
			Paleocene	65
	Mesozoic	Cretaceous		
		Jurassic		
		Triassic		250
	Paleozoic	Permian		
		Carboniferous Pennsylvanian		
		Mississippian		
		Devonian		
		Silurian		
		Ordovician		
		Cambrian		540
Precambrian		Proterozoic		2500
		Archean		3800
		Hadean		4600

http://paleo.cortland.edu/tutorial/Timescale/timescale.htm

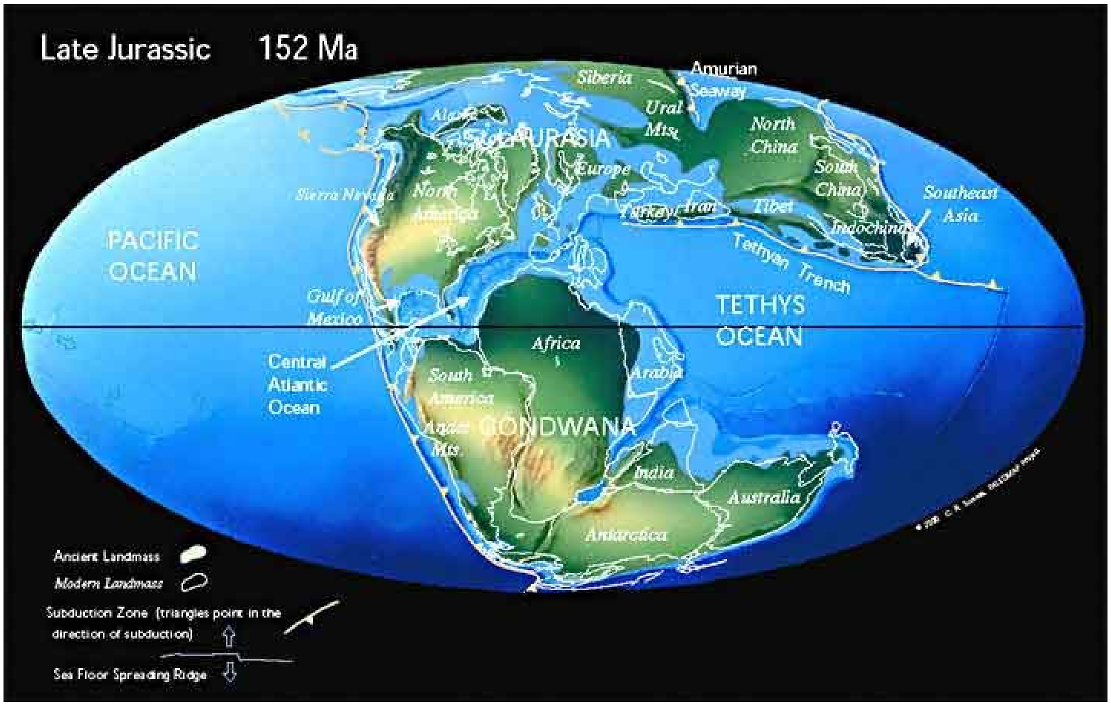
When the Pangaea land mass existed 450 to 250 million years ago, the pressure of these continental land masses shifting produced periods of uplift which created an ancient mountain range. This ancient mountain range was located where the Mountain and Piedmont physiographic provinces are located today. These ancient mountains are estimated to have been as tall as the present day Alps or Rockies. During Triassic times, around 200 million years ago, the continental land mass of Gondwanaland broke away and drifted south. On the edge of this remaining land mass, now known as Laurasia, in-rushing ocean waters and streams flowing down the sides of the mountains carried and deposited eroded material. These unconsolidated sediments gradually formed a continental shelf consisting of gravel, sand, silt and clay beneath the shallow waters of the Laurasian coast. The present day Appalachian Mountains are all that remains of the ancient mountain range. Between 200 and 65 million years ago erosion and weathering continued during the Jurassic and Cretaceous periods depositing both marine and non-marine sediments on this coastal plain shelf.



Around 65 million years ago global sea levels dropped and the portion of the continental shelf containing the modern day Delmarva began rising above sea level. By 50 million years ago, during Eocene times, when North America began splitting from Europe, the regions rainforests were being replaced by brushy grasslands as the North American continent began drifting farther north toward cooler latitudes. The vegetation of Delmarva gradually changed to dense spruce forests and tundra as the much cooler Pleistocene period began 2 million years ago. Four major glacial advances or ice ages occurred during this Quaternary period, each lasting more than 100,000 years. As glaciers advanced, ocean waters were locked in glacial ice causing sea levels to drop as much as three hundred feet below current elevations. When warmer conditions melted ice- sheets, rising ocean waters flooded continental shelf lands depositing sheets of sand, silt, gravel and clay across the Coastal Plain. These sediments, referred to as the Chesapeake Group, were deposited under/across a large part of the Coastal Plain.

Delmarva Peninsula Geology

The overall stratigraphy of the Coastal Plain is that of a sedimentary wedge, thickening seaward, with the oldest layers on the bottom and the youngest on top. The oldest sediments exposed are fluvial sands and gravels of the Potomac Group and these occur in the westernmost part of the Coastal Plain near the Fall Line, where they just barely overlap the crystalline metamorphic rock of the Piedmont. As one goes to the east/southeast, progressively younger layers are exposed at the surface. These sediments were deposited at many different time periods and were delivered by many different processes.



Underlying, at depth for the most part, the present-day Delmarva are thick marine sediments, like those that outcrop in Southern Maryland on the Western Shore of the Chesapeake Bay. The processes that deposited these marine sediments would have occurred during periods of high sea level and were low energy events that delivered fine textured silts and clays. Some sediments were deposited by fluvial processes on land surfaces by rivers that migrated back and forth across the land. These sediments are characteristic of the Beaverdam and Pensauken Formations, which are made up of sands with clay-silt beds and can be found on the interior of the Delmarva Peninsula. Some sediments were deposited in a shallow water environment, by lacustrine processes. Some sediments were transported by wind blown processes, e.g. loess (Wah, 2003). Loess, composed primarily of silt particles, blanketed much of the western edge of the peninsula and also some upland interior areas from the mid to upper parts of the peninsula during the later stages of the Pleistocene. This loess deposit covers parts of the Kent Island Formation which is made up of estuarine and fluvial deposits. The Parsonsburg Sand Formation is also an eolian surface deposit on the Delmarva, believed to have been ancient dunes and/or broad plains lying between the dunes.

The age of the surface geology of the Atlantic Coastal Plain ranges from Cretaceous to Holocene. The Delmarva Peninsula part of the Coastal Plain includes the same age range though much of the exposed areas are Pliocene and younger. The barrier island dunes, found along the eastern edge of the Delmarva, and the tidal marshes, found through out the Delmarva, are primarily Holocene.

Southern Maryland Geology

The Coastal Plain on the western side of the Chesapeake Bay, commonly referred to by Maryland natives as Southern Maryland, is generally more deeply dissected than the Delmarva Peninsula. Geologists believe that this part of the Coastal Plain was subject to more uplift hence more down cutting of streams and rivers. Many of the geologic formations that are exposed at the surface are of marine origin, including the glauconite bearing Nanjemoy and Aquia Formations. Fine and very fine sands, often containing significant amounts of diatoms and marine fossils, are characteristic of the Miocene Chesapeake Group Formations (Calvert Group). The marine origin of the sediments brings with it the likelihood of their containing sulfides. Sporadically occurring sulfidic materials have been found in nearly all of the surficially exposed Coastal Plain geologic formations on the western side of the Bay. Extensive layers of unweathered, unoxidized marine sediments are in the Nanjemoy and Aquia Formations. The clayey geologic formations, the Potomac Group silt/clay facies, and the less extensive Marlboro Clay pose both stability risks, as well as some risk of containing sulfidic or acid sulfate materials.

The broad interfluves of the south western portion of the Mid Atlantic Coastal Plain are capped with a silty mantle. These silty soils commonly have well developed fragipans. Gravel deposits of commercial interest are in many of the geologic deposits of the ancestral Potomac and Patuxent Rivers as they migrated across the area. There are numerous small faults in the bedrock and unconsolidated sediments underlying the Coastal Plain, and whose activity somewhat complicates the stratigraphy.

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Geologic Map of Maryland, Mini Version. See next page, front and back.

AN INTRODUCTION TO THE CULTURAL HISTORY OF PENNSYLVANIA AND THE MID-ATLANTIC

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The cultural history of Pennsylvania and the Mid-Atlantic region revolves around the exploitation of abundant natural resources. Terrestrial and aquatic game, mineral resources, forests for habitat and lumber, potable and navigable water, and fertile soils were utilized for support and subsistence from the time the earliest Native Americans entered the area until the mid-nineteenth century and the rise of industry and cities.

Knowledge of the period before European entry into North America is based on the archaeological record. This time is divided into three major periods and further subdivided based on changing technology, settlement patterns, and resource exploitation strategies. Dates for these periods are for the convenience of those studying them rather than reflecting abrupt cultural changes and are summarized in Table 1.

Table 1. Time periods and their approximate date ranges.

Period	Dates (Years Before Present)
Paleoindian	16,000 to 10,000
Archaic	
Early	10,000 to 8,500
Middle	8,500 to 5,000
Late	5,000 to 3,200
Woodland	
Early	3,2000 to 2,500
Middle	2,500 to 1,000
Late	1,000 to 450

(Custer, 1996; Carr and Adovasio, 2002; Stewart, 2003)

The furthest extent of Wisconsin glaciation reached into Pennsylvania, terminating 80 km north of Philadelphia about 18,000 years Before Present (B.P.) (Crowl and Sevon, 1999). Tundra climate and periglacial environment may have extended as far south as Maryland and Delaware. It was into this late Pleistocene setting after the last glacial maximum, that the first people entered. The timing of this entry is controversial with early dates of approximately 16,000 years B.P. from Meadowcroft Rockshelter in western Pennsylvania (Carr and Adovasio, 2002) and Cactus Hill in Virginia (McAvoy and McAvoy, 1997). Paleoindian people were highly mobile hunter-gatherers who traveled in small groups exploiting seasonally available plant and animal resources. In at least some instances, their routes included source areas for high quality lithic materials for stone tool production (Custer, 1996, Carr and Adovasio, 2002). Paleoindians depended primarily on stone tools for hunting and processing food but also used other tools made of antler, bone, and wood. Despite their traditional representation as strict hunters of large prey, archaeological evidence from Shawnee-Minisink and other sites demonstrates that Paleoindians were generalized hunter-gatherers who also engaged in fishing as well as gathering and processing seed, berry, and nut bearing vegetation (Dent, 1991). Figure 1 shows Pennsylvania and the Mid-Atlantic region with sites mentioned in the text.

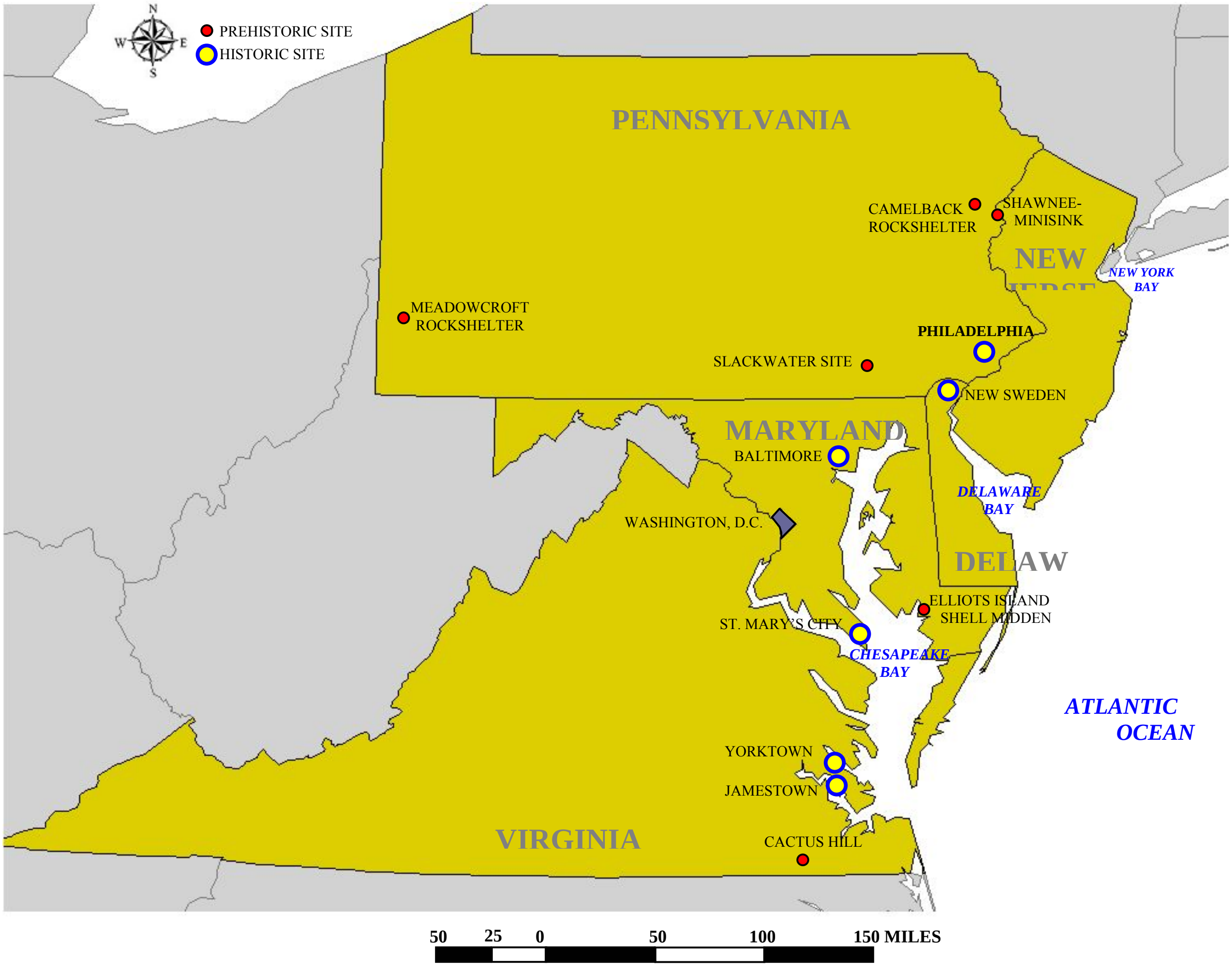

Figure 1. Pennsylvania and the Mid-Atlantic with prehistoric and historic sites.

The Archaic period began with the end of the Pleistocene and a shift from Tundra to a warmer climate with mixed mesic forest dominated by oak and hemlock (Custer, 1996). Sea level rise due to glacial melting was relatively rapid through the beginning of this period to 7,000 years B.P. (Fairbanks, 1989). People continued to travel in small hunter-gatherer groups, adjusting routes, settlement patterns, and resource procurement strategies to the Holocene environment. In the mountainous regions, rockshelters were incorporated into prehistoric settlement systems as seasonally occupied bases of operation (Figure 2). The late Archaic saw a shift to increased use of riverine environments, anadromous fish, and shell fish especially in Maryland and Delaware as estuaries began to take on their modern appearance. The occurrence of steatite bowls in the archaeological record suggests that, during the late Archaic, people were becoming more sedentary and exploiting rich, localized resources (Custer, 1996; Raber et al., 1998; Grumet, 2002).

Figure 2. Camelback Rockshelter in Monroe County, Pennsylvania, with 1 m deep deposits that bear material evidence of repeated occupations spanning the Holocene.

The early Woodland period saw a continuation of the settlement patterns and resource procurement strategies begun during the late Archaic. Migration routes became more contracted and sedentism increased as groups continued to exploit rich but spatially limited resources (Figure 3). The hallmarks of the early Woodland were the beginnings of plant cultivation and the use of ceramic pots for storage and cooking (Stewart, 2003).

More intensive horticultural activity was linked to increased sedentism and population growth through the middle Woodland. Agriculture and the establishment of villages along the lower Susquehanna River in Pennsylvania marked the late Woodland period (Custer, 1996). Late Woodland villages were located on fertile floodplains and generally encompassed more than two acres. At the Slackwater Site fifty seven houses were identified with an estimated population of 500 to 550 people (Custer 1996).

Figure 3. A middle/late Woodland oyster shell midden on Elliots Island along the Chesapeake Bay. (Image courtesy of D.L. Lowery, Chesapeake Bay Archaeological Research Foundation)

The first recorded account of contact between Native Americans and Europeans in the region was that of Verrazano exploring New York Bay in the service of France in 1524 (Richter, 2002). Early exploration and colonization efforts were largely commercial ventures financed by European monarchs. Dutch, English, and Spanish forts and trading centers were established in the region, however, these were relatively short lived. The earliest successful settlement was an English colony at Jamestown, Virginia, founded in 1607. St. Mary's City was established in Maryland in 1634, while the Colony of New Sweden was founded in 1638 in what would later become Delaware (Grumet, 2000; Klepp, 2002). William Penn received the charter for Pennsylvania in 1681 and established Philadelphia as the capital city on the west bank of the Delaware River. His desire was to create a haven free of political and religious persecution and to peacefully coexist with the native people (Dunn and Dunn, 1982). Early immigrants to the area included English, German, Dutch, Swedes, Scots-Irish, and Welsh. These immigrants came to the New World for a variety of reasons: religious freedom, to escape warfare or political oppression, out of economic hardship at home. Their endeavors included fur trading for export, early industry such as printing, weaving, metalworking, and clearing land for timber and agriculture. An important crop in Virginia and Maryland for export to Europe was tobacco. The first enslaved Africans were brought to the region in 1619 and used in agricultural production. European colonization resulted in the displacement of Native Americans (Grumet, 2000; Klep, 2002).

Through the 18th century colonial population continued to grow and expand westward. By 1750 the population had reached 380,000 and crossed South Mountain in Maryland and Virginia and Blue Mountain in Pennsylvania (Grumet, 2000; Klep 2002). Agriculture continued as the foremost occupation and the rivers and bays remained vital to the transportation of trade goods and for shellfish, fish, and game. Ongoing conflict between France and Great Britain affected the colonies as both laid claim to land on the western frontier. The French and Indian War lasted from 1754 until 1763 as a combined British, colonial, and Iroquois force eventually defeated the French and their Native American allies (Pencak, 2002). Growing dissatisfaction with governance from abroad and a sense of commonality within the colonies led to the American Revolutionary War against Great Britain beginning in 1775. The Declaration of Independence asserting the right of the colonies to rule themselves was signed in Philadelphia in 1776 and fighting in North America ended with the British surrender at Yorktown, Virginia, in 1781 (Grumet, 2000; Klep, 2002). Conflict arose again and the British burned the new American capital, Washington, D.C., and besieged Baltimore, Maryland in 1814.

The first half of the 19th century saw continued increases in population and the growth of urban centers and industry. Population in the Chesapeake Bay region was over 1.3 million by 1820 (Grumet, 2000). Textile manufacturing, metal working, and carpentry were taking hold in Philadelphia as the city's population rose to 136,615 (Wainwright, 1982). The economic mainstays of the region, however, remained agriculture and trade. The American Revolution had brought to the fore two concepts that would shape the 19th century: that all men were created equal and the idea of state's rights. Slavery had begun to be abolished in Pennsylvania by 1780 (Pencak, 2002); in 1808 the importation of slaves was made illegal by the Federal government; by 1804 emancipation laws had been enacted in all states north of the Mason-Dixon Line separating Pennsylvania and Maryland. By contrast 89,737 slaves were held in Maryland and 449,087 in Virginia in 1840 (University of Virginia Geospatial and Statistical Data Center, 2006). Southern states fearing the Federal government would threaten their right to maintain the institution of slavery seceded from the Union in 1861 beginning the U.S. Civil War. The Civil War stretched on until 1865 and the surrender of southern forces (Grumet, 2000).

After 1865 manufacturing flourished with the production of textiles, furniture, tools, machines, books, glass, and all manner of goods, aided by steam and water powered machinery. Coal mining and iron production, likewise, flourished (Licht, 2002). The population of Philadelphia was 674,022 by 1870 (Beers, 1982). Agriculture remained an important aspect of the region but not nearly so as it had been the previous century. The rise of urban centers and decline of agriculture had begun in earnest and would continue through the 20th century.

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Fanning comments on this paper. I really appreciate the efforts of John Wah and his colleague Jonathan Burns to prepare this paper on the cultural history of the region for us. John has acknowledged that they pretty much cut off their history at about 1900 A.D. I would just like to point out that one thing that came along in the 20th century that has had a big impact on the exposure of *sulfidic materials* and the associated development of active acid sulfate soils was the human development of huge earth-moving equipment and the use of this equipment in the construction of transportation facilities (highways, shipping channels by dredging, airports etc.) as well as in other "developments" and in surface mining etc. Most of the active acid sulfate soils in the region today have developed as a result of these earth-moving activities. Engineers and others who control these activities have not learned their acid sulfate lessons and probably won't until they are forced to do so by the development of laws and regulations. It is my opinion that soil scientists need to take the initiative to bring acid sulfate soils to the attention of engineers, geologists, politicians and anyone else who will join our cause to educate our fellow scientists and engineers -- as we try to do with symposia and tours like this one, but more importantly the general public and those involved in controlling earth-moving activities. On the other hand, because of the earth-moving activities of humans, we soil scientists have been able to learn much about early-stage soil genesis.

PART II -- STOPS
ROAD LOG FOR TOUR

July 7

Trip starts at Holiday Inn, Philadelphia Airport, on Hwy. 291 in Essington, PA. Proceed via highways 291 and 420 to I-95 and enter I-95 South (right by the Holiday Inn).
Take I-95 into DE and proceed to Exit for Rt. 1 South into DE, toll booth at Christiana Mall Rd. Exit to get onto Rt. 1 south into DE. Total distance from start to reach Rt. 1 is 25 miles.

Running total miles: 25 where get off I-95 onto Rt. 1.

Continue on Rt. 1 all the way to Rehoboth Bay south of Dewey Beach. On the way there is a toll booth after another 13 miles and by Dover (after another 18 miles). The modern divided highway ends south of Dover by Dover Air Force Base, but there is another section of big road for by-pass around Milford, DE. Proceed to a section of Delaware Sea Shore State Park (Indian River Inlet Park) across the bridge (construction here) over the inlet to Indian River Bay and turn in right into Indian River Inlet Park. Total mileage from when got on Rt. 1 is 95 miles. This is Stop 1 (in Park with picnic tables and rest rooms available).

Running total mileage from trip start: 120

Return to Rt. 1 and continue south for 4 miles and turn right on Fred Hudson Road and left on Central Road for 2 miles to reach Atlantic Ave. (Rt. 26) and turn right (alternatively continue south on Rt. 1 until reach Rt. 26 at Bethany Beach and turn right there and follow 26). Continue following Rt. 26 through villages and across route 113 into the state of Maryland about 2 miles south of Gumboro, DE. Here the road becomes Rt. 353. Continue on 353 until reach U.S. Hwy 50, just south of Pittsville, MD. Total mileage from Stop 1 to here is 33.

Running total mileage from trip start: 153

Take Rt. 50 west and follow it, including Rts. 13 and 50 by-pass around the NE side of Salisbury to Cambridge, MD, where we will turn left on Rt. 16. The total mileage from where we pick up Rt. 50 to Rt. 16 turn off is 39.

Running total mileage from trip start: 192

We expect a (trip unnumbered) stop where we turn off Rt. 50 on Rt. 16 to pick up lunches etc. at the MD DNR after Wal-Mart.
Proceed for 3 miles on Rt. 16 and turn left on Maple Dam Road and follow this road and succeeding county roads to reach Shorter's Wharf. The roads cross large areas of tidal marsh and Stop 2 is to examine tidal marsh soils. The bus will stop to discharge passengers just before crossing a small bridge, and then will cross bridge and park in a parking lot on right, just across the bridge to wait for passengers to reload after looking at soils and landscapes etc. at this stop. Total mileage from where we turned on Maple Dam Road is 13. Going will be slow here because of curvy and narrow road and danger of going off road into tidal marsh for part of this way. This will be stop 2. We expect to have a porta-john here and trash containers for participants to deposit their lunch trash (lunch eaten on bus on way from Cambridge to Stop 2).

Running total mileage from trip start: 208

The trip will proceed back 16 miles to Rt. 50 and Rt. 16 intersection in Cambridge and turn left on Rt. 50 toward the Bay Bridge – this turn will be 16 miles after leaving Shorter's Wharf. We will then proceed on Rt. 50 and cross the Bay Bridge (no toll going west in the direction we will be going). We will leave Rt. 50 at Rt. 2 South – distance from where we reenter Rt. 50 in Cambridge is 58.

Running total mileage from trip start: 282

Proceed south on Rt. 2 across South River Bridge and across Rt. 214, Central Avenue, until about 3 miles after Birdsville. Just after Birdsville Road on the right, turn left on Mill Swamp Road and follow it until it ends at Rt. 468, Muddy Creek Road. We will turn left on Rt. 468 and then immediately pull off on the right side of the road to examine soils in road cut on the right side. Bus will discharge passengers and wait until trip participants have examined soils in the road cut. <u>This is Stop 3</u>.

Running total mileage from trip start: 293

After bus is re-loaded, we will proceed about 2 miles north on Rt. 468 and turn right on Contee Wharf Road and follow Contee Wharf Road for about 2 miles to the SERC (Smithsonian Environmental Research Center) headquarters and lab buildings<u>. This is Stop 4, the last official stop for this day before stopping for the night in LaPlata, MD. There will be rest rooms at SERC for those who need them.</u>

Running total mileage from trip start: 297

We will return via Contee Wharf Road to Rt. 468 (about 2 miles) and turn left, south, and proceed about 4 miles to the intersection with MD Rt. 255. Turn right on 255 and proceed 3 miles to Rt. 2. We'll turn left on Rt. 2 and proceed 1 mile to Lothian PO and continue on Rt. 259 off 2 there for 3 miles to reach State Rt. 4 (divided highway) just after Bristol – 14 miles total from SERC to Rt. 4.

Running total mileage from trip start: 311

Proceed on Rt. 4 to Upper Marlboro (4 miles) and then take Rt. 301 South. Follow Rt. 301 south to LaPlata, where we will stop for people to unload and get their rooms at the LaPlata Inn Best Western Motel/Hotel. Mileage from Upper Marlboro to LaPlata is 27

Running total mileage from trip start: 342

After people have checked into their rooms and gotten ready, the bus will take the tour group to Pope's Creek (10 miles from the Best Western) for dinner at Robertson's seafood house via Rt. 301 South (7 miles) and then right on Pope's Creek Road (3 miles). On the way or on the return, if time permits, we will turn right (going to Pope's Creek) or left (returning) and proceed on a narrow road to the Loyola Retreat House where there will be about a 30 to 45 minute stop for participants to walk via path to the Potomac River cliff and beach to examine the soils in cliff face there (about 1 mile off Pope's Creek Road). Estimate 11 miles to Pope's Creek via Retreat House and 10 to return to Best Western LaPlata Inn.

Running total mileage from trip start: 363 counting to Pope's Creek and back to Best Western. This is total distance for Day 1, July 7

<u>July 8</u>

We plan to be on the road to VA by 7:30 am, if not before. We will drive via Rt. 301 to the Harry W. Nice toll bridge across the Potomac River – 13 miles from LaPlata Inn. Then we will proceed via Rts. 301 and 3 to Fredericksburg and just before Rt. I-95 we will turn Right on Mahone Road and proceed to the Great Oaks Development via Hays Street (right off Mahone etc.) and Great Oaks Lane to Hickory Court where there will be an unscheduled extra stop to look at acid sulfate disasters in new home yards – 49 miles after bridge and 62 miles from LaPlata Inn.

Running total mileage from trip start: 425.

We will return to Rt. 3 West and then take I-95 North (just beyond Mahone Road on Rt. 3). We will get off I-95 at exit 136 and take Centreport Road to Stafford Airport, where we will proceed via Aviation Way to the hangar. This is official stop 5. The bus will drive about 2 miles within the airport.

Running total mileage from trip start until we leave the airport: 439.

The trip will proceed via Aviation Way, Centreport Road North, American Legion Road (Rt. 628) east, Rt. 1 North to Stafford, and Rt. 630 West back to I-95 N (total distance from Airport, 5 miles total from Airport). The trip will then proceed via I-95 N to Exit 143B and take Rt. 610 West into Garrisonville, VA. After about 1 mile, we will turn left on Mine Road (across from Hardy's, with 7-11 stores on either side of Mine Road here at turn) and proceed about 1 mile to Stop 6.

Running total mileage from trip start to Stop 6: 450.

The trip will return by same route (about 2 miles) to I-95 North and proceed 7 miles to Exit 150 and get off I-95 following signs to Prince William Forest Park and once in the park we will follow signs to TREC (Turkey Run Education Center), total distance – about 4 miles total from I-95. This will be Stop 7 and lunch here will be provided by Virginia Tech who will bring the lunch to us. There are rest rooms here and a meeting room where we expect to have a Power Point Presentation set up and running during lunch time in air-conditioned class room.

Running total mileage from trip start to Stop 7: 463.

The tour will return 4 miles to I-95 North and proceed north toward Washington, DC. It is 21 miles to reach I-495/95 junction where we will continue to follow I-95 East and North for another 10 miles to cross the Wilson Bridge over the Potomac River. After crossing the bridge we will exit on to I-295 North/Anacostia Freeway thru Washington, DC. into MD at the Rt. 50 junction where we will take Kenilworth Ave, Rt. 201 and follow it to the River Road exit (left off Kenilworth less than a mile north of crossing Rt. 410) and take River Road and the Paint Branch Parkway (at College Park Metro Station) to the University. After we cross U.S. Rt. 1 the road becomes Campus Drive. We will follow Campus Drive around M traffic circle to H.J. Patterson Hall at top of the hill where bus can stop at parking lot for trip participants to disembark and proceed into HJP Hall. This will be Stop 8. The bus will be directed to a parking lot to wait until it is time for tour participants to reload. Someone in charge will probably stay with the bus driver to be called on cell phone when it is time for bus to come back to HJP Hall to reload passengers.

Running total mileage from trip start to Stop 8: 510.

After viewing soil monoliths and other things in Patterson Hall, passengers will reload the bus. The bus will then proceed 2 miles via Campus Drive (back toward Rt. 1) and the road to the Comcast Center and Rt. 193 and Metzerott Road to a parking lot in Park by the Paint Branch Creek where passengers will disembark again to view a geologic exposure with pyrite-bearing lignite, iron-stone etc. up the creek a short distance from where the bus will park. This is an officially unscheduled stop connected with the University stop.

The bus will go on about 1 mile after re-loading via Metzerott Road back to Rt. 193 East and take it to Rt. 1 North.

Running total mileage from trip start to reach Rt. 1 here: 513.

From here Take Rt. 1 North for 1 mile to I-95 North.

Enter I-95 North

Take I-95 for 24 miles toward Baltimore

Take I-695 East, toward Key Bridge for 8 miles

Exit at Exit 1, Hawkin's Point Road North.

Go 1 mile to just beyond entrance to U.S. Gypsum, entrance to landfill, Stop and unload bus at scheduled Stop 9.

Running total mileage from trip start to Stop 9: 547

After bus is reloaded in about 40 minutes, return about 1 mile via Hawkin's Point Road to I- 695 and take it East, toward Key Bridge.

Cross Key Bridge and go thru toll gate for bridge (about 3 miles)

Go about 12 miles and reenter I-95 North

Running total mileage from trip start to I-95 off 695 north of Baltimore: 563

Take I-95 back to Philadelphia to Holiday Inn where trip started on July 7 – total distance of 61 miles after reenter I-95 from I-695 (Baltimore Beltway).

> Will pass Kennedy Highway toll booth after 30 miles
>
> Will pass Delaware Turnpike toll booth after 19 miles after Kennedy Highway toll booth.
>
> Will enter PA and proceed to exit 9A where Holiday Inn is on Highway 291 in Essington, PA.

Running total mileage from trip start to Holiday Inn on return trip: 624

After riders who have left vehicles at Holiday Inn, Philadelphia Airport etc. have unloaded, return to I-95 and continue north into Philadelphia and get off at I-676 and go into the city to Marriott Hotel by Philadelphia Convention Center and Crown Plaza Hotel for remainder of passengers to unload – about 15 miles total distance from Holiday Inn/Philadelphia Airport.

Total distance for which the bus will be needed: 639 – round to 640.

A map for the trip as per WCSS web site may be added to the end of the guidebook (not done, DSF, 8/18/06) and if available participants may be given a Maryland State Highway Map (done, DSF, 8/18/06) that shows the total area covered by the tour except for that part into Philadelphia after the Holiday Inn at the end of the trip.

Stop 1

Welcome to the State of Delaware! This stop will be at Delaware Sea Shore State Park (Indian River Inlet Park part) after we cross the bridge going south on Rt. 1 over the inlet to Indian River Bay and turn in right into Indian River Inlet Park. Construction on the bridge that we cross over the inlet may afford an opportunity for the bus to slow up so we can look out northwest over Rehoboth Bay as well as toward the ocean beach to the east.

At this stop we will first consider coastal tidal marsh soils and then subaqueous soils. Our leader in regard to the coastal tidal marsh soils will be Delaware NRCS soil scientist Phil King. The description and some lab data for the Coastal Tidal Marsh Soil, Purnell Peat, a *Histic Sulfaquent* is given on the next three pages.

The pages for this stop after the information on the Purnell soil give descriptions and data for two sub-aqueous soil profiles from Rehoboth Bay from the draft M.S. thesis by University of Maryland graduate student Cary Coppock, who now holds a Hydrology Technician position with the USDA Agricultural Research Service in Beltsville, MD. The descriptions and data are for profiles (RB 31 and RB 46) taken with a vibracore coring device from mapping units of sub-aqueous soils in Rehoboth Bay. Cores of some similar soils taken a few days before this tour will be on display for trip participants to examine at this stop. With the descriptions the classification of the profiles is given by 1999 Soil Taxonomy, by the 2006 proposed revision to taxonomy for subaqueous soils (see the document by Rabenhorst on subaqueous soils in Part I of this guidebook) and by WRB (courtesy of Otto Sparrgaren).

For his thesis, Cary mapped the subaqueous soils of Rehoboth Bay. This map will be on display at this site and a small version of it is also provided with the information in this guidebook the end of the Stop 1 stuff. This map in the guidebook gives the taxonomic classification of soils from cores from throughout the Bay that Cary sampled. Cary will make some comments at this stop about his work.

Note that there is a document on subaqueous soils by Martin Rabenhorst in Part I of this guidebook. We are fortunate to have Marty on this trip and he and others will be making comments about subaqueous soils as well. We plan to have Marty on our tour bus as we proceed from stop 1 to stop 2 to make further comments about both subaqueous soils and about tidal marsh soils, which will be featured again at Stop 2.

STOP 1 – Tidal Marsh Soils

Coastal Tidal Marsh Soil: Purnell Soil Series

Profile Description and Data:

NRCS Sample Number: S05DE-005-001

Purnell peat, 0-1 percent slopes,

TAXONOMIC CLASS**:** Sandy, mixed, mesic Histic Sulfaquents

CLASSIFICATION BY WRB: Histic Gleysol (Epiprotothionic, Eutric, Arenic) or Gleyic Histic Tidalic Fluvisol (Epiprotothionic, Eutric, Arenic) (see comments here below)

Not classified as Fluvisol because *fluvic material* starts below 25 cm depth (from the profile description it is not evident that the Oi and Oe horizons contain stratified sediments required for fluvic material). Consequently, the soil keys out as Gleysol. Oi and Oe meet the requirements for *histic horizon*, the upper 15 cm of the soil (when mixed) has sufficient total S to qualify for *sulphidic material* (0.98%), hence Epiprotothionic, pH is around neutral, hence Eutric (which is not directly implied by Protothionic), and Arenic because of the sandy nature of the soil below 28 cm depth.

If there is evidence of stratification within 25 cm of the soil surface (the authors may want to look at this), the soil classifies in WRB as Gleyic Histic Tidalic Fluvisol (Epiprotothionic, Eutric, Arenic). Gleyic because of the colours indicating reducing conditions.

Location: Rehoboth Beach, Delaware; 38 degrees 36 minutes 14.33 N latitude, 75 degrees 04 minutes 07.45 seconds W longitude.

Landscape: Coastal Plain

Landform: Tidal marsh

Notes at time of sampling: 4 cm tidal water above soil surface; Whiff test = #2, as digging; all soil properties below are field estimates. Field description and sample collection was by Phil King, Jim Brewer and Charles Hanner of USDA NRCS.

Oi--0 to 14 cm; olive (5Y 5/4) peat (fibric soil material); fiber content is 80% soil volume after rubbing; 10 percent by weight mineral soil material; many (45%) very fine and fine, and common coarse live roots; abrupt smooth boundary; S05DE-005-001-1, SAMPLED.

Oe—14 to 28 cm; very dark olive (5Y 4/2) mucky peat (hemic soil material); fiber content is 40% soil volume after rubbing; 20 percent by weight mineral soil material; many (20%) very fine and fine, live roots; 15% pockets mucky loamy sand; clear wavy boundary; S05DE-005-001-2, SAMPLED.

Ag--28 to 34 cm; dark gray (5Y 4/1) loamy fine sand; massive; nonsticky; nonplastic; n value < 0.7; abrupt smooth boundary; S05DE-005-001-3, NOT SAMPLED.

Cg1--34 to 53 cm; olive gray (5Y 5/2) sand, massive; nonsticky; nonplastic;; common, medium, distinct very dark gray (5Y 3/1) mono sulfides?; S05DE-005-001-4, SAMPLED.

Cg2--53 to 66 cm; gray (5Y 5/1) sand; single grain loose; 2% pebbles; common (5%) medium faint (5Y 4/1) mono sulfides?; S05DE-005-001-5, NOT SAMPLED.

Cg3—66 cm; unable to extract due to slumping.

Vegetation**:** saltmarsh cordgrass (*Spartina alterniflora*), saltmeadow cordgrass (*Spartina patens*), saltgrass (*Distichlis spicata*), glasswort (*Salicornia bigelovii*).

For some lab data for this Purnell profile, see below for data pertaining to the sampled horizons, Oi, Oe, and Cg1.

Some lab data for Purnell profile samples. The pH (at approximately 1:1 water to soil material by weight) was measured by D. S. Fanning at Univ. of Maryland on samples about kept moist for about 2 weeks at room temperature or frozen after brought from the field in December, 2005. The total S, C, and N were determined at the National Soil Survey Center in Lincoln, NE, under the supervision of Mike Wilson on <2mm air-dry soil material prepared at the University of Maryland.

Horizon	Depth (cm)	pH	Total S (%)	Total C (%)	Total N (%)
Oi	0-14	6.75	1.01	9.57	0.688
Oe	14-28	7.36	0.58	4.89	0.305
Cg	34-53	7.08	0.28	0.85	0.092

Chrome-reducible S and acid volatile S were determined courtesy of Patrick Morton and Dr. Rabenhorst's U of MD lab for the Oi horizon, resulting when combined with the total S data, in the following S fraction data, for that horizon:

Horizon	Depth (cm)	AVS (%)	Cr-red S (%)	Organic and Sulfate S (%)	Total S (%)
Oi	0-14	0.078	0.289	0.642	1.01

In addition, duplicate (1 vs. 2 for given depths in table at top of next page) sub-samples of the sampled horizons were incubated to determine if they qualified as *sulfidic materials* as defined by *Soil Taxonomy*. The samples were wet on the days of pH measurement (approximately weekly) and sometimes at in-between times, but were permitted to dry to various extents (sometimes to totally air dry) between times of wetting. Data are given below. Dates are for 2006.

Purnell		Date / pH	Date / pH	Date / pH	Date / pH	Date / pH	Date / pH	Date / pH	Date / pH	Date / pH	Date / pH
Horiz.	Depth	2/15	2/22	3/1	3/9	3/16	3/23	3/30	4/6	4/13	5/13
Oi	0-14, 1	4.72	4.92	4.08	4.29	3.68	3.88	3.97	3.72	3.88	3.71
Oi	0-14, 2	6.11	5.88	5.34	5.56	4.99	4.92	5.19	4.78	4.74	4.45
Oe	14-28, 1	6.50	5.97	5.30	5.85	5.53	5.19	5.39	5.16	4.79	4.45
Oe	14-28, 2	6.92	5.68	5.45	4.81	4.05	3.93	3.92	3.30	3.23	3.05
Cg1	34-53, 1	6.41	3.43	2.42	2.47	2.34	2.46	2.52	2.59	2.57	
	34-53, 2	6.50	4.08	3.16	2.89	2.58	2.79	2.76	2.67	2.89	

DSF comments on the data, 5/17/06

The total carbon contents as measured in the lab are low in regard to supporting the top two horizons being O horizons, however, a large part of the fibers were sieved out in order to supply air-dry <2mm material to the Lincoln Lab, so including these sieved out materials they probably do qualify as organic.

Only the top horizon has sufficient S to qualify as sulphidic by the WRB definition of *sulphidic material*, which requires 0.75% or more total S.

By the incubation method for determining *sulfidic materials* by *Soil Taxonomy*, the Cg is definitely *sulfidic*, which supports the great group classification of *Sulfaquents*. For the Oi and Oe horizons, the duplicate incubated samples gave different results, with one duplicate in each case giving sufficient pH drop in 8 weeks to be *sulfidic*, whereas the other duplicate did not reach 4.0 or below within 8 weeks, although there was a strong pH drop. The rapid drop to below 4.0 with the Cg horizon is typical of what has been found with other very sandy materials in spite of an insufficient level of S to qualify as *sulphidic* by the WRB total S level definition.

Stop 1 – Subaqueous Soils

Descriptions and data for two subaqueous soil profiles from Rehoboth Bay (RB 31 and RB 46) from Cary Coppock's draft M. S thesis (Tables 1 and 2) are given on the next two pages. These soils were sampled by a vibracore coring device from a boat at sites shown on the map on the following page. The total S, C, and N data in the three columns on the right were determined at the NRCS National Soil Survey Laboratory. The O.C. data in the description column were determined by Cary at the University of Maryland by loss on ignition.

The pH data in Cary's descriptions of the RB 46 and RB 31 soils (two pH's for each horizon) are for the beginning and end of an 8 week incubation period to test for *sulfidic materials* by *Soil Taxonomy* for each horizon. If the pH dropped at least 0.5 units to a pH of 4.0 or below during the incubation period, the material of the particular horizon qualified as a *sulfidic material*. It will be noted that most of the horizons qualified as *sulfidic*, some with as little as 0.03% total S.

The classification of the soils represented by the profiles is given at the top of the profiles. Otto Sparrgaren's comments in regard to the classification of these soils by WRB are given here below.

> Classification of RB31 by Otto Sparrgaren for WRB: Gleyic Subaquatic Fluvisol (Calcaric, Arenic). Calcaric because of the large amount of shell fragments, much more than in RB 46. Calcaric makes Eutric redundant. The soil is sandy to a depth of 72cm, therefore only Arenic, no depth indication. The soil has sulphidic material (Cgb1), but that occurs too deep to be recognized with a Protothionic modifier.
>
> Classification of RB46 by Otto Sparrgaren: Gleyic Subaquatic Fluvisol (Eutric, Epiarenic). The amount of total S is too low for WRB sulphidic material, therefore the Protothionic qualifier does not apply.

One practical reason for recognizing *sulfidic materials* in subaqueous soils is that these soils represent materials that would be expected to give rise to active acid sulfate soils if they would be dredged and placed in a land-based containment site where the sulfides could undergo oxidation. If dredging of such materials would take place it would be useful to know, from a management point of view, the quantities of oxidizable S vs. the quantities of acid neutralizing substances. Soil materials with as little as 0.03% S might result in an active acid sulfate soil with a sulfuric horizon at a DM containment facility, however, it is likely that with sandy materials that the sulfides would be oxidized away and the acid leached away quite quickly with minimal detrimental environmental impact. Thus simply knowing that a soil material is *sulfidic* by *Soil Taxonomy* doesn't provide enough information for the design of good reclamation measures in the case of dredging.

It would also be good to know if subaqueous soil materials contain significant quantities of monosulfides as the monosulfides could result in de-oxygenation of the water column if they would be stirred into it by turbulence caused by storm events, which might lead to fish kills and other detrimental environmental impacts.

Soil Description for Pedon RB 31, water depth 72cm

sandy, Haplic Sulfaquent (Soil Taxonomy 1999)
coarse-loamy, mixed, mesic, Haplic Sulfowassent (Proposed 2006)
Gleyic Subaquatic Fluvisol (Calcaric, Arenic) (WRB 2006)

Horiz.	Depth	Description	Total S	Total C	Total N
	- cm -		- % -	- % -	- % -
Ag	0-14	Black (N2.5) sand; n-value <0.7; 0.13%OC; pH 6/4.8; abrupt boundary	0.02	0.12	0.085
Cg1	14-37	Black (N2.5) sand; dark gray (5Y4/1) mottles; n-value <0.7; 5% shell frags; 0.08%OC; pH 6/3.2 abrupt boundary	0.03	0.09	0.059
Cg2	37-72	Black (5Y5/1) sand; n-value <0.7; 0.06%OC; pH 6/3; grad boundary	0.03	0.07	0.059
Cg3	72-114	Very dark gray (N3) sandy loam; n-value <7; 4% shell frags; 0.7%OC pH 6.5/3.8; abrupt boundary	0.39	0.85	0.143
Oe/Cg	114-154	Very dark gray (10YR3/1) sandy loam, 45% dark brown (7.5YR3/4) hemic material; n-value 0.7-1; 9.29%OC; pH 6.7/3.9; abrupt boundary	1.46	10.13	0.595
Ab	154-160	Black (N2.5) sandy loam; n-value <0.7; 8.49%OC; pH 6.4/2.8; abrupt boundary	no sample	no sample	no sample
Cgb1	160-184	Grayish brown (2.5Y5/2); n-value <0.7; 0.43%OC; pH 6.8/2.9; clear boundary	0.22	0.36	0.06
Cgb2	184-215	Dark gray (2.5Y4/1) sand; n-value <0.7; 0.08%OC; pH 6.6/2.8; clear boundary	0.14	0.1	0.032

Table 1. Soil descriptions and profile mosaic for RB31 from a submerged mainland flat. Depth is given to left of profile. Sampled from west side of Rehoboth Bay.

Soil description for Pedon RB46, water depth 140 cm.					
sandy, Haplic Sulfaquent (Soil Taxonomy 1998)					
coarse-loamy, mixed, mesic, Haplic Sulfowassent (Proposed 2006)					
Gleyic Subaquatic Fluvisol (Eutric, Epiarenic)(WRB 2006)					
Horiz.	**Depth**	**Description**	**Total S**	**Total C**	**Total N**
	- cm -		**- % -**	**- % -**	**- % -**
A1	0-0.2	Olive gray (5Y5/2) oxidized sand			
A2	0.2-25	Dark gray (5Y4/1) sand with 40% gray (5Y5/1) faint mottles; n-value <0.7; 0.11%OC; pH 6/3.4; abrupt boundary	0.03	0.05	0.078
Cg1	25-50	Dark gray (5Y4/1.5) fine sand with 5% dark brown (10YR3/3) faint organic streaks; n-value <0.7; 0.22%OC; pH 6.4/2.5; clear boundary	0.12	0.23	0.11
Cg2	50-75	Dark gray (5Y4/1) sandy loam with dark brown (10YR3/3) very fine roots; n-value <0.7; 0.63%OC; pH 6.8/2.6; few shell fragments; clear boundary	0.46	0.72	0.146
Cg3	75-116	Dark gray (5Y4/1) very fine sandy loam; n-value 0.7-1; 0.72%OC; pH 6.9/2.6; trace shell fragments; clear boundary	0.64	0.82	0.124
Cg4	116-132	Dark gray (5Y4/1) sandy loam; n-value 0.7-1; 0.46%OC; pH 7.8/7.2; 30% shell fragments; abrupt boundary	0.35	0.52	0.075
Cg5	132-173	Gray (5Y5/1) very fine sand with yellowish brown (10YR5/4) organic fragments; n-value 0.7-1; 0.25%OC; pH 8/2.9; trace shell fragments; abrupt	0.21	0.23	0.05

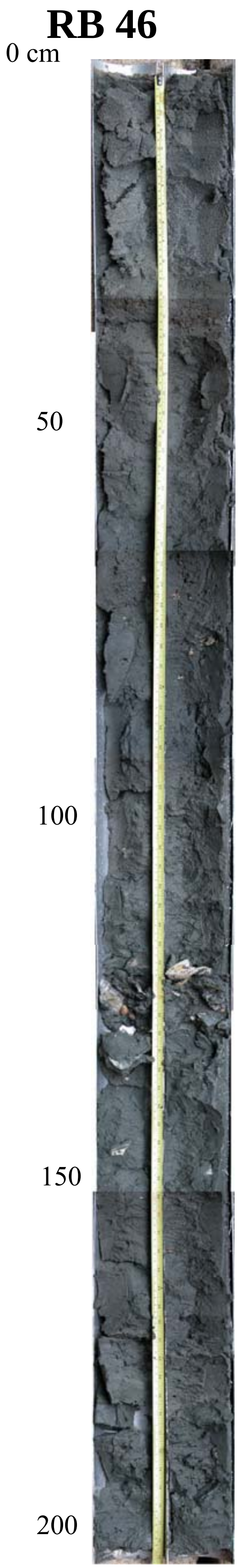
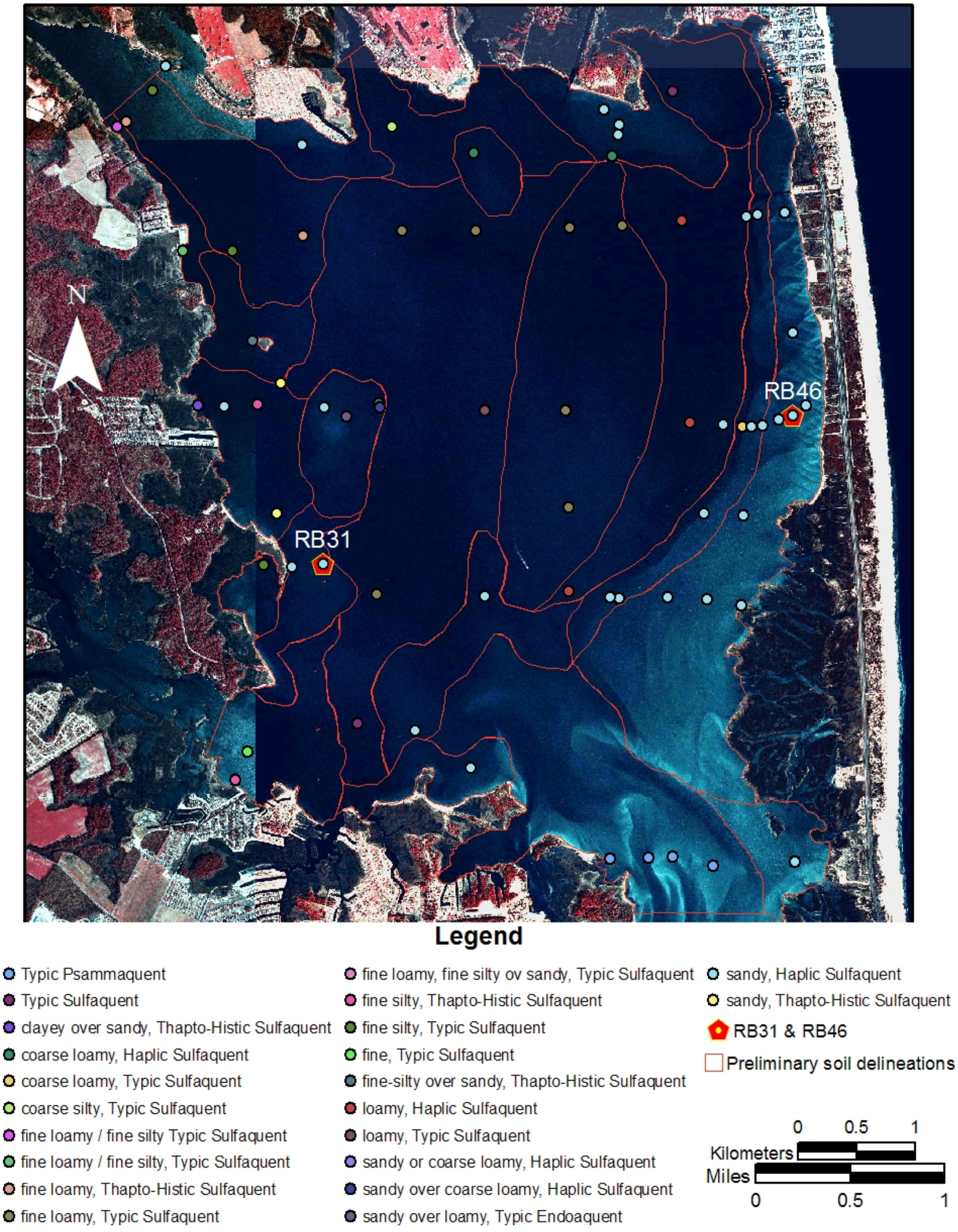


Table 2. R46 from Storm-surge washover fan flat landform. Depth is given to left of profile. Sampled from east side of Rehoboth Bay.

Soil Taxonomy Classifications for Rehoboth Bay Pedons



STOP 2

Fanning comments:
This stop is at Shorter's Wharf on lands of the Black Water Wildlife Refuge in Dorchester County, MD. The stop site is representative of the extensive tidal marshes that occur around the Chesapeake Bay in Maryland, particularly in Dorchester and Somerset Counties. Jim Brewer, NRCS soil scientist will be our leader at this stop. We also expect to hear from a scientist from the Blackwater Wildlife Refuge as our bus approaches this site. Also Dr. Rabenhorst will display new and rapid growth of iron sulfides on an iron (hydr)oxide coated IRIS tube that has been buried for a day in the marsh at this site. Marty, who has been involved in many studies of tidal marsh soils and other wetlands will also provide comments on the bus as we come to this stop and at the stop.

Blackwater Stops – Jim Brewer's Comments

These organic soils formed in decomposed plant material that accumulated on the surface of marshes or swamps at a rate that kept pace with sea level rise. Sea level has been rising in this region since the last period of glaciation. Many of these soils were influenced by salt water and by the action of tides. Marshes naturally age as they fill with organic material derived from algae, sedges, rushes, and other water-tolerant plants. The plant residue in these marshes accumulates because the permanently wet condition of the soils prevents oxidation and slows decomposition. Freshly exposed organic material commonly has a reddish brown or black color depending upon the amount of decomposition that has occurred.

The majority of the organic soils in Dorchester County are along the many rivers, creeks, and ponds in the southern part of the county. The Honga soils formed in organic deposits over mineral sediments which at one time were upland soils before the rise of sea level. These marsh areas are known as submerged upland tidal marshes. Mispillion and Transquaking soils formed in organic deposits over silty and clayey mineral sediments that were deposited in quiet estuarine tidal creeks. The mineral material settled out in these still waters and consequently is very fluid – has a high *n*-value by *Soil Taxonomy*.

Submerged Upland Tidal Marsh Soil: Honga Soil Series

Profile Description and Data:
NRCS Sample Number: S05MD-019-002

Honga peat, 0-1 percent slopes,

TAXONOMIC CLASS**:** Loamy, mixed, euic, mesic Terric Sulfihemists. DSF comment: This classification is in question because none of the horizons tested were *sulfidic materials* by the prescribed incubation method of *Soil Taxonomy* – see data following the profile description.

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CLASSIFICATION BY WRB: Subaquatic (?) Hemic Epifibric Histosol (Epiprotothionic, Eutric) – classification here courtesy of Otto Sparrgaren.

Otto's Remarks on WRB classification:

Histosol because of more than 40 cm *organic material* within 100 cm of the soil surface, with a combination of fibric material on top of hemic material, hence Hemic Epifibric. Subaquatic may apply because of landform description: ***submerged*** upland tidal marsh. Soil contains *sulphidic material* in the upper 50 cm, hence Epiprotothionic, and has a near-neutral reaction, hence Eutric.

DSF remark: Otto was confused by our statement about submerged upland. If a Tidalic class becomes recognized by WRB (see Otto's comments following the Mispillion pedon) – the soil here would presumably qualify for that.

Location: Blackwater Wildlife Refuge, Maryland; 38 degrees 22 minutes 53.82 N latitude, 76 degrees 04 minutes 07.96 seconds W longitude.

Landscape: Coastal Plain

Landform: Submerged upland tidal marsh

Notes: Whiff test = #2, as digging; all soil properties below are field estimates. Field description and sample collection by Jim Brewer, Philip King and Charles Hanner of USDA NRCS.

Oi--0 to 18 cm; dark brown (10YR 3/3) peat (fibric soil material); about 80 percent by volume fibers after rubbing; 15 percent by weight mineral soil material; many fine, medium, and coarse live roots; abrupt smooth boundary; S05MD-019-002-1, SAMPLED.

Oe--18 to 42 cm; very dark brown (7.5YR 2.5/3) mucky peat (hemic soil material); about 50 percent by volume fibers after rubbing; 5 percent by weight mineral soil material; common fine, medium and coarse live roots; clear smooth boundary; S05MD-019-002-2, SAMPLED.

Cg--42 to 56 cm; dark grayish brown (2.5Y 4/2) silt loam, massive; friable; sticky; plastic; n value > 1.0, material flows between the fingers when squeezed; S05MD-019-002-3, SAMPLED.

Ag--56 to 63 cm; very dark gray (5Y 2.5/1) silt loam; massive; friable; slightly sticky, slightly plastic; n-value less than 0.7, material does not flow between the fingers when squeezed; S05MD-019-002-4, NOT SAMPLED.

BEg--63 to 84 inches; gray (10YR 5/1) silt loam; massive; firm; slightly sticky, slightly plastic; n-value less than 0.7, material does not flow between the fingers when squeezed; S05MD-019-002-5, NOT SAMPLED.

Btg1--84 cm; unable to extract.

Vegetation**:** saltmarsh cordgrass (*Spartina alterniflora*), saltmeadow cordgrass (*Spartina patens*), saltgrass (*Distichlis spicata*)

<u>Some lab data for Honga profile samples</u>. The pH (at approximately 1:1 water to soil material by weight) was measured by D. S. Fanning at Univ. of Maryland on samples about kept moist for about 2 weeks at room temperature or frozen after brought from the field in December, 2005. The total S, C, and N were determined at the National Soil Survey Center in Lincoln, NE, under the supervision of Mike Wilson on <2mm air-dry soil material prepared at the University of Maryland.

Horizon	Depth (cm)	pH	Total S (%)	Total C (%)	Total N (%)
Oi	0-18	5.04	1.75	32.48	2.422
Oe	18-42	6.67	2.50	36.10	2.068
Cg	42-56	7.12	0.68	9.22	0.635

In addition duplicate (1 vs. 2 for given depths in table below) sub-samples of the sampled horizons were incubated to determine if they qualified as *sulfidic materials* as defined by *Soil Taxonomy*. The samples were wet on the days of pH measurement (approximately weekly) and sometimes at in-between times, but were permitted to dry (sometimes to totally air dry) to various extents (sometimes to totally air dry) between times of wetting. Data are given below. Dates are for days in 2006.

Honga		Date/ pH	Date/ pH	Date/ pH	Date/ pH	Date/ pH	Date/ pH	Date/ pH	Date/ pH	Date/ pH	Date/ pH
Horizon	Depth, cm, dup.	2/15	2/22	3/1	3/9	3/16	3/23	3/30	4/6	4/13	5/13
Oi	0-18, 1	6,47	6.02	6.01	5.92	5.75	5.89	5.63	5.65	5.81	5.28
Oi	0-18, 2	5.46	5.86	5.05	5.48	5.97	5.48	5.05	5.07	5.49	5.08
Oe	18-42, 1	6.22	6.18	5.60	6.02	5.63	5.74	5.33	5.48	5.35	5.35
Oe	18-42, 2	6.29	6.13	5.31	5.89	5.69	5.73	5.43	5.22	5.18	5.22
Cg	42-56, 1	6.37	6.30	6.48	6.66	6.45	6.36	5.99	6.04	5.62	5.74
Cg	42-56, 2	6.31	6.80	6.32	6.70	6.63	6.58	6.28	6.06	5.98	5.83

DSF comments on the data, 5/17/06.

The total carbon content of the Oi and Oe horizons support the designation of these horizons as O horizons and for the recognition of these horizons as organic soil materials. They are thick enough for the recognition of this soil as a *Histosol* by *Soil Taxonomy*.

The total S levels of the Oi and Oe horizons are high enough for the recognition of these horizons as *sulphidic materials* by the WRB system, assuming content of calcium carbonate equivalent to be less than 3 times the quantity of S. By incubation, none of the horizons tested qualify for *sulfidic materials* by *Soil Taxonomy*. This may be because of the high degree of buffering of pH by the high levels of organic matter, or there may be insufficient levels of sulfide S. Cr reducible S levels have not been measured for samples from this profile.

The picture above is of Jim Brewer, USDA NRCS Maryland soil scientist, who is our leader for Stop 2 (Jim is also MAPSS secretary and a MAPSS leader to provide lunches for the tour group on July 7) at the edge of tidal marsh at Shorter's Wharf, close to the Honga soil sampling site. This picture, taken September 21, 2005, permits appreciation of how the trees at the edge of upland that the marsh is growing over are slowly being killed off as the marsh encroaches. The peaty soil is growing upwards at about the same rate as the rate of sea level rise, land subsidence (probably close to 5 mm/year in this area). At the right and slightly above the center of the photo there is a colony of *Phragmites australis* that are growing along a tidal stream channel that is to the right of the picture.

Stop 2 Continued -- Estuarine Tidal Marsh Soil: Mispillion Soil Series

Profile Description and Data:

NRCS Sample Number: S05MD-019-001

Mispillion peat, 0-1 percent slopes,

TAXONOMIC CLASS**:** Loamy, mixed, euic, mesic Terric Sulfihemists

CLASSIFICATION BY WRB: Hemic Epifibric Histosol (Protothionic, Eutric)
WRB comments: Histosol, dominantly hemic with a fibric surface layer, hence Hemic Epifibric Histosol. Not subaquatic because the soil is not permanently submerged (I assume from the tidal water remark). The next edition of WRB may consider adding Tidalic for such soils. For the second edition we have assumed that tidal currents are too strong to permit significant peat accumulation, but apparently such soils exist and have to be recognized.

The soil has sulphidic material probably throughout the first meter (below 90 cm was not sampled, but I assume that the Oa layer has more than 0.75% total S), hence Protothionic. Soil reaction is near neutral, therefore Eutric.

Location: Blackwater Wildlife Refuge, Maryland; 38 degrees 22 minutes 57.75 N latitude, 76 degrees 04 minutes 03.93 seconds W longitude.

Landscape: Coastal Plain

Landform: Tidal marsh

Notes: 6 cm tidal water above soil surface; Whiff test = #2, as digging; all soil properties below are field estimates. The description and collection of samples was done by Jim Brewer, Philip King and Charles Hanner of USDA NRCS.

Oi--0 to 18 cm; dark olive gray (5Y 3/2) peat (fibric soil material); about 80 percent by volume fibers after rubbing; 40 percent by weight mineral soil material; many fine, medium, and coarse live roots; abrupt smooth boundary; S05MD-019-001-1, SAMPLED.

Oe1--18 to 38 cm; dark yellowish brown (10YR 3/6) mucky peat (hemic soil material); about 35 percent by volume fibers after rubbing; 5 percent by weight mineral soil material; common fine, medium and coarse live roots; clear smooth boundary; S05MD-019-001-2, SAMPLED.

Oe2--38 to 90 cm; very dark brown (7.5YR 2.5/2) mucky peat (hemic soil material); about 35 percent by volume fibers after rubbing; 5 percent by weight mineral soil material; clear smooth boundary; S05MD-019-001-3, SAMPLED.

Oa--90 to 115 cm; black (7.5YR 2.5/1) muck (sapric soil material); about 15 percent by volume fibers after rubbing; S05MD-019-001-4, NOT SAMPLED.

Cg/Oe—115 to 150 cm; very dark gray (5Y 3/1) silt loam; massive; slightly sticky, slightly plastic; n value greater than 1.0, soil flows easily between the fingers when squeezed; dark reddish brown (5YR 3/1) mucky peat (hemic soil material); about 25 percent by volume fibers after rubbing; S05MD-019-001-5, NOT SAMPLED.

Vegetation**:** saltmarsh cordgrass (*Spartina alterniflora*), saltmeadow cordgrass (*Spartina patens*), saltgrass (*Distichlis spicata*)

<u>Some lab data for Mispillion profile samples</u>. The pH (at approximately 1:1 water to soil material by weight) was measured by D. S. Fanning at Univ. of Maryland on samples about kept moist for about 2 weeks at room temperature or frozen after brought from the field in December, 2005. The total S, C, and N were determined at the National Soil Survey Center in Lincoln, NE, under the supervision of Mike Wilson on <2mm air-dry soil material prepared at the University of Maryland.

Horizon	Depth (cm)	pH	Total S (%)	Total C (%)	Total N (%)
Oi	0-18	6.32	1.07	12.86	1.054
Oe1	18-38	6.67	3.35	30.02	1.716
Oe2	38-90	7.12	3.55	36.07	1.781

In addition duplicate (1 vs. 2 for given depths in table below) sub-samples of the sampled horizons were incubated to determine if they qualified as *sulfidic materials* as defined by *Soil Taxonomy*. The samples were wet on the days of pH measurement (approximately weekly) and sometimes at in-between times, but were permitted to dry (sometimes to totally air dry) to various extents (sometimes to totally air dry) between times of wetting. Data are given below.

Mispillion		Date/ pH	Date/ pH	Date/ pH	Date/ pH	Date/ pH	Date/ pH	Date/ pH	Date/ pH	Date/ pH	Date/ pH
Horizon	Depth, cm, dup.	2/15	2/22	3/1	3/9	3/16	3/23	3/30	4/6	4/13	5/13
Oi	0-18, 1	6.35	5.12	4.05	3.82	3.53	3.64	3.51	3.50	3.43	3.62
Oi	0-18, 2	6.51	6.03	5.88	5.52	5.19	5.48	5.39	5.22	4.97	5.16
Oe1	18-38, 1	6.99	6.74	6.10	5.86	5.26	4.84	4.97	4.28	4.23	3.44
Oe1	18-38, 2	6.60	6.38	5.26	5.76	5.26	4.99	5.21	4.80	4.74	4.47
Oe2	38-90, 1	6.98	7.27	7.02	6.84	6.59	6.55	6.27	6.07	5.69	4.61
Oe2	38-90, 2	6.94	7.14	7.00	7.01	6.58	6.55	6.37	6.02	5.74	5.66

DSF comments on the data, 5/17/06.

The organic carbon levels of the soil are sufficient to support the designations of O horizons. Organic soil materials are sufficiently deep to recognize the classification of the soil as a Histosol by both *Soil Taxonomy* and the WRB system. Total S levels are sufficient to support the recognition of *sulphidic materials* by the WRB system for all horizons, assuming less than 3 times the quantity of calcium carbonate equivalent as S. The soil materials are questionable for the recognition of *sulfidic materials* by *Soil Taxonomy*. One rep of the duplicates for the Oi horizon dropped sufficiently in 8 weeks to qualify, the other one didn't. After 3 months one rep of the Oe1 dropped to below 4.0. The poor duplication with the incubation data is a little disturbing. The resistance to pH drop is probably caused by the high organic matter levels that buffer the pH.

Stop 3
Muddy Creek Road Cut

We are here to see good examples of many of the characteristics of active acid sulfate soils including:

Jarosite
Silica cementation – opal-CT – this likely formed a long time ago
“Iron oxides”
Low pH
Sulfidic materials
Maybe some mono-sulfidic black ooze in ditch if conditions favor such – unlikely at this time of year
Maybe some ferrous sulfate or other sulfate salts if conditions favor
Lack of vegetation because of acid sulfate effects

This is a well-visited road cut. You cannot take an acid sulfate soils tour in this area without seeing this site. It has changed over the years, and some hardy vegetation has taken hold. This cut was exposed in the 1960’s during the widening and realignment of Route 468 (Muddy Creek Rd.) No remediation or management of this site has occurred. Periodically the highway people scrape the sediment off the shoulder during road cleaning and maintenance. This road maintenance and erosion of the unstable slope have filled the rock drainage channel visible at the far left of the left (1981) (Fig. 1) photo below.

1981 2000

Figure 1.
This site is an exposure of the glauconitic Nanjemoy geologic formation. Sulfides in these sediments occur almost exclusively as pyrite, primarily in framboidal and euhedral forms. The pyrite is intimately associated with the glauconite pellets (See Figure 3). Silica-cemented fragments (channers and tubules) from this cut have been shown to be cemented by poorly crystalline opal-CT by X-ray diffraction (See Figure 2). In these pedogenic rock fragments, pyrite is encased in the silica.

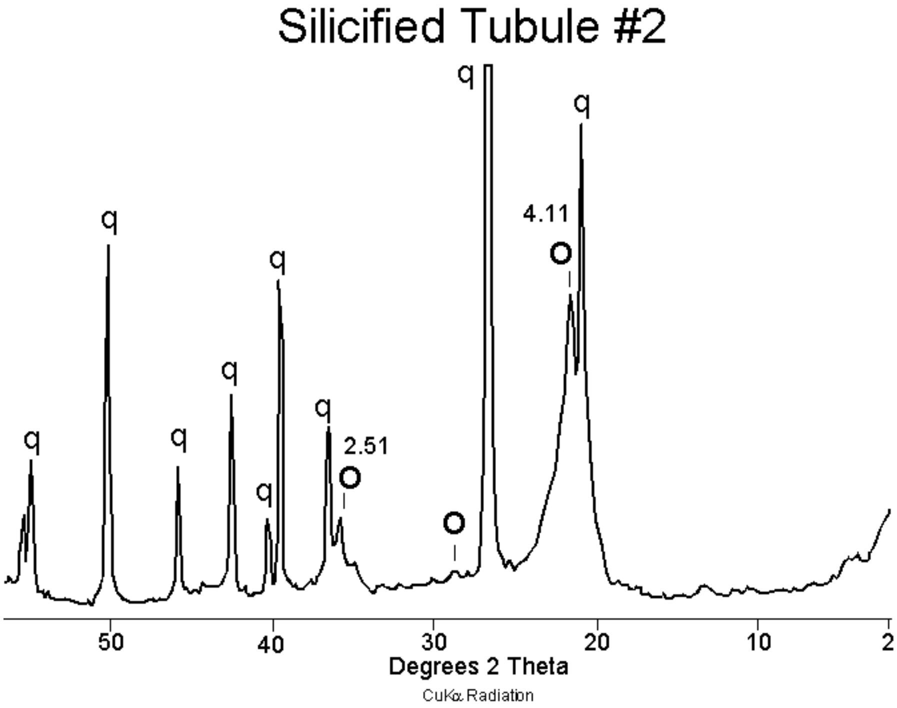


Figure 2. X-ray diffraction pattern of tubule from Rte. 468 road cut, acid sulfate soil exposure, showing the opal-CT (O) that cements this fragment. Quartz peaks are indicated by ‘q’.

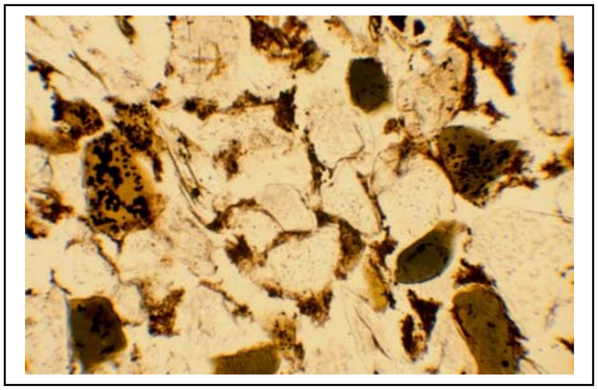


Figure 3. Photomicrograph of glauconitic sediments showing the intimate association of pyrite and glauconite. The sand sized pellets of glauconite have pyrite crystals around and inside of them. This thin section photographed in plane polarized light, frame length is approximately 1.2mm. Photo courtesy of Dr. M.C. Rabenhorst.

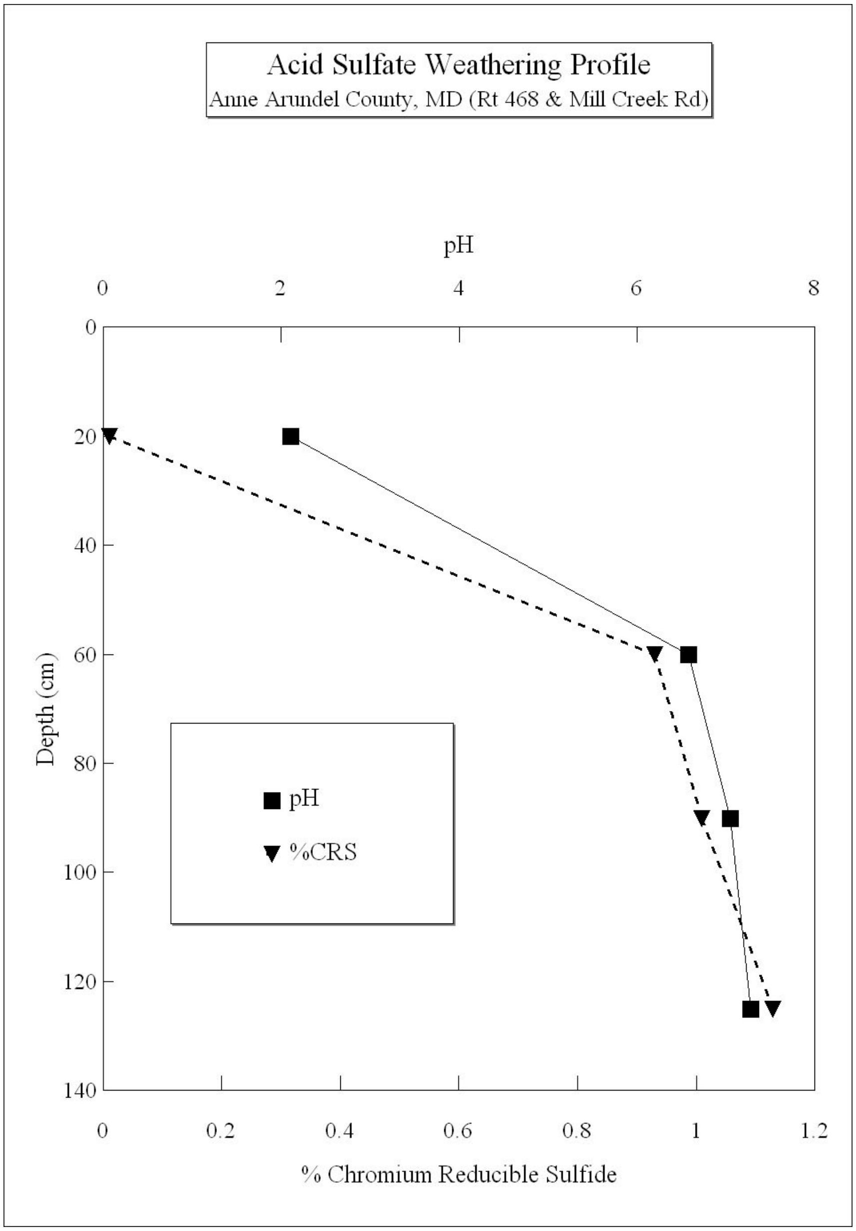


Figure 4. This road cut exhibits a typical acid sulfate weathering profile in which the pH increases with depth. The sulfuric horizon (0 to 25 cm) has low pH and low chromium reducible sulfide. There is a transition zone, from about 25 to 45 cm, to the relatively unweathered sulfidic materials, 45 to 105 cm, that have a neutral pH. Description of the soil from which samples were taken to get these data is on the next page.

Profile description

Maryland Rte. 468 at Mill Swamp Rd.

Classification*:* *Typic* (by Fanning and Fanning, 1989, proposed *Scalpic*) *Sulfudept*, sandy, mixed, mesic

Classification by WRB courtesy of Otto Sparrgaren: Brunic Arenosol (Epihyperdystic, Endoeutric). DSF: If the soil wasn't so sandy, the soil would apparently be a Haplic Regosol (Hyperdystric, Arenic) like the similar soil on the scalped land surface at the Stafford County Regional Airport to be seen at Stop 5.

Location*:* Anne Arundel County, Maryland

Native vegetation*:* None.

Parent Material*:* Scalped land surface on the Nanjemoy Formation – a glauconitic *sulfidic material*.

Slope*:* 65%

Described by*:* D. S. Fanning and S. Burch (in 1995 for Clay Minerals Society field trip?)

Horizon	Depth (cm)	Description
Bwj	0 -25	Very dark grayish brown (2.5Y 3/2) loamy fine sand; moderate coarse platy structure; friable; common to many medium & coarse prominent yellow (5Y 7/6) jarosite mottles in a banded pattern on plate surfaces, parallel to the soil surface; common medium to coarse distinct olive (5Y 5/3) mottles of silty material; ultra acid, pH 2.2; clear smooth boundary. A mixture of black (2.5Y 2.5/1) glauconite pellets and dark grayish brown (2.5Y 4/2) quartz grains give rise to the predominant matrix color.
Cg1	25-45	Black (N 2.5) loamy fine sand; moderate thick platy structure; friable; common medium faint dark olive gray mottles of silty material; extremely acid, pH 4.1. The material is predominantly sandy material with silty "mottles". The horizon boundary is arbitrary, determined by the depth dug with a spade.
Cg2	45-75	The material in this horizon has the same properties as the Cg1 except for a slightly acid reaction, pH 6.3. Again the boundary is arbitrary.
Cg3	75-105	The material in this horizon is similar to the Cg1 except for a neutral reaction, pH 6.7.

Comments by Fanning in June, 2006. The silica cementation is not directly associated with the described (above) soil profile and is best viewed at the top of the old road cut about 10 to 15 meters north of where the profile described above is located. We plan to expose again a profile like the one described above for this WCSS tour.

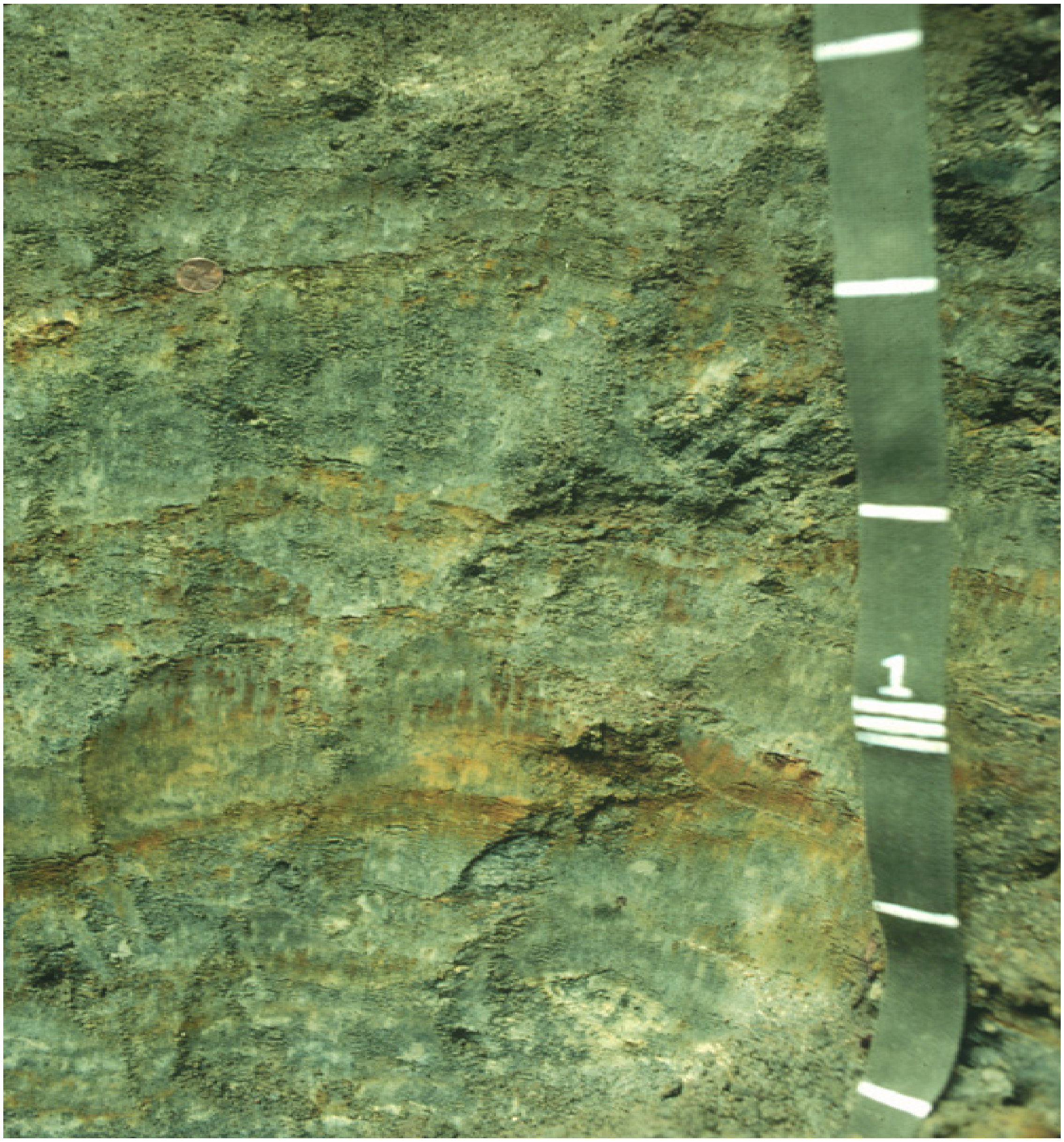
The soil where marked silica cementation occurs, presently right at the surface of that profile, itself represents an earlier scalped land surface for the old road on that surface. The original soil above that surface was very likely a post-active acid sulfate soil. I think the silica cementation formed when percolating soil solutions high in dissolved silica, from acid weathering when the oxidation front was naturally moving down the column above, penetrated the then higher pH un-oxidized zone to trigger the precipitation of the silica as opal-CT (a poorly crystalline form of cristobalite). So much of the material is silica-cemented that from a *Soil Taxonomy* point of view we could consider it to represent a *duripan* and if this profile would be described we should assign qm subscripts to the cemented horizons/layers.

Silica cementation is commonly found in these acid sulfate soils. Geologists might argue that it goes back to the time that the sediments were being deposited in the sea. I prefer to think that the silica cementation is a pedogenic phenomenon, although it may have occurred deep in the soil-geologic column. Some soil scientists studying acid sulfate weathering (e.g. Mermut and students at the University of Saskatchewan) have shown that active acid sulfate weathering can lead to very high levels of silicon, aluminum and other elements that compose silicate minerals in the soil solution. Whether silicate minerals are dissolving or precipitating hinges on the pH with much more of the elements capable of staying in solution at equilibrium at low pH than at high. The solubility of silica itself should not be affected by pH according to stability diagrams – however, higher pH may favor the precipitation kinetically by causing H^+ dissociation from dissolved silicic acid. This is speculation on my part, but based on my view of physical chemistry theory. Anyhow we commonly see silica cementation and opal-Ct associated with sulfuricization affected soils. I have seen this in Texas and in West Africa as well as in Maryland. It seems to me that petrified wood forms in such acid sulfate environments because we find it and other petrified biologic remains (e.g. tubules) in such places.

Note regarding the authorship of the materials for this site. The materials were put together by Susan Davis, who will be on the trip and offer comments on her experiences with acid sulfate soils during the update of the soil survey of Anne Arundel County, where this stop is located. The early, 1981, photo (Fig.1) is from D. P. Wagner's Ph.D. dissertation. The mineralogy work was done by Rabenhorst. The soil description was done by Fanning and Steve Burch.

STOP 4

POST-ACTIVE ACID SULFATE SOILS



Lower portion of an Ultisol in Eocene glauconitic sediments at SERC in MD. The jarosite (yellow) and iron (hydr)oxides (orange) are thought to have formed by sulfuricization many millenia in the past. Similar materials carry down at this site to a depth of 4.5 meters, where the unoxidized zone is reached (profile picture after Wagner et al., 1982, in SSSA Acid Sulfate Weathering publication). Marks on tape indicate decimeters, and number 1 at triple mark shows depth of 1 meter.

This stop is at SERC (Smithsonian Environmental Research Center) headquarters and labs at the end of Contees Wharf Road, only a few miles from Stop 3. We come here to examine and discuss post-active acid sulfate soils (e.g. see picture of one on previous page) that are exposed for our examination behind two small storage buildings (30A and 30B) along a hillside on the east side of the complex of SERC buildings. This will be the only stop on the trip for close up examination of post-active acid sulfate soils. The soils here represent the kind of soils developed in the sulfide-bearing glauconitic Eocene sediments that were presumably scalped away to expose *sulfidic materials* in the un-oxidized zone of the soil-geologic column seen at Stop 3, which upon exposure to oxidation by highway construction have given rise to active acid sulfate soils like the one described at Stop 3.

One of the main features to excite our interest at this stop is the thickness of the oxidized zone (about 4.5 meters here). The oxidized zone in uplands here in Anne Arundel County and in many places in Eastern United States south of the glaciated region typically ranges from about 2 to 20 meters in thickness. This oxidized zone in some places, such as here, has jarosite concentrations throughout, except from the top of the soil down to the lower part of the *argillic horizon*, here coming in at a depth of about 60 cm. The presence of jarosite in the oxidized zone of the soil-geologic column indicates that the soil materials experienced acid sulfate weathering (sulfuricization) as the oxidized zone was deepened during the formation of the soils. Logical reasoning leads to the conclusion that the jarosite formed during intense acidification as the weathering front passed down through the horizons/layers in which the jarosite is found, probably for as long as there was pyrite present to oxidize, and that the jarosite should be progressively younger the closer it is to where the oxidation front is today (at 4.5 meters at this site) although material has eroded away from the surface as time has gone on – but at a slower rate than the rate at which the oxidized zone has become deeper.

If we could determine the time when the jarosite formed at various depths coming down the profile we could determine the rate (depth per unit time) at which the oxidized zone has been deepening itself. That gives us the incentive to try to age-date jarosite from soils such as those seen here, as Vasconcelos has done for some soil-geologic columns for some landscapes in Queensland, Australia (e.g. Vasconcelos and Conroy, 2003). A first step in doing this is to be able to purify the jarosite from specific depths in these soils away from other minerals in these soils that contain the argon isotopes that are used in the dating. The mineral that we are concerned about here is glauconite which is in the Tertiary sediments in which the soils here are formed and which is presumed to have formed on the sea floor at the time the sediments were deposited in a marine environment, taking potassium from the Eocene sea into the structure of the glauconite as the glauconite formed. (Skip for text continuation to page following the XRD patterns on next page).

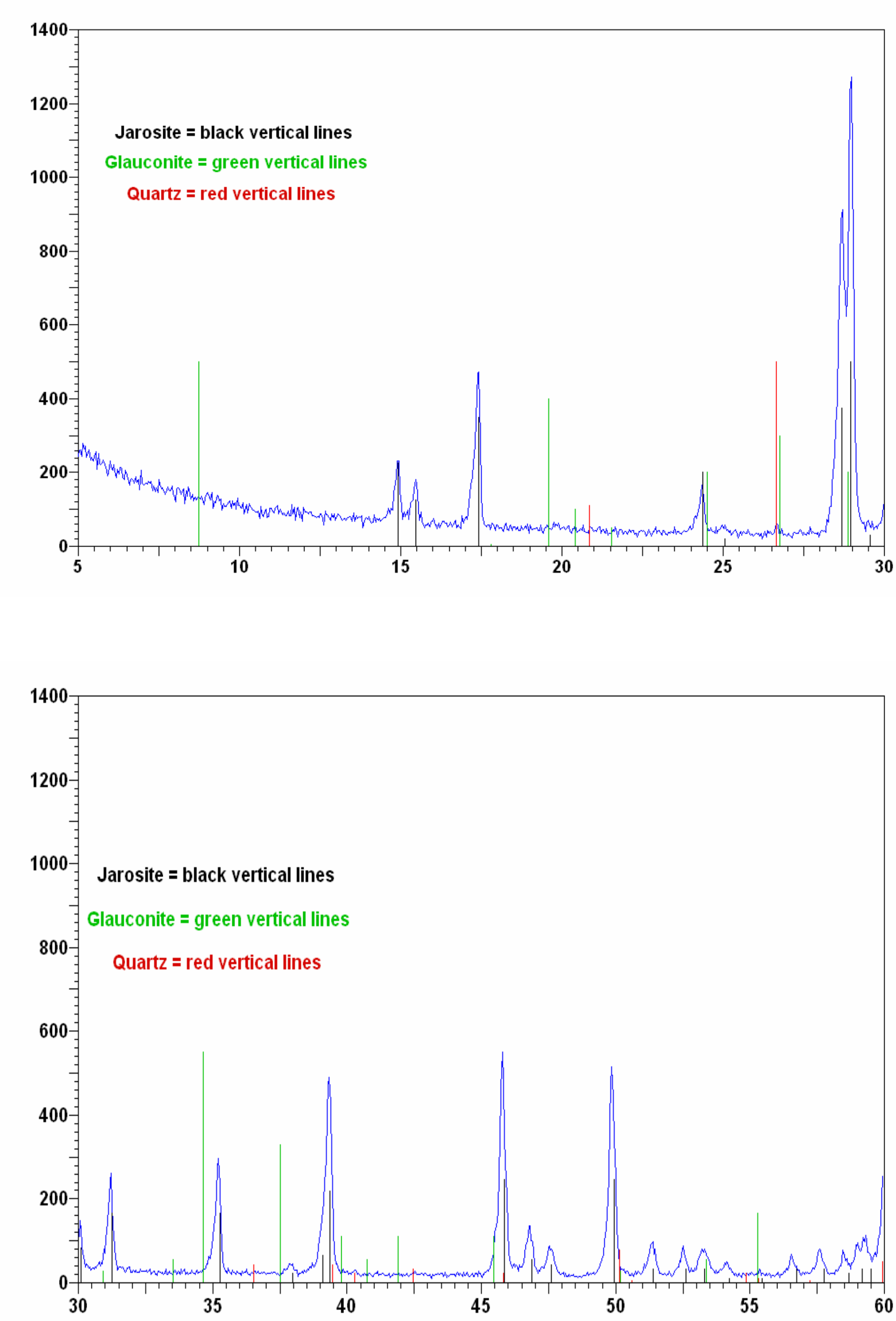


Figure. X-ray diffraction pattern in two segments for jarosite purified by P. A. Zurheide from small vugs at a depth of about 1.5 meters from a profile exposed in May 2006 behind the back right corner of building 30A at SERC. This profile, for which a monolith has been made, occurred probably about 2 meters to the right (facing profile) from the profile photographed by Wagner in 1978 that is shown in the profile picture on previous page.

We (led by the efforts of Philip Zurheide) have just, in June 2006, succeeded to purify some jarosite from a newly exposed profile, probably about 2 meters from the profile shown in the photograph on the first page for this stop. The X-ray diffraction pattern for this purified jarosite is shown on the previous page. The position and standard intensities of the peaks for jarosite, glauconite, and quartz are shown placed in the patterns. From these patterns it appears that jarosite is essentially the only mineral present in the purified material. Probably because of an inexact position of the surface of the material in the specimen holder, all peaks are shifted slightly left from their true position according to the standard pattern for jarosite. This is more noticeable on the right side of the lower pattern, where peaks are more shifted because of the nature of the sine function in the Bragg equation (small differences in d-spacing are better resolved at higher 2-theta angles).

The diffraction pattern was made with Cu Kα radiation with the specimen mounted in a quartz specimen holder. 2θ values are shown on the X-axis and peak intensities in counts per second are on the Y-axis.

About 45 mg of purified material was produced by gentle manipulation of the material with a needle under a low power microscope followed by suspending the material in a test tube in distilled water to let small pieces of presumed glauconite to settle followed by pouring off the suspended jarosite.

Dr. Vasconcelos has told us that we need between 10 and 100 mg of jarosite to do dating. We don't yet know whether we have a sufficient quantity in a proper form to date or not. We have not succeeded to contact Dr. V since we got the purified jarosite.

Profiles/Pedons. On the succeeding pages for this stop there are descriptions made of two pedons at this site on March 28, 2006, the first from behind building 30B, the second from behind back left corner of Building 30A.

Building 30B was constructed more recently than building 30A. Fanning and Wagner examined the profile shown in the photograph on page 67 behind 30A in 1978, although they first examined a profile at that location in 1976 when the soil was used as a practice pit for soil judging purposes. In 1976, building 30A had just been constructed and building 30B did not exist. It is our judgement that material from behind building 30B was placed during its construction in the hole behind building 30A, making it impossible for us to see the profile that we saw in 1978 without doing much new digging, which we haven't done. We also believe from anecdotal evidence and from an indentation in the surface of the profile/pedon behind 30A that a tree that was nearly on top of the profile we studied in 1978 (shown in our old photos from this site) tipped into the pit in front of the profile of 78 roots and all – tree throw. Our new pits behind 30A are behind the left end of the building facing the hill into which the profiles are carved and behind the right back corner – because of less digging required than where the old 78 profile occurred. The profile (S06MD003-001) behind the back left corner of building 30A has a thinner argillic horizon than the profile behind building 30B, largely because of loss of material from the surface of the profile behind 30A.

Below, on this page, there is a brief description of the soil materials from a bucket auger hole, down to the un-oxidized zone, by Fanning and Wagner in November, 2005, showing the occurrence of jarosite concentrations throughout the whole zone examined. We think that similar kinds of things would be found under all of the profiles at this site. Material from a new auger hole to the un-oxidized zone was extracted and laid out for trip participants to view on July 7 (thanks to Dan Wagner who joined us when we visited this site and offered some comments on his work).

A third new pit, behind the back right corner of building 30A, was not described in time for the guidebook, however, this is the pit from which a monolith has been extracted that was available for viewing by trip participants on July 7. This is also the pit from which the jarosite was purified (XRD patterns on page 67) from concentrations from a depth of about 1.5 meters.

Depth Feet	Meters	Colors etc.	pH (duplicate sub-samples) 1	2
5-8.6	1.5-2.58	Olive gray (5Y4/2) with common 2.5Y 4/3, 5Y 7/4 j, and 5YR 3/3-4/3 and 7.5YR 5/8 iron (hydr)oxides somewhat cemented	4.14	4.14
8.6-9.1	2.58-2.73	Olive gray (5Y4/2) with 5YR 3/3-4/3 and 7.5YR 5/8 iron (hydr)oxides and a little j – an iron “oxides” enriched zone	4.25	3.99
9.1-10.4	2.73-3.12	Olive gray (5Y4/2) with 2.5Y7/4 j, a j enriched zone, little to no Fe (hydr)oxides.	4.10	4.36
10.4-12	3.12-3.6	Olive gray (5Y4/2), more j than below, less than above	4.28	4.32
12-13.6	3.6-4.08	A little darker than 5Y4/2, little j	4.48	4.53
14-14.8	4.2-4.44	Above suspected sulfuric h. – high j with silty stuff.	4.46	4.36
14.8-15	4.44-4.5	Suspected sulfuric h above sulfidic in unoxidized zone.	4.32	4.50
15+	4.5+	Dense dark sulfidic material, tested sulfidic by incubation test.	5.14	5.06

The 15+, 4.5m, sample was analyzed by Morton/Rabenhorst for Cr-reducible S, found 0.597% Cr-reducible and no acid volatile S. Incubation data below.

Sample	Depth m etc.	2/15	2/22	3/1	3/9	3/16	3/23	3/30	4/6	4/13
SERC	4.5+ 1	4.76	4.42	4.09	4.05	3.35	3.45	2.90	2.65	2.43
SERC	4.5+ 2	4.56	4.47	4.00	4.08	3.65	3.72	2.98	2.66	2.44

The suspected *sulfuric h.* above the *sulfidic materials* was not one, the pH was too high.

STOP 4 – Pedon descriptions for soils to be examined

Post-Active Acid Sulfate Soils at SERC

Profile No. S06MD003-002
Annapolis soil behind the middle of building 30B at SERC

Profile description:

Horizon	Depth inches cm	Description
A	0-1.75” 0-4 cm	Very dark grayish brown 2.5Y3/2, dark grayish brown 2.5Y4/2 dry sandy loam about 14% clay; moderate, coarse granular structure; very friable, sticky and plastic wet; pH 5.57; clear, wavy boundary.
Bt1	1.75-4.5” 4-11 cm	Dark olive brown 2.5Y3/3 sandy clay loam about 20% clay; strong, coarse subangular blocky structure: friable, hard dry, moderately sticky and very plastic wet; pH 4.80; about 18% glauconite pellets; clear, wavy boundary.
Bt2	4.5-15” 11-38cm	Olive brown 2.5Y4/3 sandy clay loam about 25% clay; strong, coarse subangular blocky structure; friable, hard dry, sticky and very plastic wet; pH 4.86; about 25% glauconite pellets; clear, wavy boundary.
Bt3	15-27” 38-69 cm	Olive brown 2.5Y4/3 fine sandy loam about 17% clay; strong, coarse subangular blocky structure; friable, hard dry, slightly sticky and moderately plastic wet: pH 4.60; about 25% glauconite pellets; clear, wavy boundary.
BCj1/Bt4	27-36” 69-91 cm	Olive brown 2.5Y4/3 fine sandy loam about 17% clay; strong, coarse subangular blocky and massive structure: friable, slightly sticky and slightly plastic wet; pH 4.52; about 35% glauconite pellets; abrupt, irregular boundary.
BCj2	36-42” 91-107 cm	Olive 5Y4/3 with few, medium, prominent reddish yellow 5YR6/6 concentrations, and common, medium, faint dark olive gray 5Y3/2 depletions, and few (2%) pale yellow 5Y8/4 jarosite concentrations fine sandy loam about 14% clay; structureless massive: very friable, non-sticky and slightly plastic wet: pH 4.34; about 45% glauconite pellets; gradual, irregular boundary.

BCj3	**42-57” 107-145 cm**	**About 60% olive 5Y4/3, 30% very dark grayish green 10Y 3/2, 7% light yellowish brown 10YR6/4 and 3% pale yellow 5Y8/4 jarosite fine sandy loam about 13% clay; structureless massive; very friable, non-sticky and non-plastic wet; pH 4.35; about 50% glauconite pellets; clear, smooth boundary.**
BCj4	**57-74”+ 145-188 cm**	**About 60% very dark grayish green 10Y3/2, 20% olive 5Y4/3, 10% brown 10YR4/3 with about 5% yellowish red 5YR5/8 iron oxide (probably goethite) masses (concentrations) and 3% pale yellow 5Y8/4 jarosite masses (concentrations) fine sandy loam about 13% clay; structureless massive; friable, non-sticky and non-plastic wet; pH 4.11; about 55% glauconite pellets.**

Supplemental profile description information for Profile No. S06MD003-002, Annapolis soil profile at SERC behind building 30B.

Horizon	Roots	Pores	Clay films	Other Notes
A	**few very coarse, few coarse, many medium, common fine, common very fine**	**few very coarse, coarse, medium, fine and very fine**		
Bt1	**few very coarse, few coarse, common medium, few fine and few very fine**	**few very coarse, coarse, medium, fine and very fine**	**50% prominent films, 2.5Y3/3 on ped faces**	
Bt2	**very few coarse, few medium, few fine and few very fine**	**few coarse, medium, fine and very fine**	**75% prominent films, 2.5Y4/3 on ped faces**	
Bt3	**very few coarse, few medium, few fine and few very fine**	**few coarse, medium, fine and very fine**	**40% prominent films, 2.5Y4/3 on ped faces**	
BCj1/Bt	**few medium, few fine and few very fine**	**few fine and very fine**	**5% of ped faces**	**≈ 1% 10YR6/4 silt clasts 5-15 mm; ≈ 1% 5Y8/4 irregular j masses, 1-5 mm diam.**
BCj2	**few medium, fine and very fine**	**very few medium and fine**		**≈ 1% 10YR6/4 silt clasts 5-15 mm; ≈ 2% 5Y8/4 irregular j masses, 2-10 mm diam.**

BCj3	**few medium, fine and very fine**	**very few fine**		**≈ 1% 10YR6/4 silt clasts 5-15 mm; ≈ 3% 5Y8/4 irregular j masses, 2-10 mm diam**

Horizon	**Roots**	**Pores**	**Clay films**	**Other Notes**
BCj4	**few medium and fine**	**very few fine**		**≈ 5% 5YR lenticular and irregular iron oxide masses, 3-35 mm diam; ≈ 3% 5Y8/4 irregular j masses, 3-25 mm diam.**

Classification: Fine-loamy, glauconitic, mesic, Typic Hapludult. The soil appears to qualify for the Annapolis soil series by *Soil Taxonomy* and current soil survey criteria.
WRB Classification courtesy of Otto Sparrgaren: Cutanic Alisol (Alumic)

> **Otto's Comments: Alisol (high CEC assumed because of ST classification as Hapludult); Cutanic because of the presence of clay skins; Alumic is assumed because of low pH, no data are given. Amount of iron oxide masses in BCj2 is too little to qualify for Ferric. Hyperdystric may apply if BS is below 20%.**

Area: Anne Arundel County, MD, by SERC headquarters buildings

Description in field done by Eddie Earles with assistance from David Verdone and Del Fanning on March 28, 2006. The description was written in long form by Del Fanning from field notes taken by Verdone.

Location: From NRSC gps unit -- 38°53′18.2″N, 76°33′19.8″W, wp 721, 3D differential ±10 feet. The description was made in a freshened old cut behind the middle of Building 30B at SERC.

Normal Vegetation: Mixed hardwood and pine forest. It is thought that this area was cultivated at one time from an old 1930's aerial photograph but it has been naturally reforested.

Physiography and slope: The soil occurs on a slope of about 30% upwards from the profile. The profile was cut into the hill for the purpose of the construction of the cement block building that is on a flattened constructed surface down-slope of the profile. The landscape position is judged to be lower backslope.

Drainage: Well drained.

Ground water: deep, >6 feet.

Moisture when described: Dry, particularly in upper part of profile because of dry weather for several weeks preceding the description and because of being covered with a polyethylene sheet for a couple of weeks to protect the profile.

Parent Material: Glauconitic, loamy, marine geologic sediments, probably representing the Eocene Nanjemoy geologic formation that evidence indicates contained quantities of iron sulfides, probably mainly in the form of pyrite, sufficient to greatly acidify the soil when the sulfides oxidized.

Erosion: The soil appears to have suffered moderate to severe accelerated erosion because of post-colonial cultivation, probably for tobacco. This is thought to have resulted in a thinner argillic horizon than found in other, less-eroded, Annapolis soils.

Profile No. S06MD003-001
Annapolis soil behind the back left corner of building 30A at SERC. See table on next page for supplemental information on roots, pores, clay skins and other features.

Horizon	Depth inches cm	Description
BA	0-6” 0-15 cm	Very dark grayish brown 2.5Y3/2 sandy loam about 14% clay; weak, coarse granular and weak, coarse subangular blocky; very friable, slightly sticky and non plastic wet; pH 4.71; about 20% glauconite pellets; clear, wavy boundary.
Bt/BC	6-13” 15-33 cm	Olive brown and dark grayish brown 2.5Y4/3 and 4/2 with about 3% dark greenish gray 10Y4/1 depletions and 3% yellowish red 5YR5/6 concentrations sandy clay loam about 21% clay; weak, very coarse subangular blocky and massive; friable, slightly sticky and moderately plastic wet; pH 4.51; about 40% glauconite pellets; clear, irregular boundary.
BCj1	13-28” 33-71 cm	60% olive brown 2.5Y4/3, 35% dark olive gray 5Y3/2 and 1% yellowish red 5YR 4/6 fine sandy loam about 14% clay; very friable, non-sticky and slightly plastic wet; pH 4.48; about 50% glauconite pellets; clear, wavy boundary
BCj2	28-41” 71-104 cm	45% olive brown 2.5Y4/3, 45% dark olive gray 5Y 3/2 with about 2% light yellowish brown 10YR6/4 irregular silt clasts, 3-15 mm diam., 5% pale yellow 5Y8/4 irregular j masses 2-20 mm diam. and 3% yellowish red 5YR4/6 platy iron oxide masses 3-15 mm diam. fine sandy loam about 10% clay; massive; very friable, non-sticky and non-plastic wet; pH 4.27; about 60% glauconite pellets; clear, wavy boundary.
BCj3	41-47”+ 104-119+ cm	50% dark olive gray 5Y3/2, 35% olive brown 2.5Y4/3, 10% yellowish red 5YR5/8 with about 2% light yellowish brown 10YR6/4 irregular silt clasts, 3-15 mm diam., and 1% pale yellow 5Y8/4 irregular j masses 2-10 mm diam. loamy fine sand; massive; very friable, non-sticky and non-plastic wet; pH 4.11; 50% glauconite pellets.

Supplemental information for Profile 30A1

Horizon	**Roots**	**Pores**	**Clay films**	**Other Notes**
BA	**few very coarse, coarse, medium, fine and very fine**	**few fine and very fine**		
Bt/BC	**common very coarse, few coarse, medium, fine and very fine**	**few fine and very fine**	**BRF 10YR 5/4**	
BCj1	**common very coarse, few coarse, medium, fine and very fine**	**very few medium and fine**		**2% 10YR6/4 irregular silt clasts, 5-15 mm diam;** **2% 5Y8/4 irregular j masses 3-15 mm diam.**
BCj2	**few very coarse and coarse, very few fine and very fine**			**2% 10YR6/4 irregular silt clasts, 3-15 mm diam.; 5% 5Y8/4 irregular j masses 2-20 mm diam.** **3% 5YR4/6 platy iron oxide masses 3-15 mm diam.**
BCj3	**few very coarse and coarse, very few fine and very fine**			**2% 10YR6/4 irregular silt clasts, 3-15 mm diam.; 1% 5Y8/4 irregular j masses 2-10 mm diam.**

The info below is repeated from Profile 30B and should be updated to be specific for this profile

Classification: Fine-loamy, glauconitic, mesic, Typic Hapludult. The soil appears to qualify for the Annapolis soil series by *Soil Taxonomy* and current soil survey criteria.

Classification by WRB (courtesy of Otto Sparrgaren): Cutanic Alisol (Alumic)

> **Otto’s Comments on WRB Classification: Alisol (high CEC assumed because of ST classification as Hapludult); Cutanic because of the presence of clay skins; Alumic is assumed because of low pH, no data are given. Amount of iron oxide masses in BCj2 is too little to qualify for Ferric. Hyperdystric may apply if BS is below 20%.**

Area: Anne Arundel County, MD, by SERC headquarters buildings

Description in field was done by Eddie Earles with assistance from David Verdone and Del Fanning on March 28, 2006. The description was written in long form by Del Fanning from field notes taken by Verdone.

Location: From NRSC gps unit -- 38°53′18.2″N, 76°33′19.8″W, wp 721, 3D differential ±10 feet. The description was made in a freshened old cut behind the back left corner (looking upslope) of Building 30A at SERC.

Normal Vegetation: Mixed hardwood and pine forest. It is thought that this area was cultivated at one time from an old 1930’s aerial photograph but it has been naturally reforested.

Physiography and slope: The soil occurs on a slope of about 30% upwards from the profile that was cut into the hill for the purpose of the construction of the cement block building that is on a flattened constructed surface down-slope of the profile. The landscape position is judged to be lower backslope.

Drainage: Well drained.

Ground water: deep, >6 feet.

Moisture when described: Dry, particularly in upper part of profile because of dry weather for several weeks preceding the description and because of being covered with a polyethylene sheet for a couple of weeks to protect the profile.

Parent Material: Glauconitic, loamy, marine geologic sediments, probably representing the Eocene Nanjemoy geologic formation that evidence indicates contained quantities of iron sulfides, probably mainly in the form of pyrite, sufficient to greatly acidify the soil when the sulfides oxidized.

Erosion: The soil appears to have suffered moderate to severe accelerated erosion because of post-colonial cultivation, probably for tobacco. This is thought to have resulted in a thinner argillic horizon than found in other, less-eroded, Annapolis soils.

EXTRA STOP ON JULY 7, CLIFF ON MARYLAND SHORE OF TIDAL POTOMAC RIVER AT LOYOLA RETREAT HOUSE

This stop will be made in the evening of July 7 after we have checked in to our lodging at the Best Western LaPlata Inn (check-in was skipped until after dinner, DSF) and as we proceed on the way to our dinner stop for this night at Robertson's Restaurant at Pope's Creek on the shore of the tidal Potomac River about 10 miles southeast of LaPlata. The Retreat House stop is about a mile up river from the restaurant, which (the restaurant) is at water's edge.

The Loyola Retreat House sits on a hill above the river and a trail to the river beach beneath a cliff on the river can be walked in about 5 minutes. It is a steep climb back, so those who don't think they can walk down to the river and back in a few minutes should probably remain with the tour bus. It will be necessary to be quiet when we are close to the buildings of the retreat house as there will be a retreat going on and those in charge do not want us to disturb anyone.

The cliff face here has many interesting (acid sulfate) and other weathering features. It was discovered for us by graduate student David Ruppert when he was participating in a retreat at the Retreat House and he went for a walk down to the river. We have been helped at this site as well by a former graduate student, Carol Gordon, who now works for the Charles County, MD, Soil Conservation District out of LaPlata. We are here in Charles County; LaPlata is the county seat. Fanning with students visited this site on a cold, windy Sunday afternoon near the end of February, 2006, when the pictures from this site on the following two pages were taken.

One of the points of interest here is a thick Native American oyster shell kitchen midden that can be viewed from below, from the beach, up to where it is exposed at the top of the cliff – see picture X1 on the next page. There are such middens at many places along the tidal Potomac River, but this is one of the thickest that we have seen. It appears to have a buried soil surface with a thick A horizon (probably a buried *anthropic epipedon*) within it – that apparently was followed by another period of shell deposition. A few miles farther down the river, the small present-day village of Morgantown is built on an extensive midden on flat land just a little above sea level. The soils of that midden site have been studied as part of Master's thesis research by former students Jim Luzader (1983) and Ian Kaufmann. Pictures of a soil profile and a midden landscape when the soil was tilled from that site appear on page 67 in the Fanning and Fanning (1989) book.

Picture X1. Carol Gordon, who is a short person, holding a tiling spade (sharp shooter) standing on top of Native American oyster shell kitchen midden exposed on low cliff above tidal Potomac River just a short distance (50 meters) upriver from where the trail from the Loyola Retreat House reaches the river thru a creek valley to the right of where Carol is standing.

This site will also afford an opportunity to view other parts of the cliff face to see the oxidized vs. un-oxidized parts of the soil-geologic column that are in marine sediments of Miocene (probably Calvert formation) and/or Eocene (probably Nanjemoy formation) age. We are hoping to get out to this site for a further look before we bring the tour group here. One of the interesting features that occurs in the cliff face are what we think are petrified (silicified) tree logs that have petrified worm burrows within them – see the picture, X2, on the following page.

An acid sulfate weathering profile with its lower part in the un-oxidized Nanjemoy (Eocene) formation was studied on a 6 meter high cliff about a mile farther up river from the Retreat House cliff on the Mt. Air estate (Wagner, 1982). There the cliff was in a cut river terrace. At the Retreat House site the land that the cliff is cut into is hilly. We would have liked the tour to have had the opportunity to visit the Mt. Air site that Wagner studied (see picture of that cliff in Figure 1.10 of Fanning and Fanning, 1989, page 10), however, we no longer have access to that site and it is also physically much more difficult to reach than this Retreat House site. At the Mt.Air cliff, macroscopic gypsum crystals where former calcium carbonate shells have been converted to gypsum by sulfuric acid, as well as jarosite and iron (hydr)oxides formed by acid sulfate weathering are to be seen in the base of the oxidized zone and in the actively sulfuricizing zone at the top of the un-oxidized zone.

Picture X2. What is interpreted to represent a worm burrowed log, where the burrows have been silicified, from the sediments near the base of the cliff on the Potomac River at the Loyola Retreat House. The surrounding sediments, which contain shells and shell casts are also apparently silicified.

References:

Fanning, D. S. and M. C. B. Fanning. 1989. Soil: Morphology, Genesis, and Classification. John Wiley and Sons, New York.

Luzader, J. D. 1983. Characterization of soils developed in oyster shell middens in Maryland. M.S. Thesis. University of Maryland, College Park, MD.

Wagner, D. P. 1982. Acid sulfate weathering in upland soils of the Maryland Coastal Plain. Ph.D. dissertation, University of Maryland, College Park, MD.

EXTRA STOP AS FIRST STOP ON THE MORNING OF JULY 8 GREAT OAKS HOUSING DEVELOPMENT IN FREDERICKSBURG, VIRGINIA

This will be a short stop, for 30 minutes or less, at a new (3 years old or less) housing development called Great Oaks in Fredericksburg, VA, just before we reach interstate highway I-95 that we will take to succeeding stops as we head north toward Washington, DC.

Acid sulfate problems have arisen in many housing developments in Virginia and Maryland and other states in the region. We are stopping at Great Oaks because it is very convenient to the route of our trip and because some of the problems are at a spectacular stage here at the present time.

The road leading into the development along Hays Street goes past houses with no observable problems because in the construction *sulfidic materials* were not encountered. Here the road/street and the houses along it are on a ridge top, probably in Quaternary geologic deposits. We will turn left off this road onto Great Oaks Lane and proceed down slope. In about 1 block we will reach Hickory Court, which goes off to the right. It is in this neighborhood where the lawns have almost no grass, in spite of being sodded in many places with new turf two times, and the side walks in many places are coated with iron (hydr)oxides to give them a reddish/orange color -- as shown in pictures below and on the following page.

Yard with dead turf at corner of Great Oaks Lane – the street going across the picture -- and Hickory Court that leads out to the STOP sign.

Lee Daniels, soil scientist and reclamation expert from Virginia Tech is shown standing on discolored side walk around house at the corner of Great Oaks Lane and Hickory Court. Grass is growing along the edge of the concrete probably because of the liming effect of the concrete.

Dead turf on hill side coming down from house in spite of being sodded with healthy turf two times. Lee and Zenah Orndorff have worked with some home owners who had lawns looking like this one to enable the establishment of planted turf grasses as shown in two pictures from the yard of Les Hazen on the next page. About 30 tons of lime per acre and 4 inches of a compost/topsoil mix were mixed into the top 6 inches of the acid sulfate soil to achieve the excellent turf shown (pictures taken May 23, 2006). The adjoining yard below was also treated with the same measures.

The lower picture shows a peek into the soil beneath turf in Mr. Hazen's front yard. Mr. Hazen claims that prior to the soil reclamation treatment his yard looked like the un-reclaimed ones shown in the pictures on the previous pages. The geologic materials here are considered to be Tertiary Coastal Plain sediments like those at SRAP to be seen at Stop 5.

STOP 5

Fanning's preliminary comments:
This stop will be at the Stafford County, VA, Regional Airport where large areas of *sulfidic materials* were exposed on scalped land surfaces and as spoil during the construction of the airport, which opened in 2002. Virginia Tech (Orndorff and Daniels) and University of Maryland (Fanning, Coppock, Rabenhorst) soil scientists have collaborated to document information on the soils, water quality and corrosion etc. at this site and Virginia Tech developed a reclamation plan that utilized heavy applications of lime-stabilized biosolids (sewage sludge) and acid and salt tolerant grass species (e.g. hard fescue) to establish vegetation on the soils of the site, most of which were active acid sulfate soils with a *sulfuric horizon* by *Soil Taxonomy* right at the surface of the soils.

Results of our early (2001-2003) scientific efforts at this site and background information about the airport and its construction are covered in a joint paper presented at the 5th International Acid Sulfate Soils Conference in Australia in 2002 (Fanning et al. 2004 – see citation at the end of the soil description and data for a soil on the scalped soil surface at this site below). To save space in what we write here, reprints of the paper will be given out to trip participants. The leaders of the trip would be pleased to receive these reprints back after participants have looked at the paper, however, these can be taken as a souvenir of this trip etc. if so desired. What we are giving out essentially exhausts our supply of the reprints – that's why we ask for them back if you don't have a good use for them. Documentation for much of what we say at this site is in the (reprint) paper.

Our planned activities for this site are to stop at the airport hangar to pick up Dr. Zenah Orndorff and Ed Wallis, Airport Manager, and to give those who need it the opportunity to use the rest rooms in the hangar. We will then proceed to examine the soil on the scalped land surface, described below, and to discuss this soil and how it developed with reference back to the paper mentioned above. If available, we may also examine a soil in spoil on flatter ground. We then plan to drive our tour group in the bus around the airport to the southwest side for a short stop and talks there. There may be opportunities for examination of some of the concrete and metal corrosion caused by waters that have seeped and flowed out of the soils. Somewhere along the way, Zenah will comment on the water quality in stream water as affected by the airport construction and the use of the biosolids in the reclamation efforts.

Orndorff preliminary comments Construction of SRAP in the late 1990's exposed over 150 ha of lower Tertiary age Coastal Plain materials as the airport runway was constructed through a deeply dissected landscape. As construction proceeded, long spur ridges were excavated to depths $\geq$ 25 m, exposing significant volumes of gray, reduced, sulfidic (0.6 to 1.2 % pyritic-S; PPA up to 60 Mg $CaCO_3$/1000 Mg material) silty sediments, which were subsequently filled into intervening valley fills to support the > 1500 m runway. Excavated sulfidic materials exceeded the capacity of the valley fills and were also placed into several large, steeply sloping excess spoil fills along a first-order stream draining the eastern section of the site. Due to the fact that the sulfidic nature of these materials was not recognized until well after all final grading was completed, the acid-forming materials were not isolated away from drainage, and in fact were essentially scattered randomly, and thoroughly, throughout the site. Reclamation efforts over the past four years have been highly successful (> 90% of area is revegetated), although discrete problematic areas still exist throughout the airport. More detailed information regarding the soils and reclamation of SRAP is provided in Fanning et.al (2004) and an updated table of water quality data is provided on a subsequent page. Provided on this page are pictures to show some of the metal and concrete corrosion at SRAP. The first picture shows drain pipes from a sediment control pond on the south side of the airport where the pipes have been eaten thru by the acidic waters. This picture was taken by Dr. Daniels of Virginia Tech. The picture at the bottom of the page, also from Dr. Daniels, shows concrete corrosion and iron staining in a "protected" channel on the north side of the airport.

Description of Soil on Scalped Land Surface at Stafford Co., VA, Regional Airport Developed in Sandy Sulfidic Tertiary Geologic Sediments

Profile:

Oe: 0-5cm; Dark reddish brown (5YR 3/3) "Peaty" material that is essentially a root mat of many very fine roots of hard fescue (planted in 2002) and broom sedge. The earthy material that constitutes this horizon was apparently applied to the soil as biosolids (sewage sludge). It contains some admixed mineral soil material that probably became part of the horizon by mixing when the sludge amendment was applied to the soil. Friable moist; pH 3.01. abrupt, smooth boundary.

BAj: 5-10cm; Olive gray (5Y4/2) with common (<10%) medium, distinct jarosite concentrations with color like j below; very fine sandy loam with moderate, medium, platy structure; friable; pH 2.74; many very fine roots, but fewer than in Oe; clear, smooth boundary.

Bwj: 10-20cm; Dark gray (N4, probably grading upwards to a color like in BA) with common to many, medium, distinct jarosite concentrations that are mainly pale yellow (5Y7/4, but 6/4 and 7/6 also measured). Crushed and sieved the color is very dark greenish gray (10Y3/1) moist and greenish gray (10Y 5/1) dry. The concentrations are almost entirely on the faces of the platy structure; very fine sandy loam; moderate, medium to coarse – becoming coarser with depth platy structure; friable to firm consistence; pH 2.43; a few very fine roots in the upper part grading to none in deeper part; abrupt, wavy boundary.

Cg1: 20-35cm; Very dark gray (5Y3/1) very fine sandy loam; massive, friable; pH 3.39; no roots; diffuse, smooth boundary.

Cg: 35- 50+ cm; Very dark gray (5Y 3/1) very fine sandy loam; massive, friable, pH 4.29 – material continues down with depth and pH very likely increase with depth.

Classification: *coarse-loamy, mixed, mesic Typic Sulfaquept.* The soil has a *sulfuric horizon* to a depth of 35cm and may be a *Sulfudept* rather than a *Sulfaquept* – not an easy decision.

Classification by WRB: Haplic Regosol (Hyperdystric). This classification by Otto Spaargaren. Otto's comments (6/14/06) in e-mail message were "In the WRB there is no thionic qualifier to recognize the thionic horizon that is present. Maybe this should be added in the next edition. I cannot see evidence of reducing conditions, therefore it is not a Gleysol. I looked at the possibility of Umbrisol (which has a thionic qualifier) but colors, after mixing the upper 20 cm, are too light. The soil does not qualify for Cambisol because the base of the cambic horizon present is not at 25cm or more below the soil surface. Consequently, WRB ends up with Regosol."

Fanning's comment in reply to Sparrgaren was to the effect that the low chroma colors are from geologic gleying of the parent material, thus the assignment of Cg horizon symbols. Fanning thinks that a thionic modifier is needed by WRB for this soil. This soil is similar to the one on the scalped surface at Stop 3. If an engineering cut into *sulfidic materials* is made, as was the case here, a *sulfuric horizon* can form within a few months, as here. In *Soil Taxonomy* this immediately advances the soil from being an *Entisol* (*Sulfaquent*?) to an *Inceptisol*. There are big pedogenic changes in the chemistry, and in S mineralogy (mineral transformations), as well as in the physical properties of the zone in which the *sulfuric horizon* has formed – this is "big bang" soil genesis.

Described and sampled on Nov. 17 and 19, 2005 by D. S. Fanning, Department of Natural Resource Sciences and Landscape Architecture, University of Maryland, College Park, MD 20742-4452. Telephone: Office: 301-405-1308, Home: 301:864-5561. e-mail: dsf@umd.edu or DelvinDel@aol.com

Area: Stafford County, VA.

Location: Near middle of cut slope on N side of Airport, down from former engineering headquarters.

Vegetation: Hard fescue and some broom sedge.

Parent material: Very fine sand sulfidic Tertiary sediments that were in the unoxidized zone of the soil-geologic column until exposed by construction activities during the construction of the airport.

Physiography – Geomorphology: Human-made slope (scalped land surface by terminology of Fanning and Fanning, 1989, textbook) in dissected Upper Coastal Plain uplands. The scalped land surface was made during the airport construction activities in about the year 2000.

Slope and Aspect: About 25% smooth slope facing south.

Erosion: The soil was described in the west wall of a shallow gully that has formed since the slope was made by construction in about 2001.

Moisture condition when described: The soil was moist throughout. The description was made during cool weather with day time highs about 50 degrees F.

Additional Notes: The faces of the platy structure in the BA and Bwj horizons are mostly covered with jarosite. The plate faces are roughly parallel to the soil surface. This demonstrates that the platy structure formed on the new, human-constructed, land surface and that the jarosite formed after the land surface was constructed. There are some fine, sand-size lignite grains/chips in the Cg horizons that appear to constitute about 5% of the sand of these horizons. Pictures of profile and landscapes follow.

The depth increments on the tape over profile are 10cm (about 4 inches) apart.

These pictures taken in November, 2005, may be compared to the pictures of this slope when it was covered with salts etc. and not vegetated in 2001, shortly after airport construction as given in the paper by Fanning et al. (2004). For some lab data for the profile, see the next page. The top picture is a close up of the profile sampling site, the bottom is the full slope.

Some data for total S, C, and N contents determined with a CNS analyzer at the NRCS National Soil Survey Lab on air-dry, less than 2 mm soil material, for this profile from the Stafford Regional Airport are given below.

Horizon	Depth (cm)	Total S (%)	Total C ((%)	Total N (%)
Oe	0-5	0.27	2.77	0.332
BAj	5-10	0.13	0.32	0.092
Bwj	10-20	1.42	0.30	0.092
Cg1	20-35	0.42	0.39	0.062

Below: Incubation data of duplicate samples of the Cg2 horizon soil materials that show that this horizon qualifies as a *sulfidic material* by *Soil Taxonomy*. Dates are in 2006. Note that the pH had already dropped from 4.29 when the sample was collected in November, 2005, until the time the incubation was started in February 2006.

Sample	Depthcmetc.	2/15	2/22	3/1	3/9	3/16	3/23	3/30	4/6	4/13
SRAP	Cg2, 1	3.69	3.49	3.19	3.02	2.52	2.73	2.47	2.31	2.12
SRAP	Cg2, 2	3.73	3.48	3.05	3.02	2.62	2.75	2.44	2.33	2.06

References:

Fanning, D. S. and M. C. B. Fanning. 1989. Soil: Morphology, Genesis, and Classification. John Wiley and Sons, New York. 395 pages.

Fanning, D. S., Cary Coppock, Z. W. Orndorff, W. L. Daniels, and M. C. Rabenhorst. 2004. Upland active acid sulfate soils from construction of new Stafford County, Virginia, USA, Airport. Australian J. Soil Research 42: 527-536.

The table below repeats data given in Table 1 of Fanning et al. (2004) and gives some additional data from more recent dates (Sep-03, Sep-05 and Mar-06).

			(dS/m	----------------------mg/L---------------------)				
Location	Date	pH	EC	Fe	Al	S	NH3-N	NO3-N
SW 4	Apr-02	5.12	121	6.1	0.5	2	ND	0.09
(Above site)	Jun-02	5.75	93	6.8	0.1	1	0.52	0.29
	Nov-02	4.69	636	0.6	0.3	6	0.32	0.41
	Sep-03	5.29	201	1.7	0.1	2	0.28	1.38
	Sep-05	ND	ND	ND	ND	ND	ND	ND
	Mar-06	ND	ND	ND	ND	ND	ND	ND
SW 1	Feb-02	3.18	816	42.0	12.0	107	ND	ND
(In Site)	Apr-02	2.93	1489	62.0	25.0	195	0.74	0.02
	Jun-02	2.92	2080	67.0	7.0	294	46.20	0.69
	Nov-02	3.49	1496	34.0	17.0	252	3.95	8.69
	Sep-03	3.49	646	8.2	2.1	77	1.21	0.88
	Sep-05	6.31	230	14.5	0.1	21	0.17	0.19
	Mar-06	4.28	142	2.8	2.3	35	0.00	0.14
SW 6	Apr-02	3.30	1267	42.0	18.0	147	0.88	ND
(Below Site)	Jun-02	6.32	728	44.0	0.7	66	16.10	0.12
	Nov-02	4.20	143	19.0	10.0	136	2.36	4.79
	Sep-03	4.39	515	0.5	2.8	70	0.86	1.55
	Sep-05	6.72	431	8.4	1.3	17	0.08	0.10
	Mar-06	4.80	315	2.9	3.7	36	0.12	0.42
SW 7	May-02	5.48	58	2.9	0.2	5	0.13	0.05
(Above Site)	Jun-02	6.60	56	2.4	ND	3	0.43	0.04
	Nov-02	5.01	96	1.7	0.1	8	0.84	0.89
	Sep-03	5.94	206	1.2	0.1	4	0.13	0.88
	Sep-05	6.56	48	2.2	0.1	2	0.00	0.04
	Mar-06	5.35	63	0.5	0.1	5	0.02	0.15
NRCS Dam	Mar-02	3.30	590	8.7	7.7	61	0.14	0.36
(Below Site)	May-02	5.97	535	7.4	0.2	66	17.32	0.90
	Jun-02	7.37	531	0.8	ND	57	18.34	0.08
	Nov-02	5.23	962	0.3	1.0	138	1.86	12.80
	Sep-03	7.03	406	0.9	0.1	43	0.23	1.66
	Sep-05	6.30	132	1.1	0.1	10	0.00	0.10
	Mar-06	5.92	122	0.8	0.1	12	0.00	0.04

STOP 6

ACTIVE ACID SULFATE SOIL ON QUANTICO SLATE/PHYLLITE IN PIEDMONT REGION OF VIRGINIA

Orndorff Preliminary Comments on the site.

Development of Mine Road during the 1990's exposed pyritic phyllite and slate of the Quantico formation, and much of the excavated material was used as fill in adjacent subdivisions. At the time Virginia Tech was contacted, a Master Gardener's group in this area had determined that homeowners affected by acid soils should add 1 ton $CaCO_3$/acre every month through the growing season to maintain a pH > 5.5. Several samples collected along Mine Road yielded PPA (peroxide potential acidity) values ranging from 1 to 100 Mg $CaCO_3$/1000 Mg material (equivalent to 100 tons $CaCO_3$/acre), with corresponding total-S values ranging from 0.24 to 3.8%. Sulfides appear to be unevenly distributed throughout the roadcut at this site; however, more detailed sampling would be necessary to characterize this spatial variability. Drainage samples collected along Mine Road exhibited low pH values (2.5), and high metal concentrations (e.g. 249 mg/L Fe). Extensive iron-staining and concrete etching are evident along drainage ditches/gutters at the base of this road cut, and throughout an adjacent housing development. Adverse effects on surface water quality appear to be minimized by dilution as road drainage enters a local stream.

Fanning Comments

To me it is very interesting to see such a severe active acid sulfate soils situation in the Piedmont region. We used to think that acid sulfate soil problems in Maryland were pretty much confined to the Coastal Plain sediments and some of the sedimentary rock (particularly those associated with coal) in the Appalachian Mountains region. However, it was known that ores of some metals in the form of sulfides occurred in the Piedmont. Zenah has shown in her Ph.D. dissertation studies (Orndorff, 2001) that acid forming rocks, primarily because of the presence of pyrite and other iron sulfides, occur in some rock formations throughout the state of Virginia and that the Quantico formation is a very severe acid former.

From a scientific point of view, where did the sulfides in Piedmont rocks come from? To become the Quantico slate/phyllite, did the S originally get into sediments associated with the sea and then become sedimentary rock that was then metamorphosed to become slate/phyllite? How else may the sulfides have gotten into these rocks -- to be exposed to give rise to the severe active acid sulfate soil that we see on the steep scalped slope here today? One of the severe problems that frustrates those who would reclaim such soils is the steep slope and the shallowness of the soil. It is very difficult to keep soil amendments to correct the acidity on these slopes to enable the establishment of vegetation. Lee Daniels has pointed out that in some states (apparently in Kentucky) such slopes are terraced so as to give flat or gently sloping bench surfaces and that this enables management to establish vegetation.

It is strongly suspected that considerable S has been lost from the upper horizons/layers of the soil on the scalped surface that is described on the following pages. S levels are not that high in the soil, although the pH’s are very low.

Here in Virginia a soil series associated with these rocks is Watt. In Maryland the Watt series has also been mapped on such rocks that have sometimes been referred to as graphitic schists. A monolith of a Watt soil was collected many years ago for the University of Maryland soil monolith collection. The soil is black throughout (lithologic colors). This very likely is a sign that these soils contain, or that their parent material contained, sulfides. No acid sulfate soil research has yet been conducted on these soils/rocks in Maryland.

A description and data for a shallow pit on the steep scalped slope on the east side of the road here are given on the next page along with pictures of the soil and slope on a subsequent page.

Some may want to take the opportunity here to photograph the etched concrete in the road gutter where the cement between the gravel in the concrete has been etched away by acid waters that have come off the active acid sulfate soils on the scalped land surface of the slopes.

References:

Orndorff, Z. W. 2001. Evaluation of sulfidic materials in Virginia highway corridors. Ph.D. dissertation. Virginia Tech University, Blacksburg, VA.

Description of Active Acid Sulfate Soil on Scalped Land Surface on Mine Road in Garrisonville, Stafford Co., VA, developed on Quantico Slate

Profile:

Bw: 0-6cm; Very dark gray (2.5Y 3/1 grading to 3/2 when rubbed) channery, micaceous, with possible graphite or talc, silt loam – the channers are soft enough to break in fingers with common strong brown (7.5YR 5/6 and 5/8) redox concentrations on the faces of the channers; the structure is primarily inherited from rock; friable to very friable; pH 2.57; no roots – un-vegetated soil surface above; abrupt to clear, smooth boundary.

BCr1: 6-15cm; The material has an outwardly reddish appearance, strong brown 7.5YR 5/6-5/8 from iron (hydr)oxides on the faces of fine bedding planes of weathered rock that has inherited rock structure with beds a few mm in thickness that are oriented nearly vertical relative to the soil surface. The iron (hydr)oxides have probably formed during the sulfuricization that has taken place since the exposure of the rock material on the scalped land surface made during highway construction; The rock chips when broken across have very dark bluish gray (10B3/1) color; soft rock that breaks to channers; pH 2.67; no roots; diggable with a spade; clear, broken boundary.

BCr2: 15-32 cm; like the horizon above but harder to dig and with fewer surfaces covered with the iron (hydr)oxides; rock structure with beds nearly vertical; pH 2.69; no roots; diggable with considerable difficulty with a spade.

BCr3: 32-40 cm; like horizon above, but with even fewer iron (hydroxides) on rock bedding plane surfaces and even more difficult to dig with a spade; pH 3.44

RC: 40+ cm – continues down; bluish phyllite rock that is somewhat softened by oxidation of sulfide minerals in the rock.

For a picture of the profile described and the man-made landscape on which it occurs, see the pictures on the next page. The depth increments on the tape in the profile picture are 10 cm (about 4 inches) apart. Some lab analyses for total S, C, and N contents of sieved, (less than 2mm) soil material of the various horizons are given below. The C must be coming from rock sources as there is no evidence of current additions from biological activity.

Horizon	Depth (cm)	Total S (%)	Total C (%	Total N (%)
Bw	0-6	0.19	0.25	0.101
BCr1	6-15	0.32	0.91	0.123
BCr2	15-32	0.14	0.33	0.064
BCr3	32-40	0.23	0.42	0.096

Classification: *Sulfudept* (probably coarse-loamy, mixed -- or micaceous -- , mesic – but may be thermic) by *Soil Taxonomy*. The soil has a *sulfuric horizon* beginning at the soil surface down to a depth of about 40cm. It is assumed that the underlying rock qualifies as a *sulfidic material*. Although *Lithic* subgroups are not presently recognized in *Sulfudepts*, this soil appears to qualify as *Lithic* as this subgroup has been defined in other great groups in *Soil Taxonomy* – with a *lithic contact* within 50cm of the soil surface. By the system proposed in the Fanning and Fanning (1989) textbook, this soil also qualifies as a Scalpic subgroup in that it occurs on a scalped land surface as that characteristic is described in that book – thus the soil by these proposed modifications would be a Scalpic Lithic Sulfudept.

Classification by WRB, courtesy of Otto Sparrgaren: Hyperskeltic Leptisol (Hyperdystric)
Fanning comment: WRB apparently does not recognize thionic or hyperthionic in Leptisols – probably should. This soil should be recognized as having a *thionic horizon*.

Location: About 1 mile south of Garrisonville, VA in a big road cut on the east side of Mine Road. The cut is about 0.2 mile south of where a creek crosses Mine Road.

Area: Stafford County, VA.

Climate: Humid, temperate continental with hot summers and cool winters.

Vegetation: None – not yet established and will be extremely slow to establish naturally because of the ultra acidic (pH's <3.5) nature of the soil and the steep slope.

Parent Material: Quantico slate or phyllite. The rock appears to be a phyllite here.

Physiography – Geomorphology: The soil occurs on a very steep man-made slope (40%) that is a large road cut. The surrounding landscape is rolling Piedmont uplands near the Eastern boundary of the Piedmont to the Coastal Plain. The soil occurs on a cut slope, in engineering terms, made by highway construction in about 1995.

Relief/slope: Smooth man-made slope of about 40% with some shallow erosional gullies.

Drainage: Well to excessively drained.

Ground Water: none

Stoniness: There are a few quartzose stones locally on the surface from quartz veins that occur in the rock.

Salt or alkali: There presumably are acid-forming sulfate salts present at the soil surface in dry times of the year.

Moisture condition when described: moist

Aspect: west.

Erosion: both sheet and gully erosion, quite severe with no vegetation on the land surface.

Permeability: Very slow through rock.

Description: by D. S. Fanning (Dept. of Natural Resource Sciences and Landscape Architecture, University of Maryland, College Park, MD 20742-4452, 301-405-1308, dsf@umd.edu and Zenah Orndorff (Dept. of Crop and Soil Environmental Sciences, Virginia Tech, Blacksburg, VA) zorndorf@vt.edu in November, 2005.

STOP 7

PRINCE WILLIAM FOREST PARK LUNCH STOP WHERE WE WILL LEARN ABOUT A PYRITE MINE THAT OPERATED AT THE BEGINNING OF THE LAST CENTURY AND HOW SPOIL FROM IT HAS BEEN RECLAIMED

D. S. Fanning

Prince William Forest Park, federal property managed by the National Park Service of the U.S. Department of Interior is just off Highway I-95 a few miles north of Stop 6. Our group is being permitted into the park and allowed to use the Turkey Run Education Center here for free as an educational tour. Lunch will be provided by Virginia Tech. Information about the history and facilities of the park and about the old pyrite mine that operated along the edge of Quantico Creek in the park, when the property was private land in about 1900 is provided in park pamphlets that may be provided to tour participants. While at the park we will be hosted by park personnel and we hope to take the opportunity to present a Power Point slide show about the pyrite mine and the reclamation of the mine and the spoil from it along Quantico Creek. Before the reclamation took place, in the 1990's and subsequently, Quantico Creek was considered a "dead stream" from a biological point of view. A picture of this stream as an example of acid mine drainage may be viewed in the Fanning and Fanning (1989) book, cited elsewhere in this guidebook, as Plate 3D (between pages 172 and 173 of the book). Unfortunately we will not have time to go to the now reclaimed mine site to view Quantico Creek as it looks today, or the reclaimed "mine soils" along it, because it is too long of a walk (about 45 minutes each way) from where the bus could take us. At the Education Center however we plan to have a monolith of a highly jarositic soil in spoil with some macroscopic pyrite still in it that was taken in a naturally revegetated (with Virginia pine) site along Quantico Creek across the stream from the old mine entrance.

There are many interesting stories about the days of the mining in the early 1900's. The mine was shut down by the owners when the miners demanded higher wages – they wanted to be paid twenty five cents per hour (if I am recounting this correctly), but the owners refused. The pyrite was mined for the purpose of making sulfuric acid. This is interesting stuff for those of us who take great interest in acid sulfate soils.

I learned of the mine here from a colleagues, Jim Patterson and John Short (Short earned his M.S. degree with us) who at the time, early 1980's, were working as soil scientists/agronomists with the National Park Service in what at that time was their Ecological Services Lab (became Center for Urban Ecology) in Washington, DC, where they were heavily involved in managing National Park Service Land in DC and in the making of the soil survey of Washington, DC, the first survey of the soils of a city in the U.S – published by the USDA Soil Conservation Service for the bicentennial of the country in 1976. Short did studies of sulfate minerals that were present during dry times of the year on the surface of the un-vegetated spoil soils from the pyrite mine and identified soluble acid-forming minerals such as rozenite and copiapite that we now commonly associate with such soils. Patterson showed how the soils, which had pH's below 2 could be reclaimed to grow grass (fescue) using high application rates of lime-stabilized sewage sludge compost.

STOP 8
UNIVERSITY OF MARYLAND – College Park, MD
H. J. Patteron Hall and University of Maryland Soil Monoliths Collection

The University and H. J. Paterson Hall represent the professional home of those from the university who are leaders of this trip, Fanning and Rabenhorst and multiple graduate students. As we come on campus we will see signs and multiple statues of the Maryland Terrapin, the mascot of the Terps, in celebration of the 150 years from the time that the University was started with the founding of the Maryland Agricultural College in 1856.

As a bit of departmental history, Fanning came to join the then Department of Agronomy in 1964. In the 1990's this department was joined with the former Horticulture Department to become the Department of Natural Resource Sciences and Landscape Architecture. Now, on July 1 of 2006, the soil scientists are being split off, to be with some other scientists and engineers in a new Department of Environmental Science and Technology. The plant scientists and landscape architects will be accommodated in a new Department of Plant Sciences and Landscape Architecture.

Our stop here will be to give trip participants the opportunity to see monoliths of soils of Maryland and other places in display cases in the basement of the building and in a conference room on the first floor. A number of the monoliths are of acid sulfate soils and there is a display case in the newer overall cabinet devoted to acid sulfate soils. Next to the acid sulfate soils display, another case is devoted to highly human-influenced soils, and it contains some additional monoliths of acid sulfate soils. However, there are many other soils other than acid sulfate soils – unless (joke) we consider all of the soils to be post-active acid sulfate soils.

Rather than looking at monoliths, some may prefer to see some of the laboratories in the department, although we will probably be limited to seeing the facilities of pedologist Martin Rabenhorst and his graduate students. After an overall introduction, we may split into two or more groups to tour different things. Fanning would like those interested to have a chance to see monoliths of a landfill soil from New Jersey to see where/how a sulfidic "clay" was used to cap a landfill, covered in turn by non-sulfidic sand and an artificial top soil.

We won't have long to stay here as we need to get on to an unofficial extra stop on the Paint Branch Creek north of the campus to see a pyritic lignite exposure and then on to Baltimore for the last stop of the tour, thence back to Philadelphia.

EXTRA STOP TO SEE PYRITIC LIGNITE EXPOSURE ON STREAM ERODED BANK OF PAINT BRANCH CREEK BY UNIVERSITY OF MARYLAND IN COLLEGE PARK, MD

In the document on the historical recognition of acid sulfate soils near the beginning of this guidebook, a section was included about the acid sulfate soils problems on athletic fields at the University. This stop is to afford an opportunity to see the kinds of geologic materials that we think underlie the university that contain pyrite associated with lignite in Cretaceous age Coastal Plain sediments. The picture below shows the exposure that we will stop to see, assuming sufficient time, where the lignite is exposed. Graduate students Olivia Devereux on the near side and Philip Zurheide on the far side of the creek appear in the picture. At the edge of the water on the near side are (black) chunks of lignite from the exposure that were fished out of the stream. Philip has been active in studying some of the materials from the exposure and he has demonstrated that if the lignite is left sitting in water such that water can wick through the material that soluble sulfate minerals, presumably hydrated iron and aluminum sulfate minerals grow profusely on the upper surface of the lignite. During dry times these kinds of minerals can also be found at this site. At this site we also intend to display ironstone that we are convinced has formed by sulfuricization processes. Geologists have also been studying this site, but we haven’t had time to compare our findings with their’s.

STOP 9
ACID SULFATE SOILS IN DREDGED MATERIALS

Dredging of shipping channels is a huge and on-going problem in the state of Maryland, to create new and/or larger/deeper shipping channels coming into the Port of Baltimore and to maintain existing channels within and without the harbor itself etc. The bulk of the DM, dredged materials, are placed in land-based containment facilities where they are contained within constructed dikes

One way to appreciate the huge quantities of DM that are dredged is by pictures of newly deposited DM. Inserted here below is a picture of DM that were deposited only a few weeks before the picture was taken at Hart-Miller Island in Chesapeake Bay northeast of Baltimore. Hart-Miller Island was made by connecting two former islands (Hart and Miller, with a dike and extending the dike into shallow waters of Chesapeake Bay to encompass about two square miles of bay waters into which DM were then deposited. This picture looks across the constructed large island from the Northeast toward Baltimore which can be seen on the horizon left of center on the skyline where smoke is arising from smokestacks from the Bethlehem steel plant.

After the construction of Hart-Miller Island was permitted in the early 1980's it was necessary to get further permits to raise the dikes two times. Now Hart-Miller is reaching capacity and no more DM will be deposited there after 2009. A rough estimate from the Maryland Port Administration, which is in charge of dredging for the state of Maryland, is that Hart-Miller now contains about 85 million cubic yards of DM. In the north cell at Hart-Miller the DM are estimated to be 37 feet, about 11 meters, thick.

Hart-Miller Island is offshore and not capable of being visited by this tour. There are many small DM deposition areas in and around Baltimore and elsewhere in the state. Our stop for this trip will be at one of these, which is convenient to our travel route, about a mile north of the Baltimore

Beltway by the Francis Scott Key Bridge, at Hawkin's Point, in a heavily industrial part of Baltimore. In dredging operations, typically DM are deposited within a containment area, then they are permitted to settle (naturally subside) for some years and then more DM are placed on top of those previously deposited.

Most of the DM from Baltimore Harbor, and from the Bay, have textures of silty clay loam to silty clay and they qualify as *sulfidic materials* by *Soil Taxonomy*. Those from the harbor tend to be high in heavy metals and a large portion of the metals are bound in the soil materials as metal sulfides. The metals and the sulfur (converted by oxidation to sulfate) become mobile as the sulfides undergo oxidation. For some further information on the properties and genesis of soils in sulfidic DM, see Fanning and Fanning (1989, pages 306-311).

The profile pictured here (depth increments on tape are decimeters) has a *sulfuric horizon* about 30cm thick with a pH in water of about 3.3. The BC and Cg horizons displayed high *n*-values >1 in the deeper horizons and had bulk density about 0.7 Mg/m^3. The soil would be classified as a *Hydraquentic Sulfaquept* by current *Soil Taxonomy*. The soil developed in about 4 years after the DM, in which it was forming, had been deposited at the Masonville DM deposition area in Baltimore. Phragmites had not yet reached this soil when the picture was taken, but they did reach it, by rhizome spreading, shortly thereafter.

We will see a generally similar soil under Phragmites as described on the following pages at the Hawkins Point DM deposition area.

STOP 9

Description of Soil in Trashy Sulfidic Dredged Materials at MPA Hawkin's Point Dredged Materials Deposition Area in Baltimore, MD

This soil will be examined by the tour as the last stop

Profile:

Oi: 8-3cm; Plant debris/litter mainly from Phragmites.

Oe: 3-0cm; Black (5YR2.5/1) humified and partially humified plant material, mainly from Phragmites that feels like a soft silt loam, granular or crumb structure; very friable; pH 4.83; abrupt, smooth boundary.

Bwj1: 0-12cm: Dark to very dark gray, 2.5Y3/1 to 4/1 heavy silty clay loam that is gray, 2.5Y6/1 when dry with iron (hydr)oxide and jarosite (5Y8/3 dry) concentrations on ped faces. Structure appears to be prismatic breaking to blocky with the size of the peds increasing with depth. The material is firm moist with a pH of 3.27 (Average of 3.30 and 3.24 on duplicate sub-samples); Arbitrary boundary. Sampled with a spade.

Bwj2: 12-30cm: Silty clay loam with colors like the horizon above. The structure is (probably strong and coarse) prismatic w jarosite and iron (hydr)oxides on the faces of the structure with the jarosite most obvious; Firm moist; pH 3.005 (Average of 3.01 and 3.00 on duplicate sub-samples); A large (about 2 cm diameter) hollow living Phragmites root/rhizome, with smaller roots going out from nodes about 8cm apart, crossed the small pit from which the sample was described. Arbitrary boundary. Sampled (including a big segment of the large rhizome) with a spade.

Bwj3: 30-40cm; Colors like in the horizons above, silty clay loam; the structure is probably like in the overlying horizons, but not possible to determine because this was an auger sample; Jarosite color of 5Y7/4 to 8/4 where dry on a dried ped surface; firm with pH 3.01(Average of 2.99 and 3.03 on duplicate sub-samples); Arbitrary boundary; sampled with a bucket auger.

Bwj(u)4: 40-50cm; Matrix colors like in overlying horizons but a little darker (2.5Y 5/1 dry), silty clay loam; Colors measured for the iron (hydr)oxides were 5YR and 7.5YR 4/4 to 4/6 and 5Y 7/3 to 7/4 for the jarosite that seems from auger sample to be less abundant than in overlying horizons; the auger sample contained a fragment of a glass bottle and fragments of partially decomposed plant material, probably phragmites roots; Bucket auger sample has a big fragment of a hollow living phragmites root about 1cm in diameter; pH 3.115(Average of 3.17 and 3.14 on duplicate sub-samples); Arbitrary boundary; sampled w a bucket auger.

BCgu 50-70cm; Very dark gray (5Y3/1) and dark grayish brown (2.5Y4/2) matrix colors and some spots of black like Cg horizons described below and some iron (hydr)oxide concentrations; silty clay loam; This zone has a large concentration of artifacts. In the auger sample there was most of a plastic cover for a coffee cup as from McDonald's and a piece of polyethylene bag with blue writing on it on which KOR URLS as parts of separate words can be made out – probably KORN KURLS and a very legible ingredients label – ingredients: processed corn meal, vegetable oils, cheese flavor, salt, artificial flavor, BHA and BHT added as a preservative; silty clay loam; friable moist; pH 4.23 (Average of 3.83 and 4.63 on duplicate sub-samples); boundary?

The water table occurred at a depth of about 70cm when this soil was described in January, 2006.

Cgu1: 70-85cm; Black (N2.5/1) that turns to 2.5Y3/1 upon exposure to air with common (about 5% by volume Fe (hydr)oxides as fine spots with color about 7.5YR4/4); loam or sandy loam; massive; wet when sampled with *n*-value above 0.7; the material contains artifacts of modern society – e.g. a fragment of polyethylene in auger sample; the material probably has sulfides like in the layer below, but the tests were not conducted on samples from this layer. It has an oily odor like found with Cg2. Arbitrary boundary to Cg2.

Cgu2: 85-100cm; Blacker than N2.5, turns to about N3 after exposure to air for a few minutes on the outside of the soil material and throughout upon drying; loam or sandy loam – sandier than above; wet when sampled with *n*-value above 0.7; the material contains artifacts of modern society – e.g. a fragment of polyethylene in auger sample; the material has a strong oily odor; the material evolves hydrogen sulfide by odor when exposed to drops of 10% HCl, indicating the presence of monosulfides – which are presumably responsible for the black color. Material from this layer also gives a violent reaction with fumes when exposed to 30% hydrogen peroxide and this reaction causes the material to become hot. Similar material presumably occurs beneath the base of this layer.
--- note – a u subscript is used with some horizons to denote the presence of artifacts. According to Bob Engel this will become an official subscript in the 10th edition of Keys to Soil Taxonomy.

Classification: Fine-loamy; mixed, mesic *Hydraquentic Sulfaquept*.
The soil is in a *Hydraquentic* subgroup by virtue of having an *n*-value of more than 0.9 in layers between a depth of 50 and 100cm. The zone above these depths has *n*-values less than 0.7. The soil would probably be fine-silty except for the sandier zone beneath 70cm.

Classification by WRB: Fanning had e-mail exchanges with Otto Sparrgaren about this soil. A major matter for consideration is the quantity of artifacts. If there are more than 20% (by volume, weighted average in upper 100cm) artifacts the soil would be a Technosol by WRB, and from the description, Otto thought it qualified for such and he called the soil a Gleyic Spolic Technosol (Ecotoxic, Siltic). In going back and digging a larger pit at this site (available for viewing by trip participants we hope), we don't think the soil meets the 20% needed, and there is apparently not the stratification needed in the upper 25cm for fluvic material, so the soil is not a Fluvisol. Thus the soil seems to be a Technic (assuming more than 10% artifacts) Gleysol (Hyperthionic, Ecotoxic, siltic). The quantity of artifacts needs closer examination – in describing the soil the quantity was not finely judged and the initial description was from materials extracted with an auger, except for the top 30cm.

Sampled Jan. 10, 2006 by D. S. Fanning, Department of Natural Resource Sciences and Landscape Architecture, University of Maryland, College Park, MD 20742-4452.

Area: Baltimore City, Maryland Port Administration Hawkin's Point dredged material deposition area.

Location: In the northern side of the trashy DM disposal area that is the first DM disposal area north of Quarantine Road in the controlled access area controlled by Maryland Environmental Service and Maryland Port Administration where the chrome ore waste landfill occurs on the opposite side of Quarantine Road. To reach the area described and sampled, one follows the unpaved road in from the gate to the area by Quarantine Road. This road/trail runs along the fence to the west that encloses the U.S. Gypsum property to where the road bends to the east. About 50 yards beyond the bend, a ramp that was used in the deposition of the trashy DM by truck goes to the south. The spot sampled is out into the disposal area where it is heavily covered with phragmites, but slightly under the outermost trees that have grown up on the DM. In going out into the area from the ramp, the spot sampled and described is right of the ramp about 20yards.
I (DSF) will try to get assistance from USDA NRCS people to get the longitude and latitude coordinates for the sampling location – not yet done in June, 2006.

Vegetation: Nearly a monoculture of *Phragmites australis*, but the spot sampled is at the edge of the heavily Phragmites vegetated area. There are trees (tulip poplar? polonia?) that have grown up on the acid sulfate soil on DM toward the N side of the area and other plants, e.g. mile-a-minute and polkweed are also present, especially by the trees. Roots of plants, mainly from phragmites occur throughout the soil above the water table and perhaps below, some are big rhizomes as mentioned in the profile description. This is rather amazing in view of the ultra-low soil pH values found, but not different than what has been seen with phragmites at other DM deposition sites with active acid sulfate soils.

Parent material: Trashy sulfidic dredged materials deposited in the mid to late 1980's.

Physiography – Geomorphology: Diked DM disposal area by Curtis Bay, but not much dike on the landward side of the area where the profile described occurs.

Elevation: probably about 30 feet.

Slope and Aspect: About 3% to the south into the interior of the disposal area.

Moisture conditions when described: Moist, wet below 70cm – the water table occurs at 70cm depth. The soil was sampled during a period of warm weather in January, 2006, at a time calendar-wise when the soil would normally be expected to be frozen at the surface.

Additional notes: The upper part of the soil to a depth of about 35cm was exposed in a narrow (about 30cm, 1 foot) pit dug with a tiling spade. Below the bottom of this pit the soil was sampled with a 3"diameter bucket auger and the description was made employing these samples after they were laid out to dry on a table, about 5 days after the samples were laid out and still partially moist (in the interior of chunks of the material). The pH was measured on moist samples the day after they were collected using a Beckman pH meter with a glass electrode in Martin Rabenhorst's soil survey lab at the University of Maryland, H. J. Patterson Hall. The moist samples for pH measurement were weighed out in small plastic beakers and then a roughly equal amount of water by weight was added. This made the ratio of water to soil material to be greater than 1:1 if one accounts for the moisture that was in the soil material. After the pH was measured, the samples were split and about half of each sample was then immediately placed in a polyethylene freezer bag and put into a walk-in freezer.

The profile was described and samples taken primarily so that the total S content of the samples could be determined at the National Soil Survey Laboratory in Lincoln, NE on dry samples. Samples from the Cg horizons were incubated with the pH followed to see if materials from these horizons qualify as *sulfidic materials* as defined by *Soil Taxonomy*. It is strongly suspected that they are *sulfidic materials*.

The soil has a *sulfuric horizon* (pH equal to or less than 3.5 as measured in water with soil to water ratio about 1:1 by weight, plus the required additional characteristics to qualify – e.g. the presence of jarosite concentrations) as defined by *Soil Taxonomy* from the surface of the mineral part of the soil to a depth of about 50cm. A picture of the sampling location with Phragmites in winter from 2005 year's growth is shown below. The stake was driven into the ground to mark the spot for future reference and the stake was labeled. Some of the phragnites reeds were upwards of 3 meters in height to the top of the seed heads.

Some lab data for Total S, C, and N analyses from National Soil Survey Lab, Mike Wilson, Surpervisor

Horizon, Depth, cm	S (%)	C (%)	N (%)
Bwj, 0-12	0.77	3.34	0.350
Bwj2, 12-30	0.95	3.43	0.380
Bwj3, 30-40	1.19	3.38	0.409
Bwj(u), 40-50	0.63	7.59	0.418
BCgu, 50-70	1.71	11.67	0.345
Cgu1, 70-85	2.38	14.93	0.522
Cgu2, 85-100	1.51	15.14	0.428

The Cgu2 sample (85-100 cm) was determined to contain 0.064% acid volatile S and 0.951 % chrome-reducible S by Patrick Morton and Martin Rabenhorst.

The Cgu1 and Cgu2 samples were shown to be *sulfidic* by incubation test by Fanning, although the pH drop on one of two reps. of one of the samples was borderline in drop to pH of 4.0 in 8 weeks.

Acknowledgements

Many of those who have helped with this trip are acknowledged in the overall trip introduction – so please read it from an acknowledgement point of view as well as to be introduced to the tour and this guidebook.

First I thank God for permitting me and my many helpers and family members to be in good health and of reasonably sound mind through the trip preparations. Next, I thank the trip participants for signing up for the trip, without you there wouldn't be a trip. I especially thank those who signed up early because the numbers were being carefully counted then to see if there were enough to make the trip feasible. I also thank the WCSS and ASA-SSSA folks, who bent the rules a little to permit a trip even when there were not, at first, officially enough. I also thank them for making the arrangements for the lodging and the bus etc. and for handling the funding and collection of fees etc.

Next I thank the local organizations that have helped, particularly the University of Maryland for providing the facilities (computers, telephones etc. as well as office space and laboratories for gathering data etc.). Virginia Tech has also provided much support through their Department of Crop and Soil Environmental Services, particularly Lee Daniels, Zenah Orndorff and Sue Brown – they are also supplying our lunch on July 8. Thanks also to Southern Cross University in Lismore Australia for permitting Leigh Sullivan to come to see us in April/May of 04 as he traveled on his sabbatical to help to plan this trip and the symposium at WCSS. Also the USDA Natural Resources Conservation Service through their soil scientists has done much in finding the sites to visit etc., writing things for the guidebook etc. and being willing to make presentations at stops along the way. Thanks also especially to MAPSS (Mid-Atlantic Association of Professional Soil Scientists) for financial support for trip assistant Cary Coppock so he could be on the trip and for providing lunches on July 7. Thanks too to the organizations and individuals who have permitted stop visits on their properties, Delaware Parks, Black Water Wildlife Refuge, the Smithsonian Environmental Research Center, the Loyola Retreat House, the Great Oaks development in Fredericksburg, VA, the Stafford County Regional Airport, Virginia Department of Transportation, The National Park Service, and the Maryland Port Administration. Thanks to the Holiday Inn, the Best Western Inn in LaPlata, MD, and Robertson's restaurant at Pope's Creek for the good lodging and food that we received from them.

At the end as we came to getting this guidebook printed, Dean Wei of our College of Agriculture and Natural Resources stepped in as did Frank Coale, Chair of our new Department of Environmental Science and Technology to help to keep my support from the university coming and to assist with financial arrangements for getting this guidebook printed. Thanks also to the Maryland Geological Survey and US Geological Survey for the gift of geologic maps of Md and for geology advice.

Finally I thank the many individuals listed below, who have helped so much. I am sure I will miss some – sorry, please forgive. I won't list their organizations, most of which are listed above:

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As a "thank you" to everyone who has helped with the trip and before in my life I am inviting everyone to come on Wednesday night, July 12th, from 8pm until 2am on July 13th if you want to stay that long, to an "open house" in an upstairs room at Ludwig's Garten (a German restaurant/bar) at 1315 Sansun Street in Philadelphia to celebrate my 75th birthday. I was officially born on July 13th, but my Dad always told me that I should have been born on the 12th. Dr. Maxwell (who had a tendency to drink too much) was late for my home delivery at my "Womb" house in northern NY.

I think there will be folks from 13 different countries on this trip. By having the party at a German restaurant, I don't want folks to think that I especially favor Germany over other countries, although I am proud of my more than 1/4th German ancestry and I love to think about King Ludwig, the "dreamer Bavarian king", who (had) built those beautiful castles, and supported the artists/composers like Wagner so well. **Kommen Sie und trink mit mir Ein Broste der Gemutlichkeit! Del Fanning**