Post-conference excursions

August 31 and September 1, 2012

GUIDEBOOK

7th IASSC

26 August - 1 September 2012
Vaasa, Finland

7th International Acid Sulfate Soil Conference

Vaasa, Finland 2012

Towards Harmony between Land Use and the Environment

7th IASSC
26 August - 1 September 2012
Vaasa, Finland

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Friday August 31 – Saturday September 1, 2012

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Cover photos: Peter Österholm & Markku Yli-Halla

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Program

Day 1 (Friday 31 August, 2012):

8:15	Start from Radisson Blu Hotel
8:30-8:50	A site where the Skanska Civil and Ramboll Finland are carrying out road construction activities on, and stabilization of AS soil. Presentation in the bus and work performances
8:50-9:50	Travel to Pedersöre
9:50-10:45	An experimental site in Pedersöre. A soil pit in a field that has been reclaimed for agriculture in 2009.
11:15- 11:40	Villa Elba in Kokkola/Karleby. Presentation about Lake Larsmosjön and problems induced by AS soils
11:40-12:45	Lunch at Villa Elba and a short nature trail
13:10-14:20	The PAHA project area (Hömossdiket/ Kiimakorpi) in Nederveteli. Sulfidic sediments covered by peat under forest vegetation. Water monitoring activities
14:20-14:50	Travel to and sightseeing (Neristan, old wooden town) in Kokkola/ Karleby
14:50-15:15	Acid sand pits south of Kokkola/ Karleby
15:15-16:20	Travel around the Lake Larsmosjön along the Seven Bridges Road, including a coffee break in Aspegren gardens in Jakobstad/ Pietarsaari
17:40	Arrival at Vaasa. - Trains from Vaasa at 18:00 and 19:25. Flights also leaving.

Day 2 (Saturday 1 September 2012):

8:15	Start from Radisson Blu Hotel
8:45-10:00	Vassor, a 1.5-km^2 polder constructed in 1953-1966 and separated from the sea with an embankment used as a road. A potential AS soil (Typic Sulfaquents, Histic Sulfaquents) at the average sea level. In the polder, we see a Sulfic Cryaquept, developed from the sediment during 40 years of drainage, sulfidic materials remaining below 170 cm. At Vassor, the River Kyrönjoki, the main watercourse of the area enters the sea, draining extensive AS soil areas. Episodes of strong acidity occur at a few years interval.
10:00-10:20	Coffee break at Vassor
11:15-11:30	Ylistaro. Introduction of the regional research station on the bank of River Kyrönjoki. The station is occupied by two research units, Potato Research Station and MTT Agrifood Research Finland, the national organization for agricultural research.
11:30-12:15	Investigation of a rather leached Sulfic Cryaquept, that has been in agricultural use for more than 100 years. The soil profile contains plenty of jarosite and sulfidic material below 2 meters depth.
12:30-13:30	Lunch at Kalliojärvi at Isokyrö
14:00-14:30	Malkakoski rapids in the Kyrönjoki river and recreational site. Malkakoski consist of several constructed rapids to allowing fish to go upstream. We also learn how water quality of the river is monitored and how the acidity has impacted fish stocks.
14:50-15:30	Introduction of the Rintala area in Seinäjoki: water management operations and the pump station.
15:30	Stop at Seinäjoki railway station. Trains to Helsinki 15:46, 16:38, 17:41
15:30-17:00	Travel to Vaasa. On our way back we will drive through Old Vaasa, the site of the original town that burned down in 1852.
17:00	Arrival at Vaasa (airport 17:00, railway station 17:30). The last train from Vaasa to Helsinki on Saturday is at 18.00.

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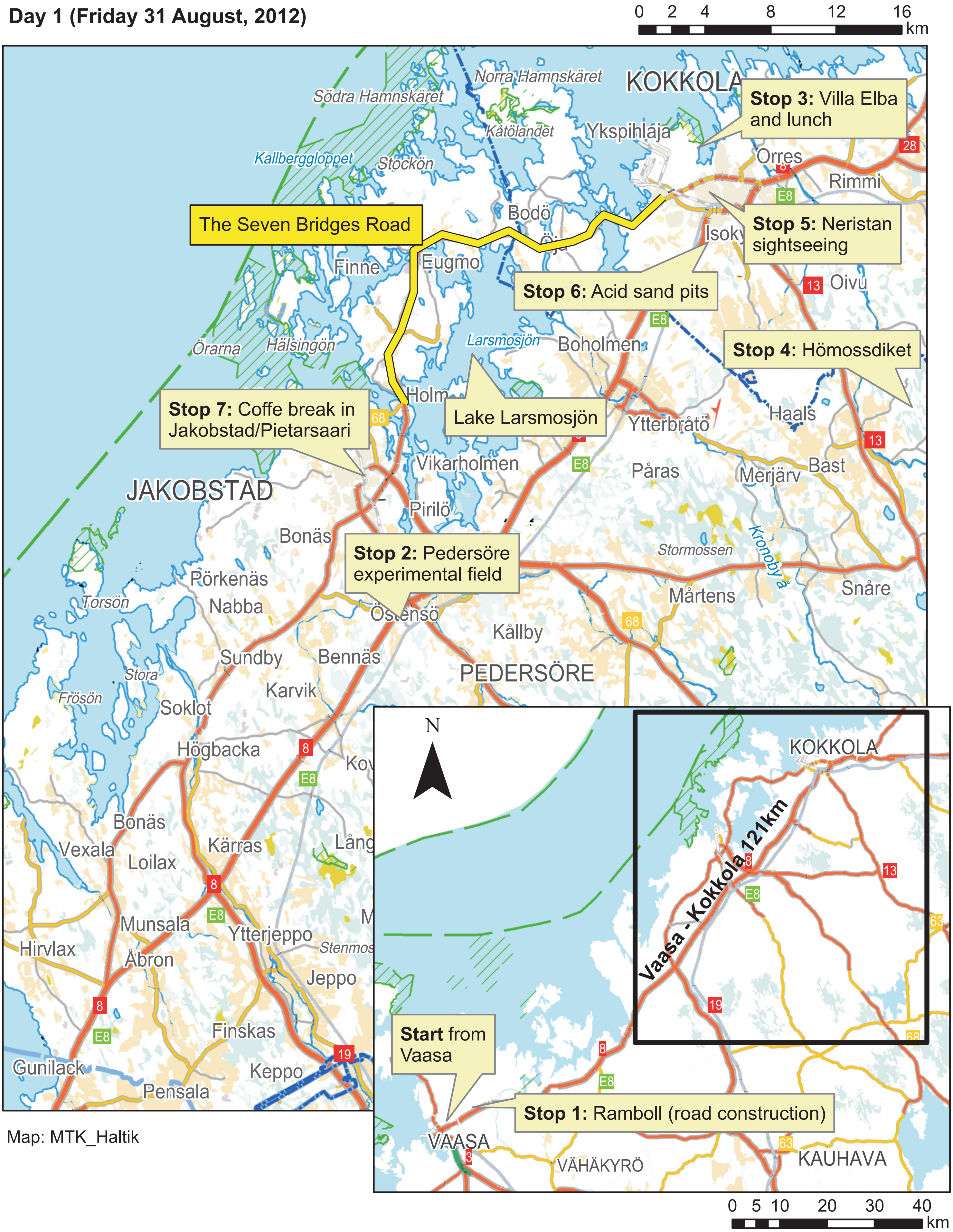
Day 1 (Friday 31 August, 2012)

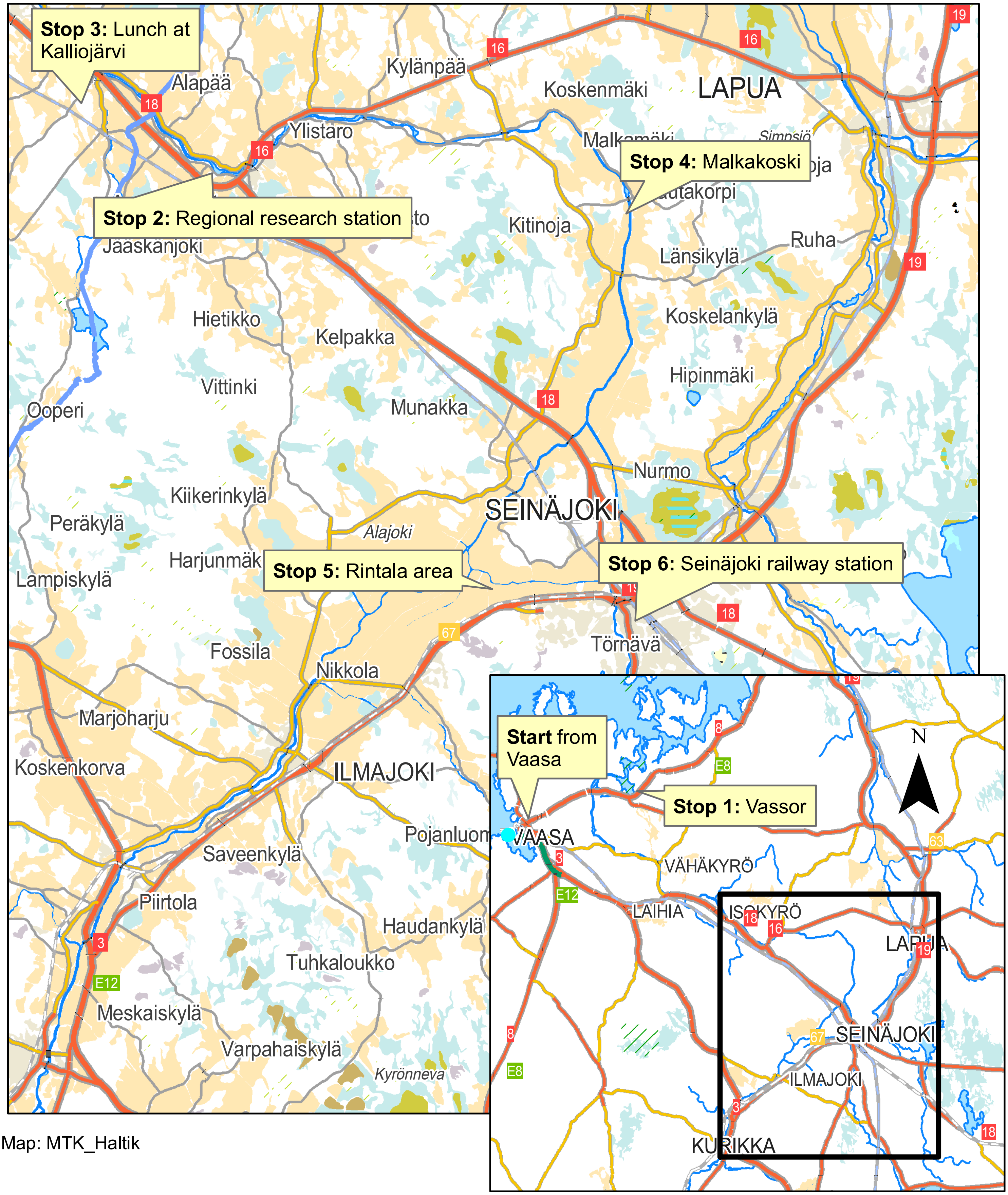


Map: MTK_Haltik

Post-conference excursions / 7th International Acid Sulfate Soil Conference, Vaasa 2012

Day 2 (Saturday 1 September, 2012)

0 1,5 3 6 9 12 km



Map: MTK_Haltik

Vassor - Seinäjoki approx. 70km

0 5 10 20 30 40 km

1. **Preface**

Welcome to see the landscapes of Southern Ostrobothnia in western Finland, and, particularly, to experience acid sulfate (AS) soils of the area. Soil excursions have always had a special place in the programs of the International Acid Sulfate Soil Symposia, and the 7th International Acid Sulfate Soil Conference does not make an exception. Actually seeing the soil profile in the pit in the natural environment cannot be replaced by listening to presentations indoors or reading papers about the soils. Visiting soil pits gives international experts an opportunity to discuss what they see and compare their idea of what processes have made the soil as it is at the moment.

The coastal city of Vaasa is centrally located in the area where AS soils in Finland are most frequent and widespread. Our excursion area, extending 120 km from Vaasa to the north and 80 km to the east, is characterized by rural landscapes with productive fields and a long agricultural history. The traditional red wooden country houses typically have 1.5 floors and are frequently located along the rivers. Seven hundred years (ca 1100 – 1809) Finland was part of the Swedish kingdom, and particularly in the 17th century on the coast of Ostrobothnia many cities were founded, officially by the King of Sweden. These cities flourished on the basis of their harbours through which goods, such as tar, were transported from inland to foreign countries. The coastal population consists of Finnish and Swedish speaking people, and often the street and road signs are in both languages.

During the first day we are heading north. The day includes visits to AS soil sites of very different landscape positions and histories of land use. First we see soil engineering operations where a road is constructed on an AS soil. Next, we see a soil that has been reclaimed for agriculture only a few years ago, reedy areas with fresh sulfidic materials and a peatland that covers sulfidic materials. In the first day we also see a man-made lake which was separated from the brackish water of the Gulf of Bothnia. Rivers draining AS soils are the main source of water to this lake which often suffers from acidic episodes. Moreover, we see a typical harbour city of Karleby/ Kokkola (founded 1620) where wooden architecture has been well preserved.

The second day takes us to the banks of River Kyrönjoki, the major river of the area with a drainage basin of 4923 km^2. Kyrönjoki was the first river in Finland where agricultural AS soils were mapped in the 1970’s, following massive fish kills after dry summers. The drainage of the fields was substantially improved by common installation of subsurface pipes, resulting in increased oxidation of sulfidic materials and leaching of the acidic solutes from the solum. These problems are common throughout the western coast of Finland, and the studies of AS soils in Finland are nowadays environmentally motivated. We start our journey from a polder at the mouth of the river, and proceed along the banks up to the elevation of about 45 meters 80 kilometers inland. During the day, we see a soil profile rich in jarosite and hear about the management of the river with constructed rapids at Malkakoski. Close to the city of Seinäjoki we see the polder of Rintala which earlier used to be plagued by annual floods, owing to the flat terrain and the fact that the post-glacial land uplift is more rapid downstream than in the headwater areas. Flood embankments have been constructed, and we can see how the river may be higher than the soil surface.

Our journey ends at Seinäjoki railway station, or the participants can return to Vaasa. Before arriving at downtown Vaasa we drive through the former location of the city, which used to be a lively harbor but, owing to continuous isostatic rebound, it is now an inland village 7 kilometers from the present seashore.

I wish you an interesting excursion in the rural landscapes of Finland.

On behalf of the organising committee

Markku Yli-Halla
Professor of Environmental Soil Science
University of Helsinki

2. Geology of Ostrobothnia

Jaakko Auri and Peter Edén, Geological Survey of Finland

Bedrock geology

Finland is a part of the ancient Fennoscandian shield, which is one of the oldest parts of the Eurasian continent. The bedrock in northern and eastern Finland was formed during Archean time, more than 2,500 million years ago. The Archean bedrock was in many places covered by younger rocks of sedimentary and volcanic origin 2,500 – 1,890 Ma ago. The southern and western parts of our country consist of 1,930 – 1,890 Ma old volcanic rocks and marine sediments that have been folded and metamorphosed and intruded by different granitic magmas between 1,890 and 1,820 Ma. Together with areas in central Sweden they make up the Svecofennian bedrock. After this there was a long, calm geological period that ended with the formation of the rapakivi granites 1,650 – 1,540 million years ago and diabase dykes ca. 1,270 Ma ago.

Approximately 600 - 500 Ma ago layers of sediments were deposited on the already weathered down and even surface, but also these sediments have been eroded during later processes. Traces of these sediments have been preserved in the meteorite impact crater (520 Ma old) at Söderfjärden in Vaasa and Korsholm in layers more than 200 meters thick. These are covered by 80 m thick glacial-postglacial deposits. The sediments have lain at the bottom of the crater, protected from erosion and weathering until this day and are unique in the extensive Svecofennian province. Practically no new bedrock has been formed in Finland during the last 500 million years

The Precambrian bedrock of Finland consists to about 50 % of different kinds of granites, 20 % migmatites (gneisses) and the rest consist of schists, volcanic rocks, gabbro, quartzite and limestone. The bedrock is very difficult to examine because only 3 % can be observed directly. The rest is covered by till, sand, clay, peat and vegetation.

The rocks of Ostrobothnia – where Vaasa is - are part of the Svecofennian bedrock and have mostly been formed 2,000 – 1,800 Ma ago. The formation started with the sedimentation of sand and clay on the bottom of a sea about 2,000 Ma ago. Volcanic rocks were intercalated in the sediments. During the Svecofennian mountain building processes, about 1,885 Ma ago, the sediments sank 15 km into the crust and were metamorphosed at high temperatures and pressures to mica gneiss (recrystallization), veined gneiss (partial melting), and in extreme cases it would be completely molten into a granodioritic melt, which later solidified into diatexite (called Vaasa granite). About 1,270 Ma ago a basic melt intruded close to the surface of the Earth and formed olivine diabases in the western part of the archipelago. These were the final parts of the basement of Ostrobothnia. Due to weathering and erosion during hundreds of millions of years these rocks can now be seen at the surface of the Earth.

Quaternary geology

The old bedrock has been weathered and worn down by ice, water and wind during hundreds of millions of years. Ice sheets have repeatedly covered northern Europe and Finland during the last 2,5 million years. This has left clear tracks in the environment. The continental ice sheet carved the bedrock clean and thereafter deposited, on average, a 7 metres thick layer of till on it. It also created moraine ridges and lakes, carried with it gigantic boulders of rock and pressed down the crust of the Earth. Even today you can still see clear traces of the ice age in these regions. In the archipelago, where the rocks have been cleaned by waves you can clearly see striations in the rock made by the ice. From these it is easy to determine in which direction the ice was moving. In many places you can also find large erratic boulders that the ice has carried with it for long distances. Something that is very noticeable in the coastal areas is the isostatic land uplift, which still continues today as a result of the ice age. The several kilometres thick ice pushed down the crust, which is now returning to its original position. The isostatic uplift is the largest in the world in the Bothnian Bay area and the Quark (Kvarken) outside Vaasa. Where it is at its largest, the land has risen more than 250 meters after the ice melted (10,000 years ago) and today the land uplift can still be as much as 90 cm in 100 years.

Scandinavia and the Ostrobothnia region in Western Finland were glaciated many times during the Quaternary Period (last 2,5 Ma) and was located in the middle of the Late Weichselian glaciation about 28 000 – 10 000 years ago (Fig. 1) (e.g. Donner, 1996, Svendsen et al., 2004). As a result of the erosional and depositional processes during the glaciations and deglaciations the area is covered by a complex overburden of glacial and post-glacial Quaternary sediments. The glacial deposits in the area are mainly products of the drift of the last (Weichselian) glaciation.

The Earth´s youngest period, the Quaternary, is characterized by alternating glacial and interglacial stages. Most of the Finnish and Swedish Quaternary deposits were formed during and after the latest glaciation. The term Quaternary deposits refer to the loose overburden on the surface of the Earth and they are classified according to genesis and the environment in which they were formed. They consist of two main groups: glacial and postglacial. Glacial deposits were formed by an ice sheet or its melt-water and includes till, glaciofluvial sediments and glacial clay. Post-glacial deposits were formed independently of the melting of an ice sheet.

At the final stage of the latest deglaciation beginning about 10,500 years ago, the glacier terminated into a fresh water body, the Ancylus Lake, which was a precursor of the Litorina Sea and the present Baltic Sea in the area. The earth’s crust was depressed by the weight of the glacier and the coastline of the Ancylus Lake in the area is today located over 200 meters higher than the present Baltic Sea. During this late-glacial and following post-glacial times fine-grained water-lain sediments were deposited over the former sea bottom, bays and river mouths. Because of the post-glacial isostatic rebound (land uplift) and the marine regression these areas are now found on dry land which in places stretches more than 100 km inland. After the emergence of the flat coastal area from the sea the climate and the soil have been moist and favorable for mire development. Nowadays mires cover about 17 % of the land area in Ostrobothnia.

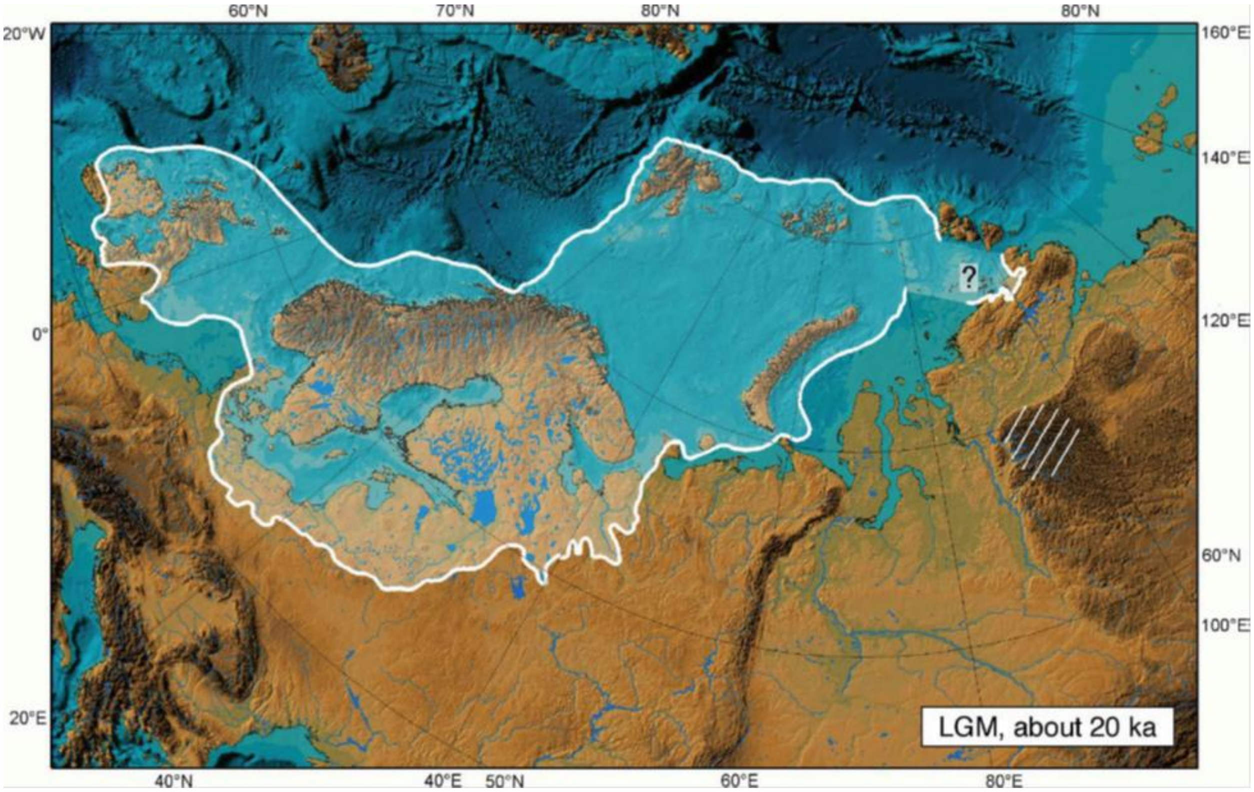


Figure 1. Extent of the Eurasian ice sheet during the Late Weichselian glacial maximum (from Svendsen et al. 2004)

Deglaciation of the Scandinavian ice sheet during the Late-Weichselian is quite well studied (e.g. Lundqvist 2007, Lunkka 2004). During the last glacial maximum (LGM) about 21 ka ago the Eurasian ice sheet covered the whole Scandinavia (Fig. 1.) and the center of the ice sheet was located approximately 100 km west of the Gulf of Bothnia (Lundqvist 1969), where the retreat of the margin was towards north or north-west (Lundqvist 2002, 2007). The retreat of the ice margin in the Kvarken area was fast (Lindén et al. 2006, Lindén and Möller 2005) and the eastern area (Ostrobothnia) was deglaciated about 10,500 years BP (Lundqvist 2002, Wohlfarth et al. 2008).

According to the LGM models and other studies, the maximum thickness of the ice sheet was 2.5 – 3 km (Svendsen et al. 2004, Fjedskaar 1994, Peltier 1994). The thickest parts of the ice were located over the Bothnian Sea because the basin was deep (Lundqvist 2007). The calculated total depression of the earth crust because of the weight of the ice is 800-1 000 m (Kakkuri & Virkki 2004, Eriksson & Henkel 1994, Taipale & Saarnisto 1990). The rebound had already begun during the melting and thinning of ice in the Baltic area about 15,000 years ago. During the first thousand years, the land uplift rate in the deglaciated areas was calculated to be up to 10 m in 100 years (Saarnisto 1981). The highest shoreline is 286 m.a.s.l. in the High Coast area on the Swedish east coast. Based on these observations, the water depth was approximately 250 – 280 m in the Kvarken (Vaasa) region immediately after deglaciation.

The current relative uplift rate is about 8.0 mm on the Finnish side of the Kvarken area. It is assumed that the land uplift will continue 10,000 to 12,500 years in the Kvarken area and it will still probably result in 100-125 m of isostatic land uplift (Ekman 1996, Mäkinen & Saaranen

1998). The uplift will continue until the depression of the geoid is reversed or the next oncoming glaciation begins to load and submerge the earth's crust.

Quaternary sediments

The Baltic Sea of today has evolved after the deglaciation through several separate stages: The Ancylus Lake 10,700 - 9,800 BP, the Litorina sea starting ca. 8500 cal yr BP – ca. 4,000 BP, the Limnea sea after that has gradually become less saline and evolved in to the Baltic Sea (Wohlfarth et al. 2008, Björck 1995). The present Baltic Sea is the world's largest brackish water body. It is very closed-in and quite shallow with a maximum depth of 459 m. The only straits are located between Sweden and Denmark. The salinity ranges between 1 ‰ in the north to 6-8 ‰ in the central Baltic (Björck 1995).

The onset of the Litorina Sea stage (Fig. 2) is defined over the whole Baltic Sea area in the sedimentary record. In the clay strata, the arrival of brackish water at the transition of the Litorina Sea stage is marked by a sharp litostratigraphic boundary (e.g. Breilin et al. 2004 and Saarnisto 1974). The widely spread greenish mud, rich in organic matter, sulfur and saline diatom flora was deposited on the bottom of the Litorina Sea. Today, these sediments form the most fertile agricultural areas on the coast of the Bothnian Bay area but also a potential environmental risk as they are easily turned into acid sulfate soils as a result of artificial lowering of ground water level. All ancient shorelines and beach deposits in Ostrobothnia date back to the Litorina Sea stage and are less than 8 000 years old (Winterhalter et al. 1981).

Till is the most common sediment type in the area and was deposited mainly during the last glaciation. Till is poorly sorted sediment, consisting of material from boulders to clay and forms laterally alternating stratigraphic units in the region. Till is typically found covering and smoothening the bedrock surface. In many places, however, especially in the Kvarken region outside of Vaasa, till can be found as distinct geomorfological formations. Most common of these are drumlins, hummocky moraines, De Geer moraines and ribbed moraines. Glacier polished and eroded crystalline bedrock outcrops can be found in many places where the wave action has washed the loose overburden away.

Sand and gravel deposits cover relatively small portions of the area and are mostly of glaciofluvial or littoral origin. Glaciofluvial deposits are typically eskers which have been remoulded by wave action or are covered by fine grained sediments. It is also quite common to find till covered eskers which were deposited before the last glaciation. Beach sands, beach ridges and dunes are found on the flanks of the eskers.

Fine-grained sorted sediments (clay and silt) cover wide areas in river valleys but are also found in smaller topographic depressions. The clays in the area typically lack the annual varved structure of glacial clays. Glacial clays are usually covered by younger postglacial Ancylus, Litorina and Post-Litorina sediments. Ancylus sediments are typically light gray clays deposited in freshwater and they are usually covered by Litorina and post-Litorina clays and silts which were deposited in saline and brackish water. Litorina and post-Litorina sediments show higher organic matter and sulfur content than the older sediments. On higher elevations and at the margins of the river valleys, the thickness of fine-grained sediments is typically from less than a meter to a few meters, but in the river valleys the thickness can be up to several tens of meters. In many places fine-grained sediments are found covered by peat or younger littoral, fluvial or alluvial sediments.

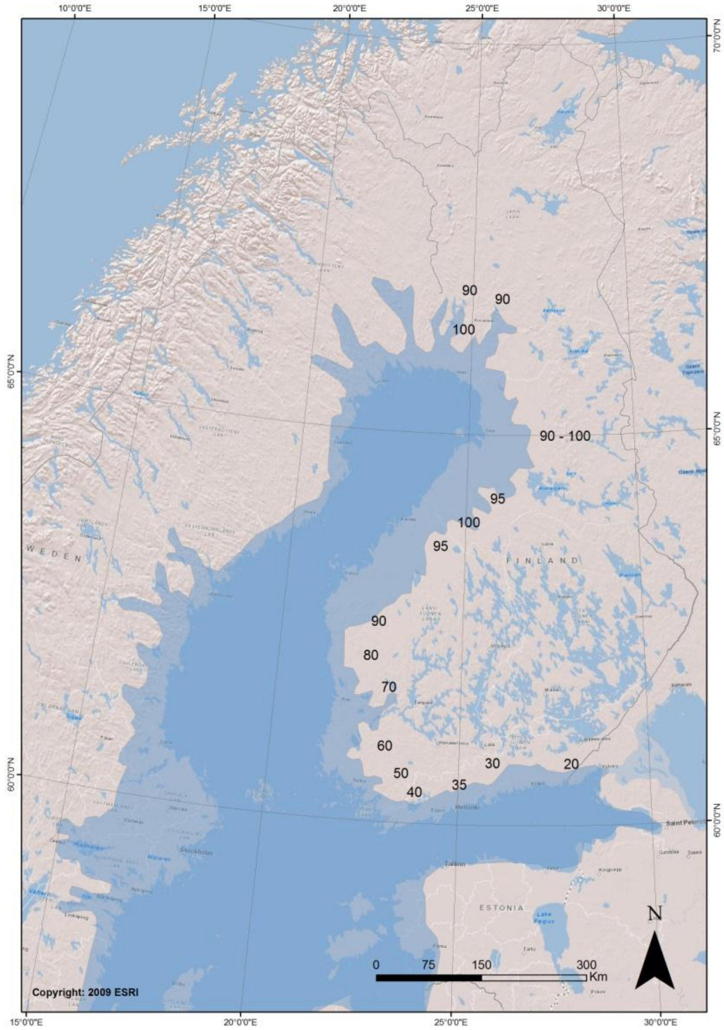


Figure 2**.** Extent of the Litorina Sea about 8000 years ago (Tikkanen & Oksanen 2002). The number values indicate the highest shorelines (meters above present sea level) during the Litorina Stage (Eronen 1974).

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3. Acid Sulfate Soils in Finland: mapping, definition and classification

Peter Edén, Jaakko Auri and Emmi Rankonen, Geological Survey of Finland

Europe's largest occurrences of Acid Sulfate soils (ASS) cover areas along the west coast of Finland (Yli-Halla et al. 1999). Sulfide-bearing fine-grained sediments were deposited in the sea between Finland and Sweden after the latest continental ice sheet had melted about 10,000 years ago. ASS are found in northern Finland below the 100 meters contour line and in southern Finland below the 40 meters contour line (Fig. 1). In places the formation of such sediments is still going on today. The rapid isostatic land uplift (more than 250 m after the ice melted, today up to 8 mm/year) after the retreat of the continental ice sheet has lifted these sediments above sea level. These "gyttja-containing" soils are very suitable for agricultural purposes, and most of them are low-lying and moist and artificial drainage is, therefore, required prior to farming. Especially modern subsurface drainage, forest drainage, peat mining, dredging and intensified building activities expose thick layers of the sediments to oxygen, leading to increased leaching of acidity and metals and deterioration of streams, rivers and estuaries.

Figure 1. Upper limit of the Litorina sea and the coastline of today in the Baltic Sea region. The total land area, which has been covered by the Litorina sea in Finland is ca. 5.100.000 hectares (51.000 km^2).

Figure 2. Typical ASS landscape in Ostrobothnia. This area is cleared for agriculture, covered by a one-meter layer of peat. Deepeing of the ditch has revealed a sulfide sediment layer, the surface of which has oxidised and turned grey. Events like this should be avoided in the future with the help of mapping, better information and guidance. Photo: Emmi Rankonen

The harmful consequences of ASS in Finland have been known for decades, but due to the sporadic occurrences, diffuse knowledge and lack of responsible organisations, no serious steps to reduce the problems connected with these soils were made. Sporadic, local mapping projects had been done in the 1950's (Purokoski 1959), in the 1970's (Erviö 1975) and several by Palko and co-workers (Palko 1994). They were, however, all made using a variety of methods and criteria. The first estimation of the total extent of ASS in Finland was made by Puustinen et al. (1994). Based on a wide–spaced sampling, they concluded that there is approximately 336,000 ha of ASS in Finland. They occur below the upper limit of the Litorina-sea, which today is about 40-100 meters a.s.l. on a land area of about 5 million ha. Yli-Halla et al. (1999) later made calculations using international criteria for the same data, ending up with 60,000-130,000 ha.

Severe fish kills in 2006-2007 and EU's Water Frame Directive (a legislative instrument adopted to restore ground and surface waters (rivers, lakes and coastal waters) in Europe to "Good Status" by 2015) brought about wide cooperation and work have commenced during the last few years to localise ASS and find methods to prevent or reduce their harmful effects. The Geological Survey of Finland (GTK) created a national network of actors to commence work on ASS. The Ministry of the Environment and the Ministry of Agriculture and Forestry (2011) developed a National Strategy for Acid Sulfate Soils, and ASS are also included in the Programme for Implementation of River Basin Management Plans 2010–2015 (Ministry of the Environment 2011). All agencies recommend the commencement of immediate ASS mapping of the whole coastal area using uniform and internationally valid methods.

Systematic mapping and classification of ASS started in Finland in 2009 with GTK as responsible partner, together with Åbo Akademi University and the University of Helsinki. The first year consisted mainly of method development. In the beginning of the mapping process we use airborne geophysical data together with other databases of GTK (soil maps, bedrock geological maps, peat-bottom soil information and topographic data including LIDAR surveys). This data excludes about half of the area, while the other half is considered to have the potential of ASS and is being mapped. Profiles for detailed observations and sampling, as well as reconnaissance probe drillings are made to 3 meters depth. On the basis of observations, measurements and analyses, we are classifying ASS, compiling ASS maps and reports, which are being made available to the public on GTK's web-pages (Fig. 3) (Edén et al. 2012a).

The first results of the mapping indicate that the area of ASS in Finland is larger than earlier estimations. This is due to systematic and denser sampling and observations to greater depth than before. A rough estimation ends at 200.000 – 400.000 hectares.

During the mapping process we have made a definition of Finnish ASS and we have made a Finnish (risk) classification system for them (Edén et al. 2012b). Both differ considerably from the internationally accepted ones (WRB and Soil Taxonomy). The different approach in Finland is a result of the different way ASS have formed and evolved in the Boreal environment and the observed/measured qualities leading to harmful impacts on the environment.

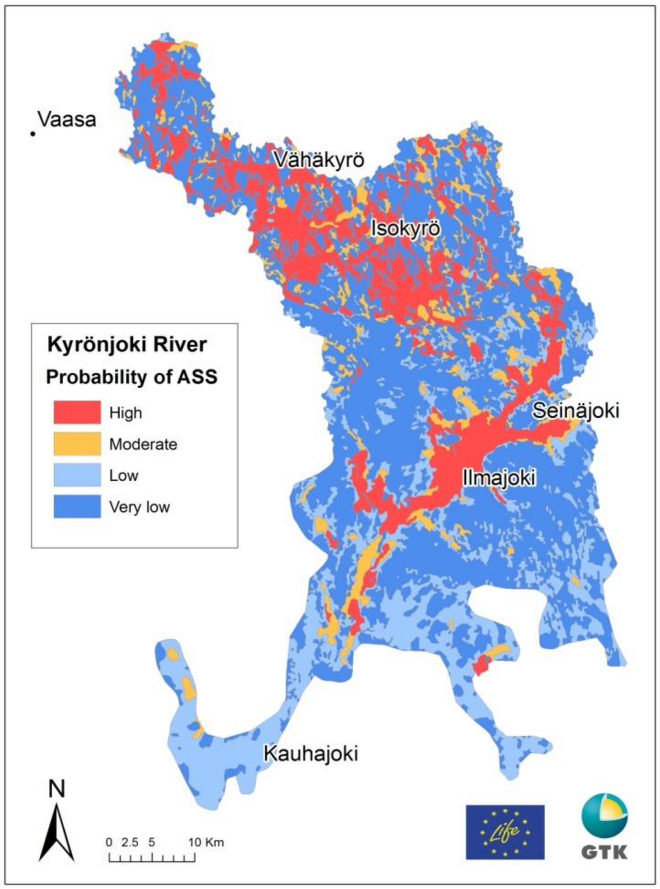

Figure 3. Map showing probabilities for ASS to exist in the Kyrönjoki river catchment, western Finland.

Acid sulfate soils are soils with elevated content of Sulfur and consisting of an oxidised acid horizon (actual acid sulfate soil) and/or a non-oxidised (reduced) sulfide-bearing horizon (potential acid sulfate soil). Acid sulfate soils are usually fine-grained gyttja soils (clay or silt).

Actual Acid Sulfate Soil (AASS)

- field-pH < 4,0 as a result of oxidation of sulfides and measured directly from the sample of oxidised minerogenic sediment or gyttja (not peat)
- if pH is 4.0-4.4 and there is no observation of underlying sulfide, further determinations are required (incubation or Sulfur content)

Potential Acid Sulfate Soil (PASS)

- Sulfur in the form of sulfides (reduced, not oxidised)
- pH > 6.0
- $S_{(tot)} \geq 0.2$ %
- incubated pH $\leq$ 4,0 and drop more than 0,5 units compared to field-pH

A risk classification of Finnish ASS has also been made. It is based on three parameters:

- Starting depth of the sulfidic horizon (the mapping / observation depth is 3m)
- minimum field pH / minimum incubated pH
- Sulfur-content

The described mapping, definition and classification are made in two projects: (i) a LIFE+ -project (EU's Financial Instrument for the Environment) and (ii) an ERDF –project (EU's European Regional Development Fund). Both projects will end in 2012. After that GTK will finish this general-scale mapping by the end of 2015 according to an agreement with the Ministry of Employment and the Economy.

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4. The soil profile at Söderfjärden

Markku Yli-Halla, University of Helsinki

A soil profile about 500 m from the present CATERMASS experimental field at Söderfjärden was described and sampled in October, 2008 (Fig. 1). The soil pit was about 20 metres from the major ditch bordering the experimental field. The field had no subsurface pipe drainage but rather shallow (0.5 m) open ditches. Barley had been grown in the previous summer.

Figure. 1. The Söderfjärden soil on 6 October, 2008 (Photo: Johanna Laakso).

The horizons down to 1.5 m were oxidized, indicated by the thick continuous iron hydroxide coatings on aggregate faces (Table 1). Jarosite coatings were observed immediately below the plough layer. The structure of the B horizon was very strong, consisting of very coarse prismatic aggregates in the lower part. The Cg horizons below 1.5 meters were reduced, indicated by high pH (Fig. 2) and the lack of iron hydroxide mottles. The Cg horizons had a total sulfur content of about 0.8% (Table 2), which is typical of the area. The negligible water conductivity of the reduced subsoil was demonstrated in the soil pit. Some groundwater was observed at the bottom of the pit only after six hours in spite of the fact that the water level in the major ditch 20 meters away was about 1 meter higher than the bottom of the pit.

Table 1. Morphology of the Söderfjärden soil. Description was made on 8 October, 2008.

Horizon	Morphological characteristics
Ap, 0-28 cm	Very dark grayish brown (10YR 3/2) silt loam; moderate medium platy and subangular blocky (2m pl/sbk) structure; many roots; abrupt smooth boundary
Bgj1, 28-50 cm	Gray (2.5Y 5/1) matrix, many coarse prominent yellowish brown (m3p 10YR 5/4) mottles as continuous color around aggregate surfaces, common fine-to-medium prominent yellow (c1-2p 2.5Y 7/6) jarosite mottles; silty clay loam; moderate fine and medium angular blocky (2 f-m abk) structure; few roots; clear smooth boundary
Bgj2, 50-86 cm	Gray (2.5Y 5/1) matrix, many coarse prominent dark brown (m3p 7.5YR 3/3) mottles as continuous color around aggregate surfaces (thickest and darkest coatings in this horizon), few fine prominent yellow (f1p 2.5Y 7/6) jarosite mottles; silty clay loam;

	weak medium prismatic parting to strong fine and medium angular blocky (1 f pr/ 3 f-m abk) structure; no roots; clear smooth boundary
Bg, 86-152 cm	Gray (2.5Y 5/1) matrix, many coarse prominent dark brown (m3p 7.5YR 4/6) mottles on aggregate surfaces (much weaker coatings than in the horizon above); silty clay loam; moderate very coarse (length 30-40 cm) prismatic (2 vc pr) structure; clear smooth boundary
Cg1, 152-182 cm	Black (N 2.5 Y) matrix; silty clay loam; massive, with some desiccation cracks with no coatings; no roots; gradual smooth boundary
Cg2, 182-220 cm	Black (N 2.5 Y) matrix, silty clay loam; massive; no roots

Table 2. Characteristics of the soil profile of Söderfjärden.

Depth (cm)	Horizon	Texture[1)]	pH(H2O) fresh	C_{tot} (%)[2)]	N_{tot} (%)[2)]	S_{tot} (%)[3)]	SO_4-S (mg/kg)[4)]	Clay (%)	Silt (%)	Sand (%)
0-28	Ap	sil	6.7	2.3	0.23	0.23	17.2	26	68	6
28-50	Bgj1	sicl	4.7	1.2	0.16	0.35	15.3	32	65	2
50-86	Bgj2	sicl	4.0	1.5	0.22	0.39	39.7	38	60	3
86-152	Bg	sicl	3.8	1.9	0.28	0.18	592	36	64	0
152-182	Cg1	sicl	7.9	2.2	0.32	0.83	409	38	61	1
182-220	Cg2	sicl	8.6	2.1	0.29	0.79	759	40	60	1

1) sil = silt loam, sicl = silty clay loam
2) Dry combustion with LECO apparatus
3) digestion with concentrated nitric acid
4) 0.01 M $CaCl_2$ extraction of air dry samples

Pedological features:

- The plough layer is an **ochric epipedon**. The dry color is too light for an umbric epipedon.
- In large parts of the profile, the aggregates are covered with thick coatings of iron hydroxide, and the aggregate interiors are homogeneously gray. The **gleyic color pattern** starts right below the Ap horizon and extends to the depth of the investigated soil profile.
- At least the soil at 28-86 cm meets the requirements of a **cambic horizon**.
- **Colors of jarosite** are visible at 28-86 cm.
- The Bg horizon at 86-152 cm meets the requirements of a **Thionic horizon** (WRB: pH<4, sulfate concentration >500 ppm, thickness >15 cm).
- **Sulfidic materials** occur below 152 cm.
- The low pH is associated with **low base saturation** and most likely to high Al concentration.
- The concentration of **organic carbon is >1%** throughout the investigated depth in each horizon.

Classification according to Soil Taxonomy: ***Sulfic Cryaquepts.*** This classification arises from the 1) cambic horizon, 2) aquic soil moisture regime, 3) cryic soil temperature regime and 4) a horizon between 86-152 cm meeting the requirements of a sulphuric horizon, except the pH which is between 3.5 and 4.0.

Strictly following the criteria of the WRB system (2007 edition), this soil falls out of the Gleysols because, owing to deep ploughing, the Ap horizon is too thick (28 cm) to allow the gleyic color pattern to start *within 25 cm of soil surface*. The classification is:

Thionic Endogleyic Cambisol (Ferric, Alumic?, Humic, Dystric, Siltic).

Evidently, with a more shallow ploughing, the criteria of a Gleysols would be met. Waiving the depth criterion of the gleyic color pattern is waived, the soil is:

Haplic Gleysol (Thionic, Humic, Alumic?, Dystric, Siltic)

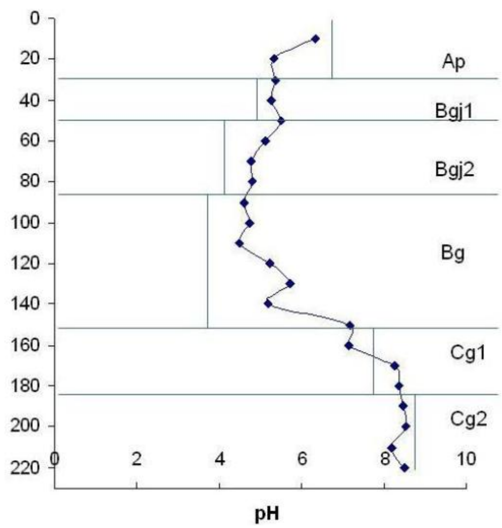

Figure. 2. Soil pH measured in the field at the intervals of 10 cm (-■-). Vertical lines indicate the pH measured in the laboratory from a composite sample of the respective horizon.

5. Excavation practices in sulfide clay areas: project Highway 8 Sepänkylä bypass

Merja Autiola, Ramboll

The new Vaasa bypass road was planned to cross large areas of clay. Road construction in such conditions is only possible either due to extensive mass exchange, mass stabilization or a combination of columns and mass stabilization. Mass exchange and excavation of sulfide clays from the anaerobic environment under the ground-water level and moving them to aerobic conditions is not recommended without prior treatment such as, for instance, stabilization. The excursion presents various alternatives to a large mass-exchange operation on the Highway 8 and the Vaasa bypass road at Sepänkylä at Vaasa and Mustasaari.

While designing the details of the project (Ramboll and Skanska), the sulfide clay problem was taken into consideration and the final solutions were created in such a way that allowed to leave the sulfide clay on-site and therefore, to avoid mass exchange almost entirely. The solutions include such procedures as column stabilization, mass stabilization and stabilizing berms.

Figure 1. Project area in the new bypass road of Vaasa

6. Pedersöre: an experimental field

Peter Österholm, Åbo Akademi University

In the Larsmo Lake catchments (c. 100 km north of Vaasa) acid sulfate soils are most common 0-20 m above the current sea level (Toivonen & Österholm 2011). The Pedersöre test field (5.8 ha; Fig 1) which is underlain by acid sulfate soils belongs to the catchment of Purmo River, which discharges in to the Larsmo Lake. As the field is only c. 2 m above the current sea level, the sediments are young and emerged above sea level 200 - 300 years ago. As compared to the large acid sulfate soil areas in the Vasa - Seinäjoki area, the sediments in this field are somewhat coarser (clay content 10 – 20 % in the oxidized zone) and more shallow (c. 3 m underlain by till), which is also quite typical for the Larsmo area as a whole Toivonen & Österholm 2011.

The field was drained with shallow open ditches in to the adjacent Kyrkbäcken brook and used for farming within the first half of the 20th century after which it became largely forested (mainly birch trees; Fig 2). In 2008 - 2009 the field was reconverted in to farmland Fig 2; the forest was removed, soil surface leveled and controlled pipe drainage (CPD) installed to a depth of 1.1-1.5 m. The field was divided in to three subfields with their own control well (enables regulation of outflow), each subfield having a somewhat different land use history. In addition, vertical plastic sheets (0.3-1.8 m) were installed around each subfield to prevent by pass flow to adjacent drains or subfields (Fig. 1). The reason for this is that previous experience indicates significant by-pass flow to main drains through soil cracks and macropores The main aim with the test field is to demonstrate the use of controlled drainage with bypass prevention in order to minimize sulfide oxidation. Interesting questions of research include the role of previous and present land use/cover on sulfide oxidation and acidic metal discharge.

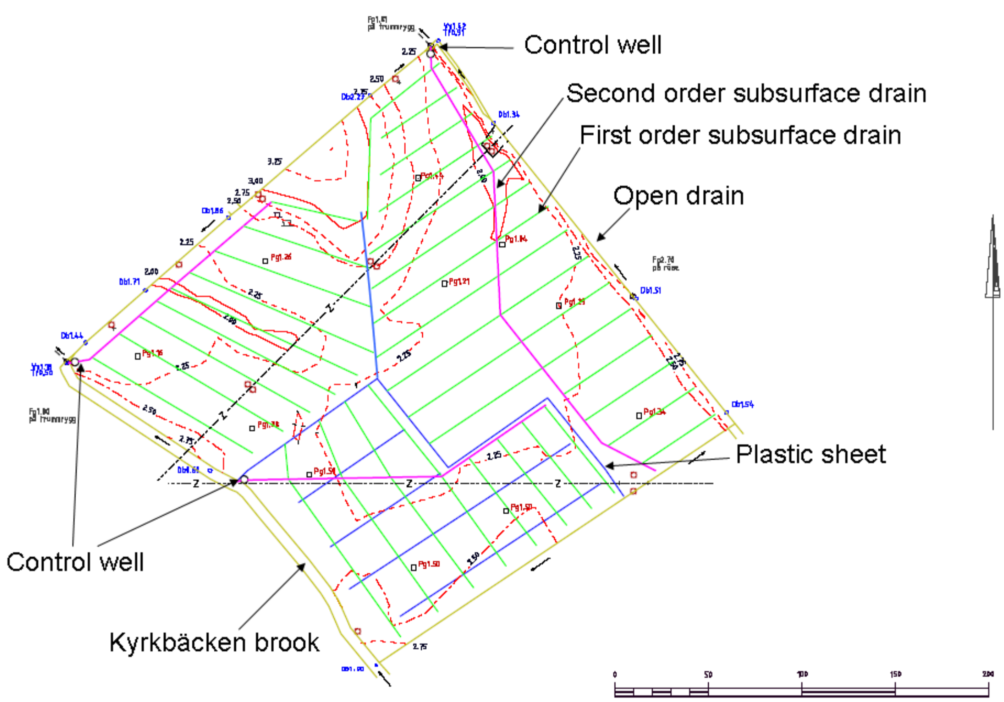

Figure 1. The Pedersöre test field in midwestern Finland.

Figure 2. Before (above) and after the field had been converted in to farmland (below).

The soil was first characterized in spring 2009, before drainage after the forest had been removed and soil surface leveled/prepared. The soil had been oxidized down to c. 2.3 m with minimum pH around 3.5 and exchangeable acidity near 50 mmol kg^{-1} (Figure 3). Significant occurrences of vertical old iron(hydr)oxide covered root channels enhancing the oxidation process were found down to c. 2 m. Jarosite mixed with iron oxides were also been found at a depth around 1 m. However, large amounts of pyrite (typically >0.1% with CCr extraction) and total acidity up to 200 mmol kg^{-1} (end point 5.5) was still present in the "oxidized zone". It is notable that the acidity in the test field is relatively high as compared to other AS soils in the Larsmo catchment. Thus, further oxidation of this zone should be prevented. As expected, parent sediments had higher sulfide contents with pyrite (CCr) typically >0.2 % but only small amounts of monosulfide (AVS typically ≤ 0.1) that gave the parent sediments a blackish color at several sites within the field. Consequently, significant oxidation has occurred prior to the installation of modern efficient subsurface drainage.

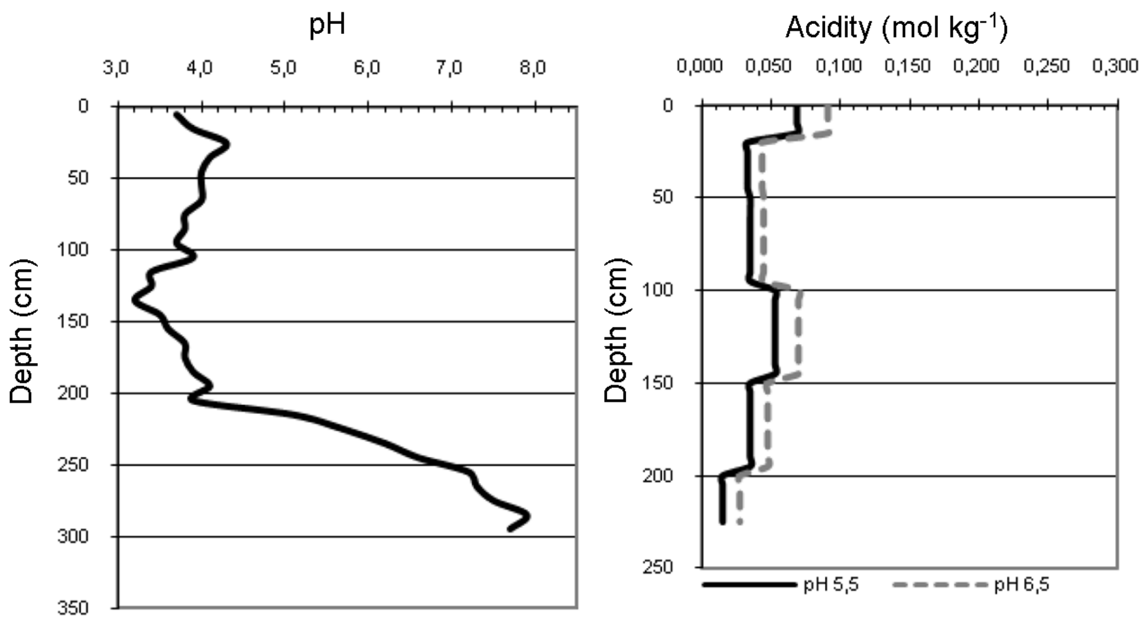

Figure 3. The pH and exchangeable acidity (1 M KCl) in a representative soil profile

As installation of the CPD system required somewhat dry conditions, we were not able to store the winter/spring water during the first year of operation (2009) and as a result the groundwater dropped at most to c. 2 m, i.e. to the maximum depth of previous soil development. It is notable that this is below the water level in the recipient Larsmo lake, i.e. evapotranspiration is significant in the field. However, the actual acidity did not increase due to this but was remarkably similar to conditions before CPD. The second year of operation (2010) was very challenging as the summer was very hot and dry. Nevertheless, although the groundwater level decreased 10 cm per week or more during the hottest period in July, the groundwater was still above 1.5 meters throughout the summer. Sulfate concentrations have been high in two of the control wells (typically >300 mg/L) of two subfields, and remarkably high (>1000 mg/L) in one of the subfields although sulfur contents in soils are rather similar. It seems that prior to subsurface drainage, there has been a significant buildup of sulfate, particularly in the latter field, due to evapotranspiration and slow groundwater seepage to adjacent drains.

The study on the Pedersöre test field has been funded by Renlunds stiftelse, Finnish Field Drainage Association, the EU-Life+ programme in a project titled Climate Change Adaptation Tools for Environmental Risk Mitigation of Acid Sulfate Soils (CATERMASS), Oiva Kuusisto säätiö and KWH-Pipe.

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7. Lake Larsmosjö - Lake Öjasjö area

Janne Toivonen, Åbo Akademi University

The Larsmosjö - Öjasjö Lake system was in early 1960s still a part of the archipelago of mid-western Finland with brackish sea water (salt content up to 3 ‰). However, the local industries needed fresh water, and embankments were built in narrow straits (Larsmosjö Lake in 1962 and Öjasjö Lake in 1969, Fig. 1), creating a fresh water reservoir. A small canal links the two lakes together. The lake is also a popular area for fishing and recreational houses, and the water level is kept stable since 1998 due to recreational needs.

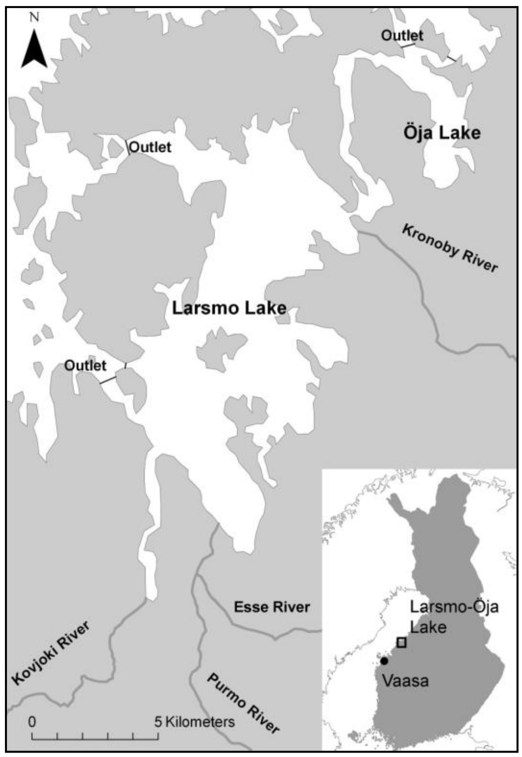

Figure. 1. The Larsmosjö - Öjasjö Lake system in Midwestern Finland.

The total area of Lake Larsmosjö is 73 km^2, and 12 km^2 for Lake Öjasjö. Both lakes are shallow. The average depth in Larsmo Lake is 2.6 m and in Öja Lake 1.6 m and the lakes have a combined water volume of 200 million m^3. The total drainage area is 4290 km^2. There are four rivers discharging into Lake Larsmosjö: Esse River (catchment size 2048 km^2), Purmo River (866 km^2), Kronoby River (767 km^2) and Kovjoki River (292 km^2). The near-field (area drained by low-order streams discharging directly into the lake) has a drainage area of 320 km^2. The catchments of the rivers consist of forest (49 – 59 %), swamp (20 – 34 %), agricultural land (14 – 19 %), water (1 – 10 %) and urban areas (< 1 %). The total amount of inhabitants living in the drainage area of the lake is 45900. There are three outlets from the lake: two in Lake Larsmosjö and one in Lake Öjasjö (Fig. 1).

The ecological condition of the Larsmosjö - Öjasjö Lake system and the rivers discharging into the lake are classified in the national classification system as bad to moderate due to effects from human land use and water works. The catchments of all four rivers and the near-field contain a.s. soils in various proportions, and cause an evident effect on the water quality (low pH and high concentrations of sulfate and metals). The river- and lake water is also brown in color caused by humic acids, and suffer from eutrophication.

The rivers and the lake became acidified mainly in late 1960s due to intensified land use on sulfidic sediments, causing large fish kills. After that, fish kills have occurred on several occasions, with the most recent occurring in autumn and winter 2006 – 07. These events have occurred mainly during high flow in spring or autumn. The summers preceding these events were unusually dry, causing the groundwater level to drop to an exceptionally low level, increasing the oxidation of sulfides in the catchment. The building of the embankments is considered to enlarge the water area affected by discharge from a.s. soils because sea water is prevented from dispersing into the lake, which reduces the buffering capacity and dilution effects in the lake. Even though visible fish kills are relatively rare (about once every ten years), smaller acidic events in the rivers and the lake when pH drops below 5.5, and even 5.0, occur quite frequently. These small acidic events may not affect most adult fish, but are likely to cause disturbances in the reproduction, hampering the recovery of fish stocks between the big fish kills.

8. The PAHA-project: Control of acidity in the lower course of river Perhonjoki

Juhani Hannila and Mats Willner, City of Kokkola

Plenty of research has been done in Finland about acidity from drained farmlands. But there is only little research about acidity from drained forest areas, even if the total area of drained forest is much larger than drained farmlands.

The PAHA-project aims at identifying effects of peat-soil forest drainage in areas with acid sulfate soils and how the effects on water quality can be minimized.

8.1. Objectives

The PAHA project has the following objectives:

- Increase landowners knowledge about acid sulfate soils and their effects on water quality
- Help to identify acid sulfate soils, especially for those who plan forest drainage in peat covered soils, and that way minimize the effects of acidification
- Find out how different forest drainage methods affect water quality and develop new and more gentle drainage methods
- Upkeep a webpage, so that everybody can read about the project and see the results
- Produce material, for forest planners and the public, about acid sulfate soils in forest drainage areas
- Plan nature biotope management projects in the catchment area of river Perhonjoki and that way enhance the water quality
- The results for control of acidity caused by forest drainage, can be used as a guideline acid sulfate soil areas all over Finland

8.2. Test field

Kiimakorpi (approximately 100 ha) pine bog in Nedervetil functions as project test-field. The bog will be divided into five different sections + one control area. In each section, different drainage methods will be tested. Automatic water-quality measurement stations (e.g. pH, conductivity and discharge) will be situated in three of the sections. The other sections will be measured by hand. If severe acidification occurs, even concentration of metals (e.g. Fe and Al), sulfate / Sulfur, acidity and alkalinity will be determined.

8.3. Funding of the project

The total budget (2011-2013) is estimated to be around 280 000 €. The project is funded by the European Regional Development Fund ERDF (80%), the City of Kokkola (14,6%) and the trust for river Perhonjoki (5,4%). Main partners are the City of Kokkola, the Southern Ostrobothnian Center for Economic Development Transport and the Environment, the Forestry Development Center TAPIO, the Geological Survey of Finland and the landowners.

8.4 Kiimakorpi pine bog – An example of peat covered potential acid sulfate soils

Jaakko Auri and Anton Boman, Geological Survey of Finland

The Kiimakorpi pine bog is approximately 100 ha large and located in Alaveteli in Ostrobothnia. This site is an example of potential acid sulfate (PAS) soil materials covered by peat. The PAS soil materials generally consist of gyttja-bearing iron sulfide-containing silt materials. The thickness of the peat layer is generally just below 1 m but can reach a thickness of 1.5 m at some locations. The oxidized part of the peat layer is naturally quite acidic (pH<4.0) due to the occurrence of organic acids. During incubation, the pH of the peat material generally does not decrease further indicating that iron sulfides are not very abundant in this layer. However, at one location (Figure 1) pH in the peat layer dropped during incubation which may indicate the presence of iron sulfides. Below the peat layer, anoxic conditions prevail and iron sulfides (presumably FeS and FeS_2) are preserved. The total S concentration (dry weight) in the PAS soil materials are quite high and range between 0.6% and 2.6%.The field pH of the PAS soil materials range between 5.8 and 6.5. During incubation of the PAS soil materials, the pH can drop considerably and reach values close to 2 (see e.g. Figure 1).

The sulfidic materials (i.e. PAS soil materials) in this area can be divided into two types. In the bottom of the profiles, very black (indicating the presence iron monosulfides) and thick (several meters?) gyttja bearing sulfidic silts occur and on top of this material a rather thin layer (c. 0.3-0.7 m) of greenish colored gyttja bearing sulfidic silts occur (see e.g. Figure 1). Possibly, the color change from black to green indicates conversion of iron monosulfides to pyrite.

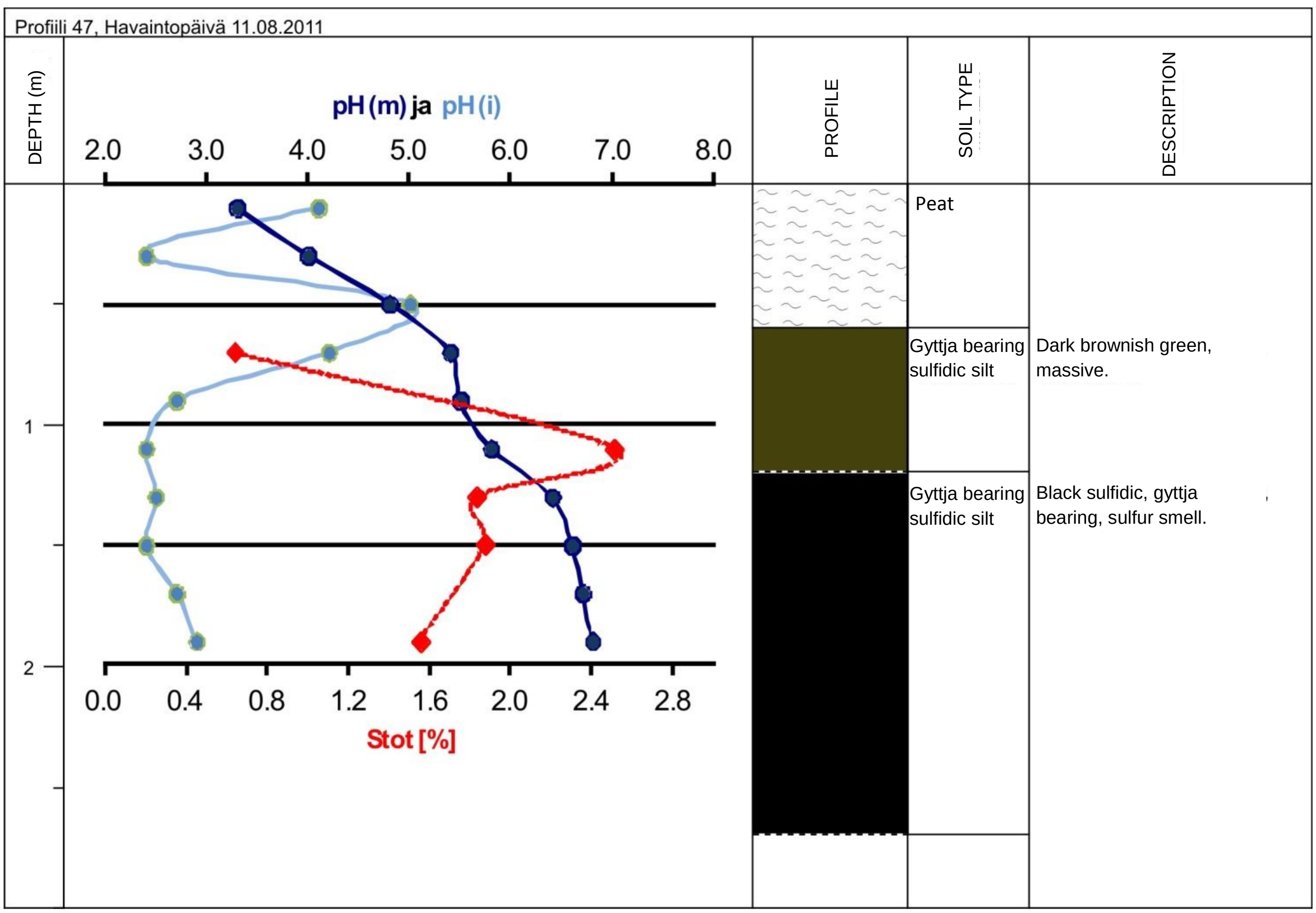

Figure 1. Total S (red line) and field (m) and incubated (i) pH from a profile in Kiimakorpi.

9. Sulfidic sediments at Vassor Bay

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Area description

The Vassor Bay (Fig. 1) is located c. 30 km northeast of Vaasa and is part of the delta of the river Kyrönjoki which flows into the Gulf of Bothnia (part of the Baltic Sea). The river Kyrönjoki has a drainage area of c. 1300 $km^{2,}$ one third of which is agricultural land and c. 19% is covered with acid sulfate (AS) soils (Erviö, 1975). In this area, postglacial land uplift is very pronounced and sulfidic sediments are continuously brought above the current sea level. During late Pleistocene, the continental (Weichselian) ice sheet had a thickness of up to c. 3 km and forced the bedrock downwards by several hundred meters (Eronen, 2005). After its retreat, the bedrock rebound was initially rapid but has since tapered off and is currently c. 9 mm/year in the Vassor area (Eronen, 2005; Johansson et al., 2004). The Baltic Sea, which was entirely covered by the Weichselian ice sheet, has during the Holocene (postglacial period) experienced four distinct phases (Sohlenius, 1996 and references therein): (1) The Baltic ice Lake (15 000-10 300 B.P.), (2) the Yoldia Sea (10 300-9500 B.P.), (3) the Ancylus Lake (9500-8000 B.P.), and (4) the Litorina Sea (8000-3000 B.P.).

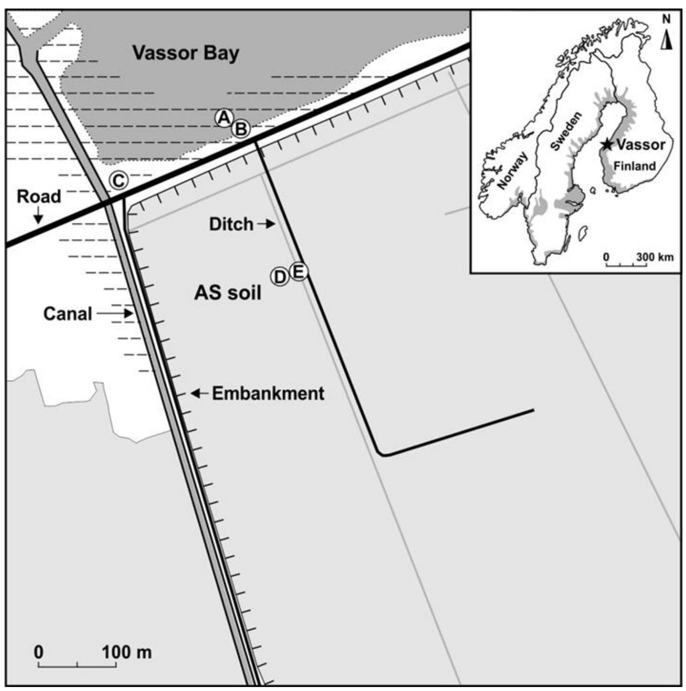

Figure 1. Map of Vassor showing part of the embanked area and the Vassor Bay. Sites A–E show the locations of previously collected soil/sediment cores in the study by Boman et al. (2010) and include subaqueous sediment (A), shoreline sediment (B), peat covered sediment (C), drained sediment (D; AS soil), and drain bottom sediment (E). The shaded area in the small picture indicates the extent of the Litorina Sea and thus the area where AS and potential AS soils can be found.

The ice smoothed the forms of the bedrock, drifted the superficial deposits and deposited a basal till layer covering most of bedrock in the area (Heikkilä, 1999). Sediment strata formed during the Litorina and Baltic Sea periods are mainly dominated by silts and clay particles. Mineralogically, the bulk material in the sulfide-rich sediments corresponds to the fine fraction of till derived mostly from Proterozoic granites and gneisses in the area, and therefore is dominated by silicates (micas, feldspars and quartz) which are very poor in carbonates (Åström, 1998). The sediments have a characteristic black color caused by metastable iron sulfide, which is probably a mixture of mackinawite (FeS) and greigite (Fe_3S_4) (Boman et al., 2008). Due to the isostatic rebound, sulfidic sediments have been lifted above the current sea level and because of agricultural works the majority of these sediments have been drained and turned into productive farmland. This has resulted in the formation of AS soils.

In 1953-1966 about 1.5 km^2 of the inner Vassor Bay (63°9.484´N, 22°0.549´E) with water depths up to c. 80 cm was turned into farmland by embankment (Fig. 1). This farmland area has been efficiently drained for c. 40 years with the aid of a pumping station and up to 2 m deep ditches. In the Vassor Bay (north of the embankment), the bottom sediments are continuously brought closer to the sea surface by the postglacial land uplift, and in the near-shore areas sediments are exposed to the atmosphere when the sea level is low as indicated by the destruction of the lamination by burrowing organisms in the upper 15-20 cm. The Vassor Bay is not affected by tidal action and is thus exposed to only minor variations in water level (commonly within ±25 cm). It is, however, impacted by the Kyrönjoki River which drains large AS soil fields upstream.

Stratigraphy and soil classification

Stratigraphy of five previously collected (August 2005) soil/sediment profiles (sites A-E in Fig. 1) from Vassor (including the Vassor Bay) are presented in Fig. 2. For subaqueous and shoreline sediments (e.g. sites A and B, respectively) north of the embankment, the upper 15-20 cm has a greyish color and bioturbation occurs as indicated by the destruction of the lamination. Both the color change from black to grey and the occurrence of bioturbation indicates oxic conditions. Below this upper oxic layer, lamination is preserved and the color of the sediment is black, indicating the presence of metastable iron sulfide (Boman et al., 2010). There are also sediments north of the embankment (e.g. site C) that have been above the sea level for a few decades. On top of these sediments a layer of peat (c. 20 cm thick) has formed. Below the peat layer, there is a gradual switch in the upper c. 60 cm from grey to black colored sediments.

Because of the land uplift (sites north of the embankment) and artificial drainage (sites within the embankment), the surface soil is oxidized. For the subaqueous and shoreline sediments (e.g. sites A and B, respectively), the redox change has most likely occurred within the last decades.

Within the embankment, the extensive drainage of the sulfidic sediments has resulted in the formation of AS soils (e.g. site D). The AS soils are characterized by a clayey cultivated layer in the upper c. 40 cm, followed by close to 1.5 m of acidic (pH <4) material (brown/grayish clay) with precipitates of jarosite [$KFe_3(SO_4)_2(OH)_6$] and Fe-oxyhydroxides [e.g. $Fe(OH)_3$ and FeOOH]. Below the acidic material, black sulfidic parent material prevails. Occurrence of vivianite [$Fe_3(PO_4)_2x8H_2O$] (white colored lenses that turns blue after a few hours of exposure to air) have been found intercalated with the black sediments.

According to Soil Taxonomy (Soil Survey Staff, 2006), the subaqueous and shoreline sediments (e.g. sites A and B, respectively) are classified *as Typic Sulfaquents*. This is because they are basically saturated with water and contain sulfidic material close to the surface. Also the drain sediments (e.g. site E) within the embankment fall into this category. The emerged peat covered sediment (e.g. site C) has a histic epipedon above the sulfidic material and is classified as a *Histic Sulfaquent*. The drained sediment (e.g. site D) has a sulfuric horizon (pH <3.5) above the sulfidic material and is classified as a *Sulfic Cryaquept*.

Characteristics of soil/sediment profiles

Underneath the anoxic boundary for the soil/sediments at Vassor, metastable iron sulfide and pyrite carry similar amounts of S up to 0.88% in total and the variations in pH, and concentrations of metals, As, and organic matter are small both between and within the sites (Figs. 3, 4). Median values for selected parameters for subaqueous sediments, peat covered sediments, and AS soils are shown in Table 1.

Above the anoxic boundary the concentration of metastable iron sulfide decreases at all sites, whereas the pyrite concentration increases in the subaqueous sediments (and partly increases in the shoreline sediments and peat covered sediments), or decreases in the AS soil (and partly decreases in the shoreline sediments and peat covered sediments). The concentrations of other S-species (elemental S, sulfate and organic S) also increase to variable extent above the anoxic boundary (Fig. 3). The concentration of organic matter has increased (>60% for the emerged peat covered sediment) in the upper parts of the sediments north of the embankment (Fig. 4).

After part of the Vassor Bay was embanked and artificially drained (ditching and pumping), the formation of AS soils was fast (Boman, et al, 2010). The extent of oxidation (pH down to 3.3) and extreme leaching (down to c. 190 cm) of S and metals (e.g. Cd, Co, Ni, and Zn) in the AS soil (see e.g. site D in Fig. 3; Table 1) is remarkable considering the relatively short time of drainage (c. 40 years) and the cold climate inhibiting soil-forming processes much of the year. The reason for the fast AS soil development is most likely related to the abundance of metastable iron sulfide (Boman et al., 2010).

In contrast to the rapid AS soil formation following artificial drainage, the effects of natural drainage are much less pronounced (Boman et al., 2010). In the emerged peat covered sediments (e.g. site C) loss of S only reaches a depth of 30 cm (Fig. 3). The peat layer effectively prevents the groundwater table from dropping, which in turn means that metals that are typically lost from AS soils (e.g. Cd, Co, Ni, and Zn) are not lost, but instead transported downwards and precipitated just below the groundwater table. The pH in the oxic part of the peat covered sediment has a median value of 5.1 (Fig. 3; Table 1) which is considerably higher than in the AS soil. Iron, Mo and As are not considerably lost from any of the profiles in this area (Table 1). The concentration peaks for Co, Ni, and Zn, seen in the drain sediment (site E in Fig. 1) within the embanked area, is most likely because of precipitation with iron sulfides forming in the uppermost part of the drain during reducing conditions (Boman et al., 2010).

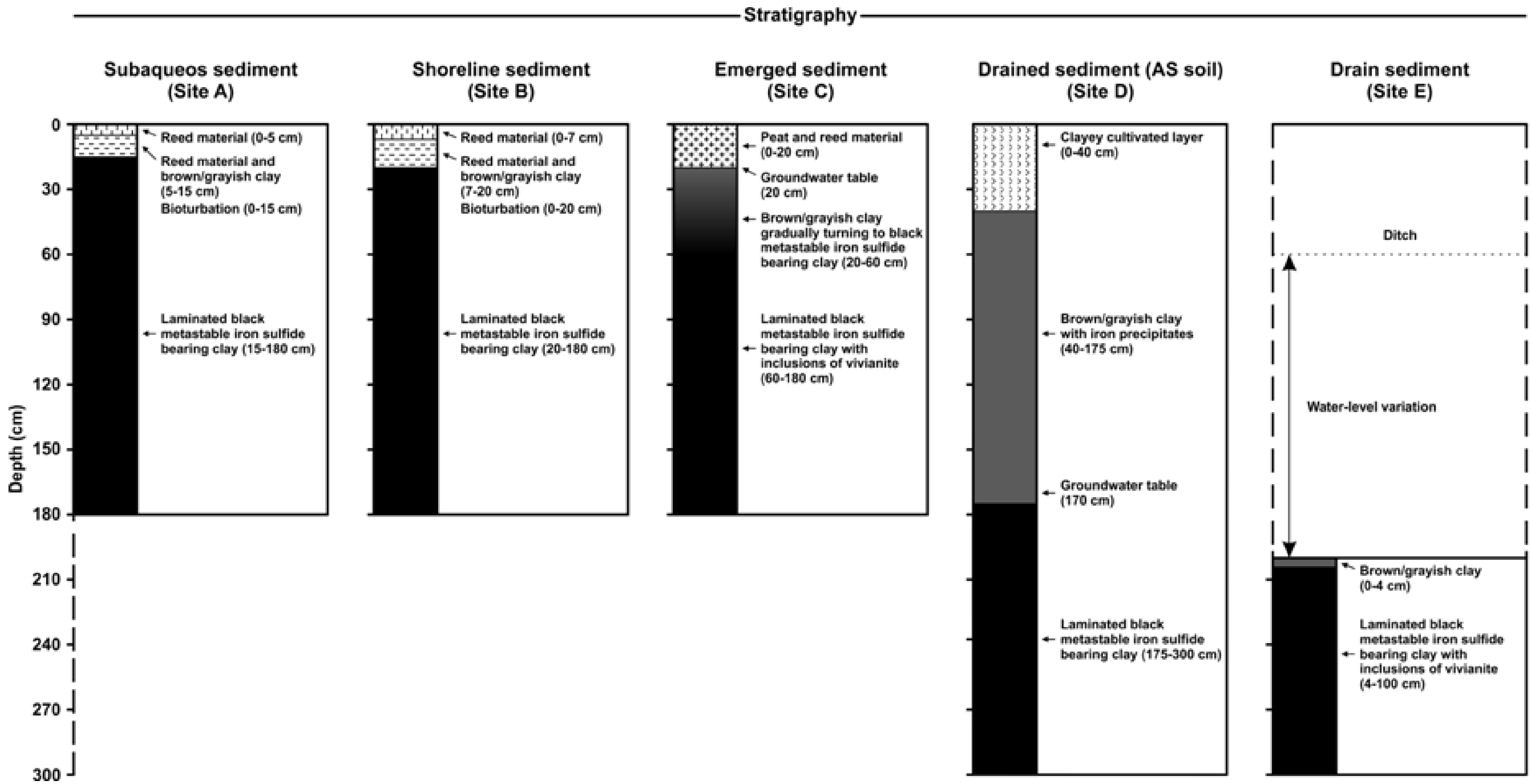

Figure 2. Field observations and stratigraphy at Vassor. See map in Fig. 1 for location of the profiles. The figure is slightly redrawn from Boman et al. (2010).

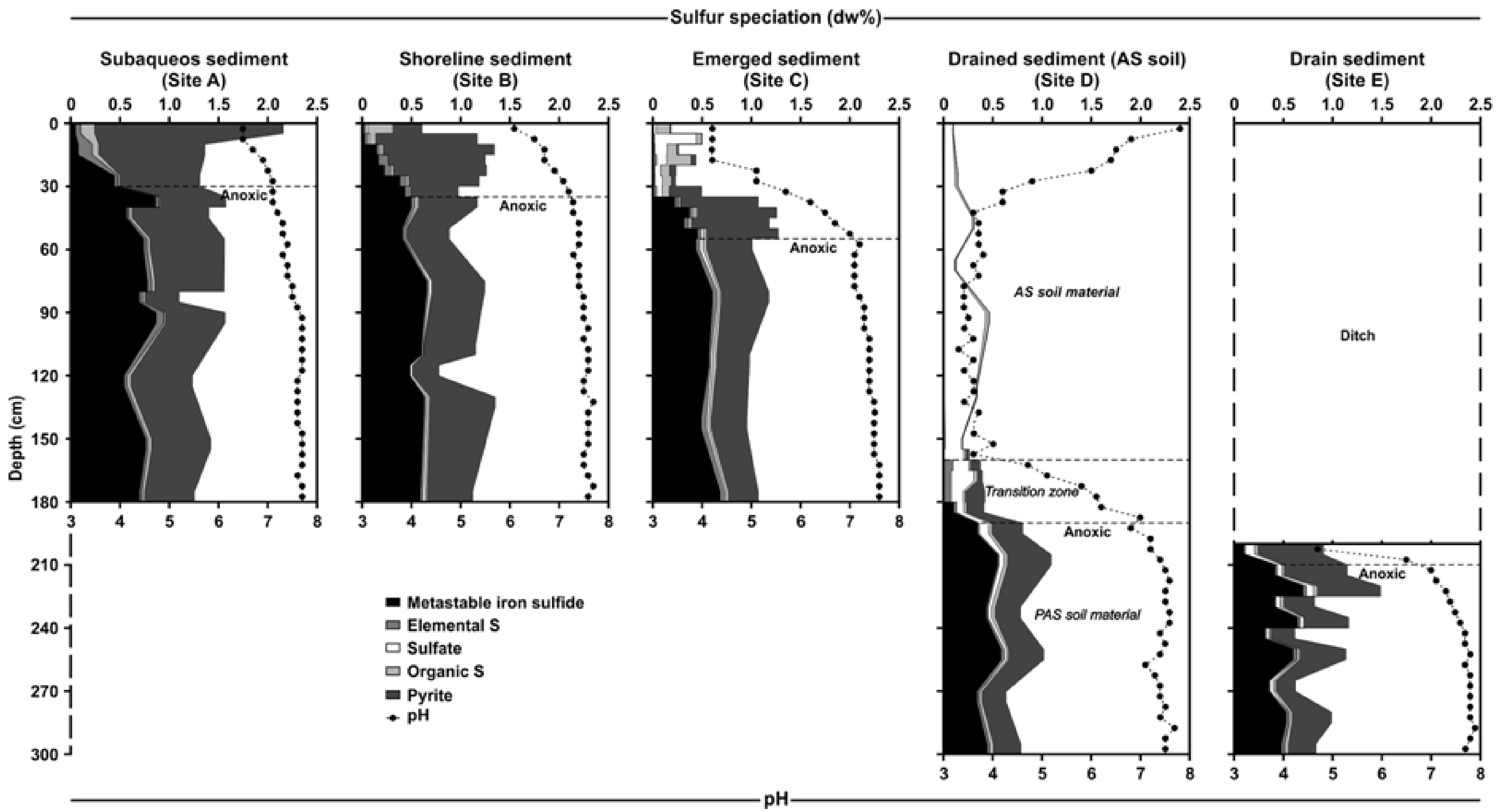

Figure 3. pH and sulfur speciation at Vassor. See map in Fig. 1 for location of the profiles. The figure is slightly redrawn from Boman et al. (2010).

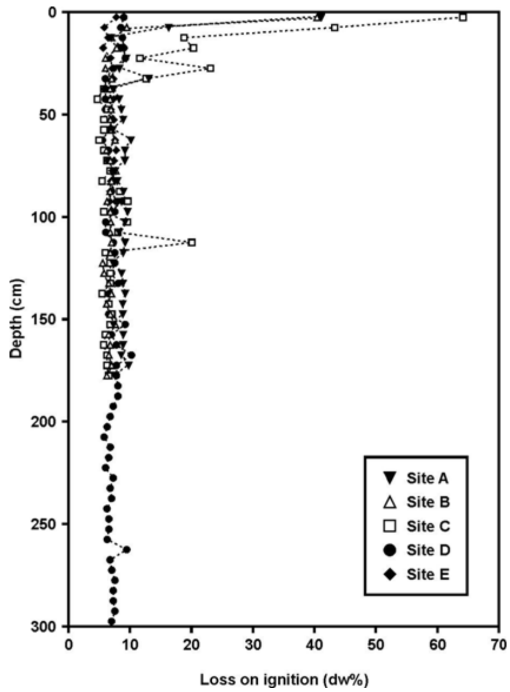

Figure 4. Organic matter (LOI) at Vassor: Site A = subaqueous sediment, B = shoreline sediment), C = emerged peat covered sediment, D = AS soil, and E = drain bottom sediment (adjacent to D). See map in Fig. 1 for locations of the profiles. Figure from Boman et al. (2010).

Table 1. Selected parameters (median values) for subaqueous sediments, peat covered sediments, and AS soils at Vassor. Data from Boman et al. (2010).

	Subaqueous sediment		Peat covered sediment		Drained sediment (AS soil)		
Parameter	Oxic	Anoxic	Oxic	Anoxic	Oxic	Trans. zone	Anoxic
FeS (%)	0.08	0.70	<0.01	0.57	<0.01	<0.01	0.44
FeS_2 (%)	1.08	0.71	0.07	0.36	<0.01	0.13	0.30
S(0) (%)	0.05	0.03	0.03	0.04	<0.01	0.08	0.02
SO_4^{2-} (%)	<0.01	<0.01	0.05	0.02	0.19	0.14	0.03
OrgS (%)	0.06	0.03	0.08	0.03	0.01	0.03	0.04
TotS (%)	1.37	1.41	0.50	1.01	0.23	0.40	0.80
pH	6.80	7.60	5.10	7.40	3.60	5.80	7.45
LOI (%)	8.86	8.64	12.5	6.40	7.01	7.70	6.71
As (ppm)	9.35	9.30	5.60	8.50	8.40	7.80	8.00
Cd (ppm)	0.25	0.20	0.20	0.10	0.10	0.20	0.30
Co (ppm)	23.1	16.0	9.20	16.4	9.40	13.1	15.8
Fe (%)	4.15	4.56	3.84	4.25	3.92	4.58	4.04
Mo (ppm)	1.60	1.40	1.10	1.20	1.40	1.00	1.05
Ni (ppm)	37.9	31.2	29.3	32.6	21.9	29.5	32.9
Zn (ppm)	128	105	72	101	80	92	99

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10. The soil profile at Ylistaro

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Description of the pedon

The Ylistaro pedon (Fig. 1) (62°55'N, 22°29'E) is in the field belonging to MTT Agrifood Research Finland. The pedon is located on a flat coastal plain with an elevation of 26 m asl and has a relatively long agricultural history of about 100 years. The field is artificially drained with subsurface pipes installed to the depth of 1.0 – 1.2 m. Small grains (oats, barley), grasses and potato are usually grown in the field.

The pedon is characterized by plenty of jarosite at 50-150 cm occurring on aggregate surfaces and in pipestems. On aggregate surfaces at 50-100 cm jarosite is covered by brown iron hydroxide but at 100-150 cm the prism faces are covered with continuous jarosite coating. Sulfidic materials were found at about 180 cm.

The pedon represents a typical cultivated acid sulfate soil which exhibits rather deep oxidation and sulfidic materials occurring only at the depth of 200 cm. Even though the sulfidic materials occur much below the drainage pipes, the drainage waters are acidic and much beyond the desired water quality (Joukainen and Yli-Halla, 2003).

Figure. 1. The Ylistaro soil

Table 1. Morphology of the Ylistaro pedon. Description by Markku Yli-Halla and Delbert Mokma 3 June 1997 (modified from Yli-Halla, 1997).

Horizon and depth	Morphological description
Ap, 0-30 cm	Very dark brown (7.5YR 2.5/2, moist), light brownish gray (10YR 6/2, dry) silt loam; moderate medium subangular blocky structure. Many roots. Abrupt smooth boundary.
Bg, 30-52 cm	Gray (5Y 5/1) silt loam, common coarse prominent brown (7.5YR 4/4) mottles on aggregates and coatings lining previous root channels; moderate medium prismatic parting to moderate medium angular blocky structure. Few roots. Abrupt smooth boundary
Bgj1, 52-70 cm	Gray (5Y 5/1) silt loam, many coarse prominent dark brown (7.5YR ¾) mottles on aggregates and lining previous root channels; common coarse prominent yellow (2.5Y 8/4) jarosite mottles between the brown surface and gray matrix of the prisms. Moderate medium prismatic parting to strong medium angular blocky structure. Few roots. Clear smooth boundary.
Bgj2, 70-100 cm	Gray (5Y 5/1) silt loam, aggregate faces and old root channels continuously coated with dark brown (7.5YR ¾) and dark reddish brown (5YR 3/3) iron hydroxide; many coarse prominent yellow (2.5Y 8/4) jarosite mottles between the brown surface and gray matrix of the prisms. Moderate coarse prismatic parting to strong coarse angular blocky structure. Few roots. Clear smooth boundary.
Bgj3, 100-150 cm	Gray (5Y 5/1) silt loam, aggregate faces and old root channels nearly continuously coated with dark brown (7.5YR ¾) iron hydroxide; many coarse prominent yellow (2.5Y 8/4) jarosite mottles between the brown surface and gray matrix of the prisms (100-125 cm) or without the brown coating (125-150 cm). Moderate very coarse prismatic parting to strong coarse angular blocky structure. No roots. Clear smooth boundary.
Cg 215-235 cm	Bluish black (10B 2.5/1) silt loam. Massive.

Table 2. Chemical characteristics of the Ylistaro pedon

Horizon, depth (cm)	C, %	$pH(H_2O)$ 1:1	Clay, %	Fine silt, %	Coarse silt, %	Sand %	CEC, pH 7 cmol/kg	BS %	Total N, %	Total S, %	SO_4-S[1] mg/kg
Ap, 0-30	4.6	4.3	24	38	26	12	20.5	9	0.40	0.17	29
Bg, 30-52	1.1	3.9	28	38	26	9	12.3	13	0.19	0.19	42
Bgj1, 52-70	1.0	3.8	27	34	33	7	9.5	13	0.18	0.17	60
Bgj2, 70-100	1.0	3.5	26	37	30	7	11.1	17	0.18	0.21	112
Bgj3A, 100-125	1.2	3.4	28	37	27	8	12.1	16	0.22	0.22	156
Bgj3B, 125-150	1.3	3.4	26	36	29	9	13.2	29	0.24	0.31	480
Cg 215-235										0.70	

[1] extraction with 0.01 M CaCl2 after 6 weeks of aerobic incubation.

Classification

The soil has an **ochric epipedon** and a **cambic horizon** and the colour pattern is **gleyic**, starting at the bottom of the plough layer. Starting at 70 cm, the soil has a pH value of 3.5 or less and colours indicating the presence of jarosite, and, at 125-150 cm, more than 0.05 percent water-soluble sulfate. The soil thus meets the criteria of the **sulfuric horizon** (Soil Taxonomy) or **thionic** horizon (WRB). The soil contains **sulfidic materials**, but the starting depth is unclear.

According to Soil Taxonomy (2010 version), the soil is a **Sulfic Cryaquept.**

According to the WRB system (2007 version), the soil is a **Thionic Endogleyic Cambisol (Ferric, Alumic ?, Dystric)**. Attributable to deep ploughing, the gleyic colour pattern starts only at 30 cm, not within 25 cm of soil surface, as required for Gleysols. If this criterion is waived, the soil is a **Haplic Gleysol (Thionic, Alumic ?, Dystric)**.

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11. Rintala embakment area

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The Rintala embankment area (23 km^2) near Seinäjoki is c. 40 m above the current sea level, i.e. considering the land uplift, the sediments in the area were deposited in the Litorina Sea more than 4000 years ago. About 70% (17 km^2) of the area consists of acid sulfate (AS) soils (pH < 4; Fig. 1) that have developed on parent sediments with S concentrations between 0.2% and 1.1% (Österholm and Åström 2002). Monosulfides are common in the area. The oxidation depth is near 1.8 m throughout the area and the clay content is 25–35% (hydrometer analysis; data from Österholm and Åström 2002). Almost all of the ASS in Rintala are Sulfic Cryaquepts in Soil Taxonomy and, as elsewhere in Finland, only a small minority (~5%) of the ASS are Typic Sulfaquepts. The remaining area consists of moderately acidic soils (pH 5–6.5) with either low S-concentrations (< 0.1%) or very high concentrations of organic matter (C > 4%; Fig. 1).

On the basis of long term monitoring, the current flux of sulfur from these soils is extremely high (c. 600 kg/ha.year) as compared to the sulfur pool in the soil (currently c. 20 t S/ha and originally c. 50 t S/ha). Therefore, it is clear that the leaching is in practice completely anthropogenic. Otherwise, the sulfur pool would have been depleted a very long time ago (Österholm and Åström 2004). Thus, the development of active ASS and the subsequent discharge of acid- and metal rich waters from Rintala did not start until the early 19th century (and even then only on a relatively small scale) when Sotaoja stream was dug through the central and southern parts of the area (Fig. 1) and the peat cover was burned. Thereafter a network of surface ditches have successively been dug denser and deeper throughout the area. To make the drainage efficient enough for modern agricultural activities, subsurface drainage was introduced in the1950s and became the main drainage type in the 1970s. Since 1982, most of the water in Seinäjoki stream has been redirected into an artificial channel.

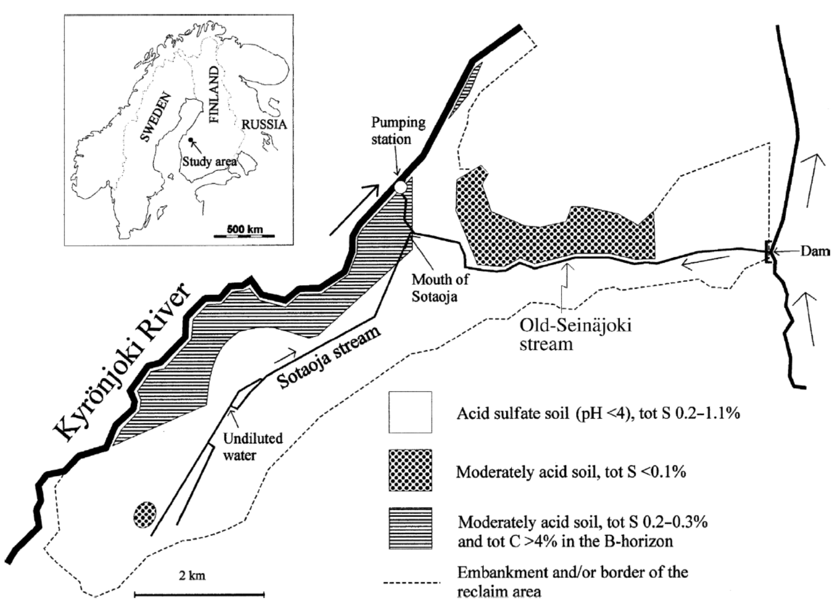

Figure. 1. Rintala plain near Seinäjoki in western Finland.

In order to even more efficiently control the hydrology of the Rintala plain, in the early 1980s embankments were raised along the Kyrönjoki river to prevent flooding and a pumping station was built at the old-Seinäjoki outlet (Fig. 1) to maintain stable water levels. This pumping station is one of the biggest of its kind in Finland. Another pumping station was built in the northernmost part of the area but its capacity is only a few percents of the former. The Finnish Environment Institute applied for the environmental permit for building of the embankments and pumping stations and the water-rights court granted it in 1984. The water-rights court, however, considered that these procedures could increase the metal- and acid load on Kyrönjoki river. In connection with the renewal of the environmental permit in 1992, the Finnish Environment Institute was obliged to improve the quality of the drainage water either by preventing the oxidation of the soils or by treating the water before letting it into Kyrönjoki river. The Finnish Environment Institute which regarded this obligation (among others) as unreasonable, appealed against the decision to the water-rights court of appeal in 1994. The appeal did not result in any changes regarding the obligation to improve the water quality. Rintala was the first ASS area in Finland to be put under such an obligation. However, it is notable that this obligation, focusing on the pumping and embankments, did not address the main cause of the poor water quality, i.e. previous and current drainage works in the area (Österholm et al 2005).

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