

**P-06-321**

## **Oskarshamn site investigation**

### **Extended soil chemistry in three site types**

Lars Lundin, Elve Lode, Johan Stendahl  
SLU, Department of Forest Soils

December 2006

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*Keywords:* Aqua regia, Base cation, Dithionite citrate extraction, Metal, Mineral soil, Peat, Regolith, soil, Soil chemistry, AP PS 400-05-030.

This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the authors and do not necessarily coincide with those of the client.

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# Abstract

The Swedish Nuclear Fuel and Waste Management Ltd (SKB AB) carries out site investigations to give prerequisite information for long-term storage of nuclear waste. Ecosystem functions are crucial in this management. The range of the scope is wide including bedrock, regolith, hydrosphere and biosphere. The interface between deep geological formations and surface systems is then considered most important. This interface would be the top of the regolith, where soils have developed. Special attention has been paid these layers. The Department of Forest Soils, Swedish University of Agricultural Sciences, carried out Field investigations for the Oskarshamn candidate area in 2003. In this area, the investigation instead focused on thorough determination in relevant selected soil types.

Based on a first surveillance, ten soil types were selected and surveyed in two replicates. In this report extended chemical results are presented from three of the locations, i.e. these were forested sites with oak, spruce and alder. Soils on the three sites were sandy till and two on peat, respectively. Vegetation conditions were fairly well characterized by soil moisture conditions with low sedges over fairly rich wet mosses on the alder wetland, grass and low herbs over fresh mosses on the oak site and with also blueberry on the spruce site.

Soil chemical conditions were to a large extent reflected in the pH value, which furnished patterns rather similar to the region and mainly also to Sweden as a whole. In the O-horizon  $pH_{H_2O}$  was on average 4.3 and in the mineral soil layers close to 5.2 all through the soil profile. Under oak the pH was 5.3 in the top layers and 4.9 in the layer below. For the spruce site pH was 3.9 in the top 30 cm and 4.7 below. In the alder forest the top soil showed a pH of 5.3 in the top 30 cm and 4.6 below.

Carbon contents in the O- and C-horizon of the total Oskarshamn area were somewhat higher as compared to all Sweden, with values on 39% and 1.2%, respectively. In the upper mineral soil horizons the contents were considerably higher with values on c. 10%. Partly, this could be explained by a low frequency of Podzol soils and thereby rather few bleached horizons. Nitrogen content are often related to carbon and therefore higher values were found compared to total Sweden but in the C-horizon, the 0.12% was similar to Sweden region IV. In the oak site carbon concentration was 11.8% in the top soil and 0.5 in the C-horizon while the peat soils showed values on c. 50% in the top soil but only c. 18% in the deeper layer.

For the three sites investigated rather different conditions appeared with the “oak” being a mineral soil and the other two organic soils. The “oak” site was fairly nutrient rich compared to the overall picture for the Oskarshamn area with fairly high nitrogen and base cation contents. The two organic soils differed considerably and the “alder” site was comparably more nutrient rich in relation to the “spruce” site.

# Sammanfattning

Svensk Kärnbränslehantering (SKB AB) undersöker platsförhållanden i Oskarshamnsområdet. Undersökningar genomförs för att klargöra förutsättningar och fastställa förhållanden inför långtidslagring av utbränt kärnbränsle. Dessa platsundersökningar har stor omfattning, alltifrån det djupa berget upp till de lösa avlagringarna ovan berg samt vatten- och biosfärssystemen. Känsliga delar i hela systemet är övergången från geosfär till biosfär, där de övre marklagren och jordmånsskiktet är avgörande för de ytliga ekosystemen.

Fältundersökningar av Oskarshamnsområdets jordar genomfördes 2003 av Institutionen för skoglig marklära, SLU. Markprover för laboratorieanalyser togs från 20 ståndorter och från dessa har tre valts för utökade kemiska analyser. Dessa tre lokaler återfinns på sandig morän och två på torvmark. Lokalerna domineras i trädsiktet av ek, al och gran och har valts att benämnas med detta i rapporten.

Markkemin speglas delvis av pH värdet, som uppvisar likheter med förhållanden för regionen och även övriga Sverige med pH i O-horisonten på 4,3 och i mineraljorden ca 5,2 från de övre lagren ner i C-horisonten. På eklokalen var pH 5,3 i de ytligaste lagren medan skikten därunder hade pH av 4,9. För granlokalen var motsvarande värden 3,9 respektive 4,7 medan allokalen hade 5,3 respektive 4,6.

Innehållet av kol visar något högre värden än Sverige i övrigt vad avser O- och C-horisonterna med 39 % respektive 1,2 % medan de övre mineraljordshorisonterna har klart högre halter med ca 10 % än vad som vanligen präglar skogsmineraljordar i Sverige. Kväveinnehållet påverkas delvis av kolinnehållet och därmed är halterna något högre än för Sverige i övrigt, särskilt i de övre mineraljordshorisonterna medan värdena i C-horisonten är likartade övriga Sverige. På eklokalen var kolinnehållet 11,8 % i de ytliga skikten och 0,5 % i C-horisonten medan torvmarkerna hade 50 % kolhalt i ytlagren och ca 18 % i djupare lager.

De tre undersökta ståndorterna skiljde sig markant från varandra. ”Ek”-ytan var på mineraljord med brunjordsliknande jordmån och tillhörde de mer näringsrika ståndorter som finns i hela Oskarshamnsområdet. Kväve och baskatjoninnehållen var tämligen stora. De två organiska jordarna uppvisade skillnader och ”al”-ytan var näringsrikare än ”gran”-ytan.

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# 1 Introduction

This document reports the results gained by extended analysis of samples from investigations on soil and site types at three sites in the Oskarshamn area, which are one of the activities performed within the site investigation at Oskarshamn. The work was carried out in accordance with activity plan AP PS 400 05 030. In Table 1-1 controlling documents for performing this activity are listed and is SKB's internal controlling documents. All data from the investigation have been stored in the database SICADA.

This special investigation is part of the large scale project under the auspice of the Swedish Nuclear and Waste Management Company (SKB) to find prerequisites and conditions for long-term storage of nuclear wastes. The soil conditions of the regolith are of great significance in the transfer of water and elements from the bedrock to the surface ecosystems. Information on the spatial variations with horizontal distances as well as with soil depth contributes in clarification of pathways and transfer in the regolith. The interface between deep bedrock and surface systems, i.e. the soils are given special attention.

In 2003, soil and site types were inventoried in the Oskarshamn candidate area /Lundin et al. 2005/. In the area 20 plots were investigated and soil samples taken. Basic analysis and site conditions were reported in 2005. However, in connection with trench investigations in 2005 /Sohlenius et al. 2006/ extended chemical analysis were carried out. Together with the trench soil samples, three of the site pits from 2003 were included for extended chemical analysis and was carried out by the Department of Forest Soils, Swedish University of Agricultural sciences. The results from the three site pits are reported in this document.

**Table 1-1. Controlling documents for the performance of the activity.**

<b>Activity plan</b>	<b>Number</b>	<b>Version</b>
Analys av ämnesfraktioner och lermineralogi i jord.	AP PS 400-05-030	1.0

## **2 Objective and scope**

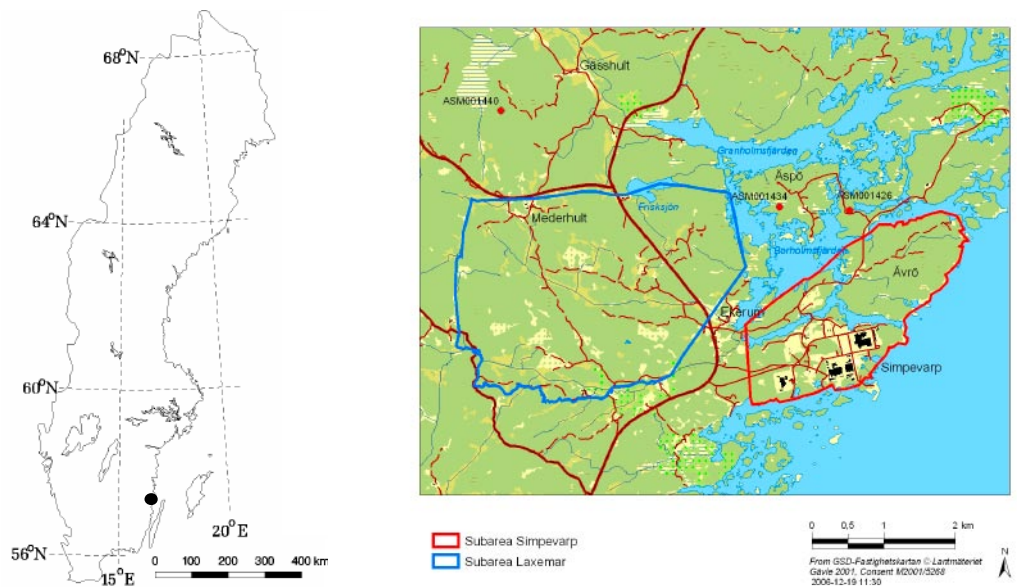
The purpose of this investigation was to extend the information on soil chemical conditions, at three sites, by further analyses compared to the ones made in 2004 /Lundin et al. 2005/.

### 3 Investigation area

The Oskarshamn area is located on the west Baltic Sea coastline in the south-east part of Sweden. The area is c. 20 km<sup>2</sup> and located approx. N 57°25' and E 16°33', west of the Oskarshamn nuclear fuel plant (Figure 3-1). The altitudes of the area range from coastal sea level up to c. 53 m about sea level but with most of the area below 20 m. The main and cover is forest on different soil types, together with partly open land on wet soils and bedrock outcrops. The landscape type has a lowland broken topography of small hills of till and bedrock with small, mainly wet soil valleys in-between. There, the land types are forest, pasture and arable.

The climate of the region is characterised by a snow covered winter period during three months and the vegetation period extends over 195 days, mainly April to October. Hydrology is characterised by fairly dry summers, autumn rains with increasing runoff as well as with snowmelt periods during winter. Annual precipitation amounts to c. 600 mm, evapotranspiration reaches over 400 mm resulting in a runoff of less than 200 mm. The mean annual temperature is c. +6.5°C /Raab and Vedin 1995/.

The soils of the Oskarshamn area are fairly young. The mineral soil material is of till origin, which has been influenced by the sea during the transgressions of the Baltic Sea. By these, redistribution of soil material occurred and left coarse water washed tills in higher locations, also with thin soils and bare bedrock. Elsewhere, in depressions the redistributed fine material has been deposited as sorted sediment soils. During the overall transgression, sea bays have been cut off and now form wet soils and peatlands.



**Figure 3-1.** Geographical location of the Oskarshamn investigation area and the three soil site types (ASM001426, ASM001434, and ASM001440) from where samples were taken marked with red dots.



## 4 Execution

### 4.1 Background

The investigations on site and soil conditions are linked, by mainly using similar methods, to the Swedish Forest Soil Inventory /RIS-MI 2003/. Conditions and properties of the Oskarshamn area were classified from the plots investigated with the intention to compare with other parts of Sweden /Lundin et al. 2005/. Site determinations included in the investigations embraced vegetation, humus layer, stoniness, root depth, soil profile development, sampling for soil physical and chemical conditions /Lundin et al. 2005/. Soil here refers to the upper part of the regolith, which is characterised by horizons with certain physical and chemical properties (Figure 4-1).

### 4.2 Samples

From all the site pits investigated /Lundin et al. 2005/, three locations were selected for the extended analysis, i.e. the Unbrisol/Regosol type (ASM001426, pit 1:13), the forested Histosol (wetland forest type; ASM001434, pit 1:14) and the drained forested Histosol (forested peat soil; ASM001440, pit 1:13). One sample from each horizon and pit were analysed and the study comprised in total seven samples. On each plot, being 15×15 m, a 5×5 m grid was established and used to select the exact soil profile locations. One of these grid points were used for the extended analysis. The three sites included in this extended chemical report constituted one mineral soil with three sampling depths but no organic top layer and two peat soils with two sampling depths each.

#### Rock, Regolith and Soil Sampling

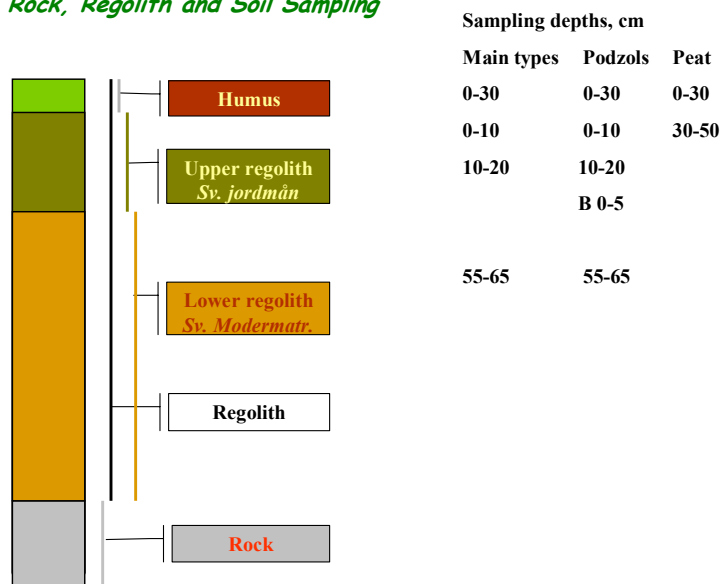


Figure 4-1. The regolith over the bedrock with soil sampling depths in three categories of soils.

### **4.3 Analyses and interpretations**

Chemical analysis were made according to SIS standards. A special analysis was carried out with dithionite-citrate extraction giving the amorphous and crystalline bound elements /Mehra and Jackson 1960/.

Chemical analysis included pH, C, N, exchangeable Na, Ca, Mg and K in 1 M NH<sub>4</sub>Ac at pH 7, titratable acidity, extractable K and P in ammonia-acetate (AL) and 2M hydrochloric acid (HCl). Further, also *Aqua Regia* extractions were made with determinations of Fe, Al, Mn, Na, K, Ca, Mg and Zn. *Aqua Regia* extraction does not give total values but should extract more than NH<sub>4</sub>Ac. Three profiles were analyzed. Analysis was performed during autumn and winter 2005/2006.

For more information of the extraction procedures, see Appendix 1.

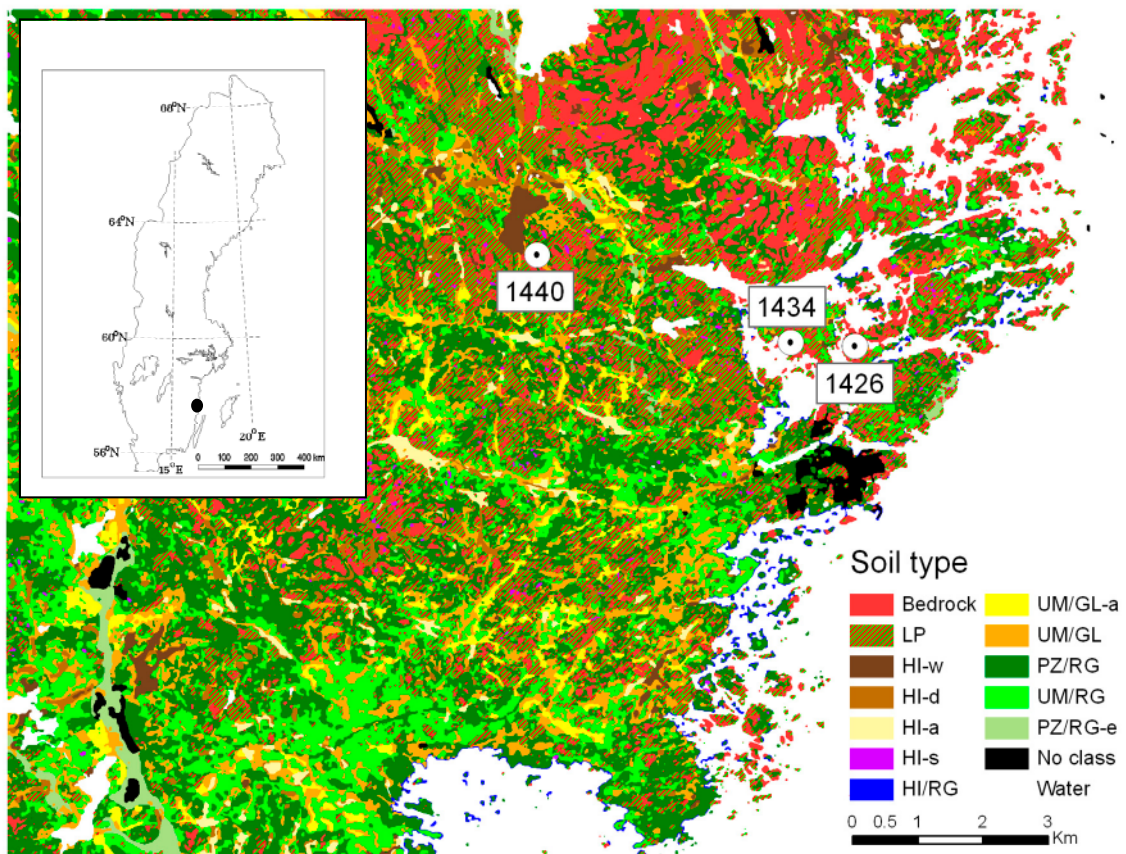
### **4.4 Nonconformities**

No nonconformities.

## 5 Results

### 5.1 Conditions at selected sites

The soil refers to the upper part of the regolith, which in total rests on the underlying solid bedrock. The soil is the result of many interacting processes that are commonly summarized in the soil forming properties, being climate, parent material, topography, biota and time. Although these properties interact in a complex way, the soil type in a location is often influenced more strongly by one or a few of these properties. The soil is characterised by soil chemical and physical properties different from the material of the regolith underneath. Based on the fundamental theory of soil formation, the Oskarshamn area was classified into different soil types from secondary geographical information describing different properties as basis of soil formation. The distribution of the derived soils formed a soil map for the Oskarshamn area (Figure 5-1) /Lundin et al. 2005/.



**Figure 5-1.** Sweden and location of the SKB Oskarshamn area and the soil types within the area with location of the three selected sites for extended chemical analysis included.

Three site types were selected for extended chemical analysis and these were ASM001426, ASM001434 and ASM001440. One was located on mineral soil (ASM001426) and the other two on peat soils. The site conditions are described for the three sites “Oak forest”, the “Alder forest” and the “Spruce forest”.

#### **ASM001426, “Löv 1:13”, Oak forest**

##### **UM/RG “Löv” – Forested relatively nutrient rich site types – “ASM001426”**

Sites are located on the hillside slopes. Deciduous trees such as oak, birch and mountain maple mainly dominated the tree layer. Ground vegetation was composed of fresh mosses, grass and low herbs on well-drained soils of fresh soil moisture type. Fairly coarse till soils of sandy and sandy-silty texture occurred with one site being fine grained (silty sandy). The developed soil types varied between Regosols and Umbrisols with a dominating mull humus form and probably in a long-range time perspective turning more frequently into better developed Umbrisols.

#### **ASM001434, “Sump 1:14”, Alder forest**

##### **HI-f “Sump” – Wetland forest type – “ASM001434”**

Forested sites with rather rich peat soils covered by more rich mosses compared to *Sphagnum* spp. and field layers of broad leaved grasses. The humus form is peat and the soil type Histosol. The mineral soil under the peat varied from clay and sand to peat on bedrock and the humification degree was moderately well decomposed in the upper layer and strongly decomposed in the deeper one. This field inventory class was merged with the previously presented “peat soils in downslope locations” (HI-f “Gran”).

#### **ASM001440, “Gran 1:13”, Spruce forest**

##### **HI-f “Gran” – Forested (f) peat soils in downslope locations – “ASM 001440”**

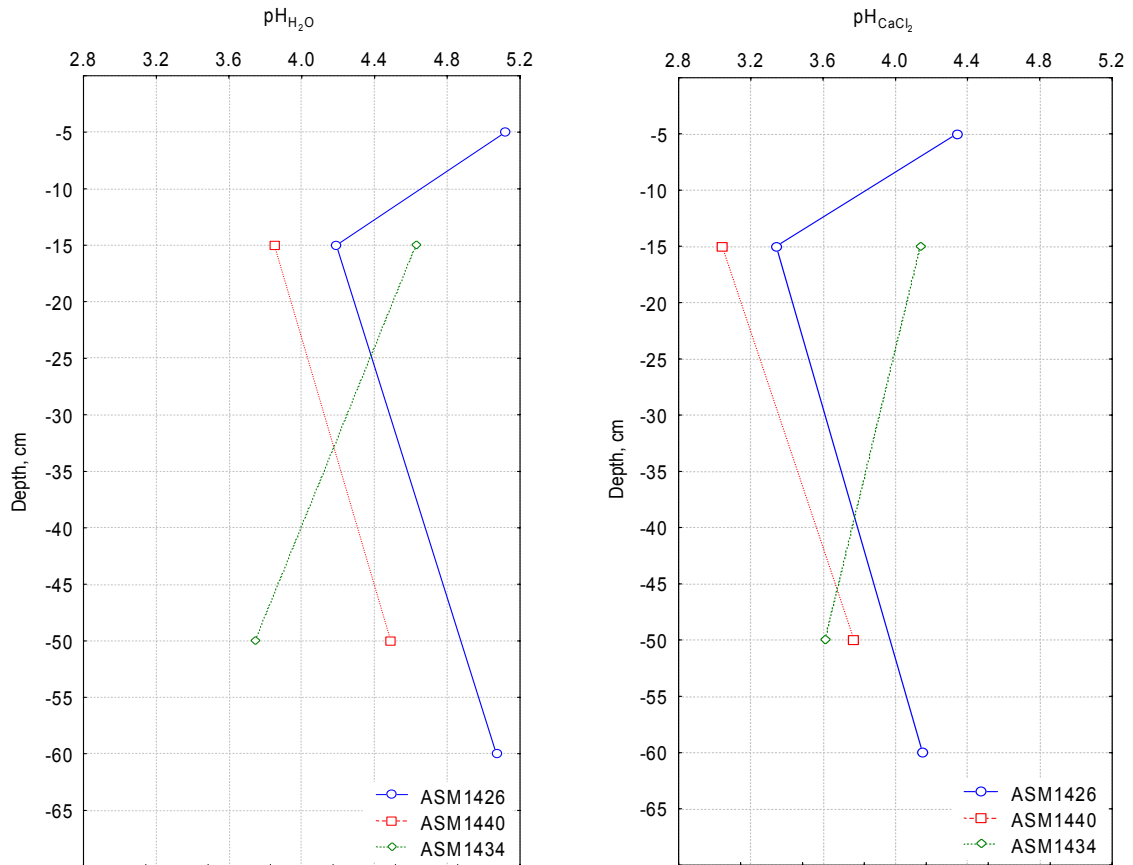
These are drained peatlands with spruce on fresh and fresh moist soils. During periods of more wet conditions the soils most likely turns into imperfectly drained sites with high groundwater levels. The combination of ditches and forest evapotranspiration, provides a field vegetation type of blueberry and low herbs. Partly, these spruce forests could provide high yields. The drainage furnishes fresh mosses in the bottom layer. However, there is still more than 0.4 m organic layer resulting in a Histosol soil. In this case the humus form is peat and sampling made of the two pre-set peat layers. The humification degree was dominated by strongly decomposed peat in both layers. Under the peat there are mainly coarse mineral soils such as stones and boulders, perhaps occasionally also the bedrock surface. This field inventory class was merged with the following forest wetland type (HI-f “Sump”).

## **5.2 Soil chemical conditions at three selected sites**

The results below concerning *soil pH* and *soil carbon and nitrogen*, are presented earlier /Lundin et al. 2005/, but are included in this report in order to keep relevant information together.

## Soil pH

In the upper mineral soil (0–10 cm), the pH in water on the 11 sites investigated in 2003 was on average 5.2 and almost the same in both the ten cm layer below and the deeper horizon at 0.6 m depth /Lundin et al. 2005/. In all three selected sites  $\text{pH}_{\text{H}_2\text{O}}$  was lower with a variation in the top soil from 3.8 to 5.1 but a deviating stratification with depth. Compared to Swedish conditions, pH was mainly higher in the three pits. Under the alder forest pH decreased with depth while the other two sites showed low values in 10–20 cm depth but increasing with depth. For  $\text{pH}_{\text{CaCl}_2}$ , the stratification patterns were the same but pH on average 0.6 pH units lower (Figure 5-2 and Table 5-1).



**Figure 5-2.** The three site ASM001426 (Oak), ASM001434 (Alder), and ASM001440 (Spruce) pH values stratification with depth.

**Table 5-1. Chemical conditions for the three pits (ASM001426, ASM001434, ASM001440) with extended chemical analysis.**

Variable	Unit	Profiles						
		ASM1426 (Oak)			ASM1434 (Alder)		ASM1440 (Spruce)	
Sampling depth	cm	0–10	10–20	55–65	0–30	40–60	0–30	40–60
Horizon		A	A/AB	B/C	Peat	Peat	Peat	Peat
C <sub>tot</sub>	%	22.3	10.7	0.5	22.7	15.4	46.0	16.7
N <sub>tot</sub>	%	1.25	0.59	0.05	1.82	1.76	2.06	1.04
pH <sub>H2O</sub>		5.12	4.19	5.07	4.63	3.74	3.85	4.49
pH <sub>CaCl2</sub>		4.34	3.34	4.15	4.14	3.61	3.04	3.77
K <sub>Aqua Regia</sub>	g/kg	0.44	0.47	0.33	0.88	1.17	0.12	0.24
K <sub>NH4Ac</sub>	g/kg	0.43	0.13	0.02	0.44	0.88	0.17	0.02
K <sub>Al</sub>	g/kg	0.39	0.14	0.04	0.40	0.79	0.15	0.04
K <sub>HCl</sub>	g/kg	0.48	0.36	0.35	0.85	1.24	0.16	0.09
P <sub>Al</sub>	g/kg	0.10	0.03	0.01	0.03	0.04	0.05	0.03
P <sub>HCl</sub>	g/kg	0.43	0.13	0.47	0.38	0.36	0.76	0.05
Fe <sub>Dit.citr.</sub>	g/kg	4.22	6.93	5.00	19.86	12.17	3.76	2.19
Fe <sub>Aqua Regia</sub>	g/kg	4.67	7.57	9.57	12.53	10.19	2.74	1.96
Al <sub>Dit.citr.</sub>	g/kg	0.66	1.32	0.40	4.80	2.89	4.57	7.67
Al <sub>Aqua Regia</sub>	g/kg	1.26	2.85	2.93	6.36	6.10	6.01	9.70
Zn	g/kg	0.03	0.02	0.02	0.03	0.05	0.01	0.01
Mn <sub>Dit.citr.</sub>	g/kg	0.269	0.017	0.006	0.013	0.020	0.020	0.003
Mn <sub>Aqua Regia</sub>	g/kg	0.234	0.068	0.095	0.032	0.048	0.016	0.006
Mn <sub>NH4Ac</sub>	g/kg	0.049	0.003	0.001	0.007	0.013	0.008	0.001
Ca <sub>Aqua Regia</sub>	g/kg	3.10	0.90	1.62	1.75	1.89	1.51	0.46
Ca <sub>NH4Ac</sub>	g/kg	3.03	0.31	0.09	1.62	1.90	1.15	0.40
Mg <sub>Aqua Regia</sub>	g/kg	1.03	1.96	2.12	1.97	2.04	0.30	0.23
Mg <sub>NH4Ac</sub>	g/kg	0.60	0.24	0.05	1.32	1.30	0.28	0.06
Na <sub>Aqua Regia</sub>	g/kg	0.14	0.04	0.04	3.77	4.84	0.12	0.10
Na <sub>NH4Ac</sub>	g/kg	0.03	0.03	0.01	2.82	3.06	0.13	0.06
AC <sub>tot</sub>	mmolc/100g	28.4	24.3	2.8	42.9	50.7	109.9	51.3
CEC <sub>tot</sub>	mmolc/100g	50.0	28.3	3.8	79.4	94.3	119.0	54.2

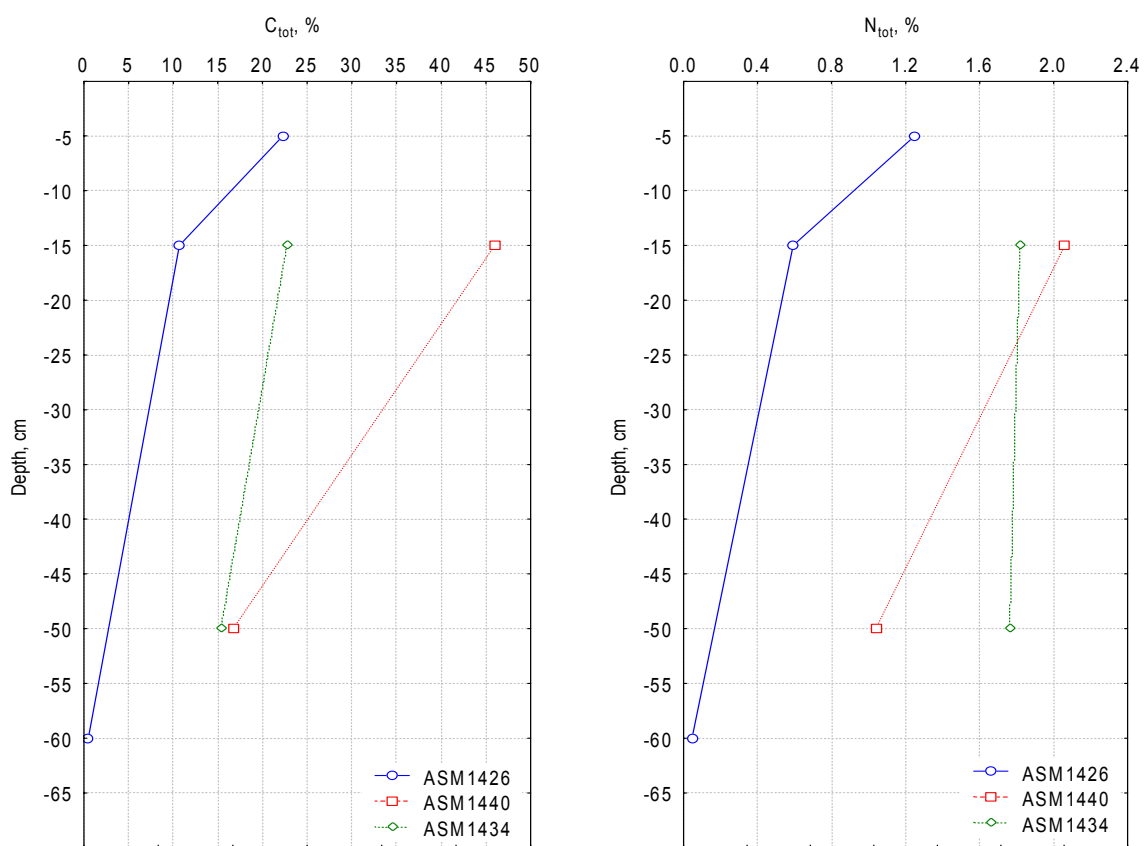
### Soil carbon and nitrogen

Storage of carbon in the soil depends to a large extent on the site adherent biota, i.e. vegetation and fauna. Organic matter is furnished by litter fall on top of the soil and roots and other organisms in the soil. There is also a part added by deposition. Most organic matter input is in the upper layers of the soil. Therefore, organic carbon, making up roughly 50% of the organic matter, displays stratification towards depth with higher contents in the upper layers and low in the deeper soil. In the Oskarshamn area, the average content is 39% in the organic layer, c. 10% in the upper mineral soil layers and only c. 1% in the deeper C-horizon (Figure 5-3 and Table 5-1). Most soils show this pattern but Histosol with peat, of course, has fairly high content all through the peat deposit /Lundin et al. 2005/.

Nitrogen concentrations in the Oskarshamn area showed a similar pattern as for carbon meaning decreasing values with depth (Figure 5-3 and Table 5-1). This was, of course, dependent on the dominating organic nitrogen fraction being stored in the soil. Nitrogen is one element in the organic substances, thereby coinciding fairly well with the organic matter and carbon storage. The overall relation to other parts of Sweden was similar, however, with low concentrations in the organic layer. Deviations occurred between the soil types with the common conditions of

high nitrogen content in organic soils, i.e. the Histosol. On average for the whole Oskarshamn area the nitrogen content was 1.7% in the organic layer, 0.6% in the top 10 cm, 0.5% in the 10 cm below and only 0.1% in 0.6 m depth /Lundin et al. 2005/.

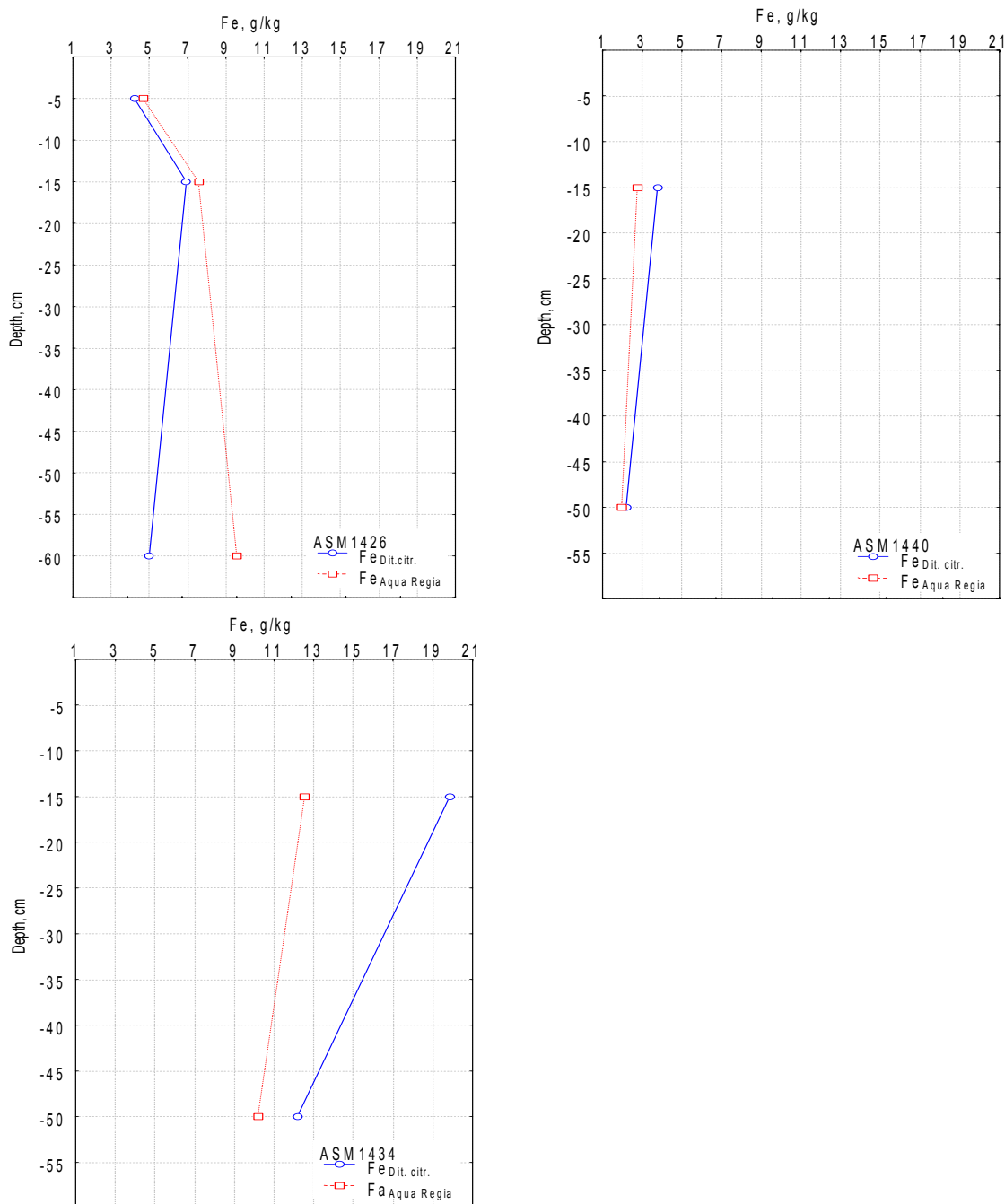
In the “oak” site both carbon and nitrogen levels were lower compared to the organic sites “alder” and “spruce”. CN-ratios in the upper layers were 18 for the mineral soil site and 12 and 22 for the “alder” and “spruce” peat soils, respectively. In the deeper horizon carbon and nitrogen were 8 in the “alder” site and 17 in the “spruce” site. This indicates a more nutrient rich soil under “alder” with fairly high nitrogen content while under “spruce” a high carbon content in the upper layer and fairly low nitrogen content in the deeper layer furnished higher CN values (Figure 5-3 and Table 5-1). Compared to the overall Swedish conditions the carbon concentration in the “oak” site was higher in the upper soil horizons but the peat soils furnished lower contents. For nitrogen, the “oak” site showed higher content in upper soil layers with the peat probably also in the upper range for Swedish organic soil conditions.



**Figure 5-3.** The three site ASM001426 (Oak), ASM001434 (Alder), and ASM001440 (Spruce) carbon (C) and nitrogen (N) content stratifications with depth.

## Soil iron, Fe

Iron content is related to the mineral soil but could be combined with organic matter in a large extent. In the three sites Fe contents were high in the soil under “alder” with oxide and crystalline Fe (dithionite citrate) values being 20 g/kg in the top soil and 12 in the deeper layer. Total analysis values of c. 30 g/kg would be typical for the region and Sweden /SoilInfo 2006/. The “Aqua regia” extractable Fe showed lower values with almost 13 g/kg in the upper layer and 10 g/kg in the deeper one. In the other two sites Fe contents were lower with values at 1–9 g/kg. In the peat under “spruce”, values mainly below 4 g/kg was observed while the “oak” mineral soil showed low contents in the upper soil layer but higher “Aqua regia” in the deeper layer (Figure 5-4 and Table 5-1).

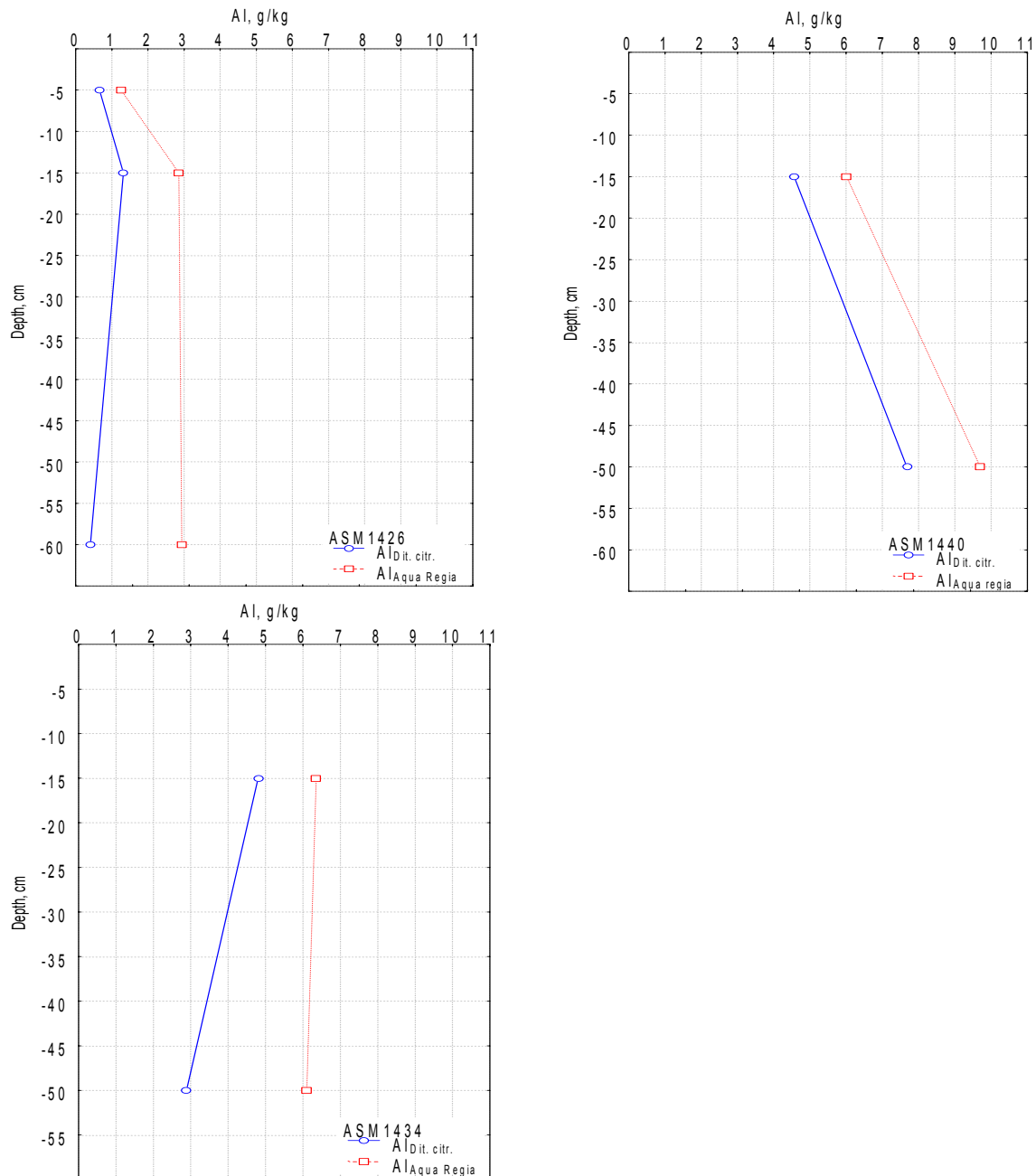


**Figure 5-4.** The three site ASM001426 (Oak), ASM001434 (Alder), and ASM001440 (Spruce) iron, Fe content stratifications with depth at the two extractions “Aqua regia” and dithionite citrate.



### Soil aluminium, Al

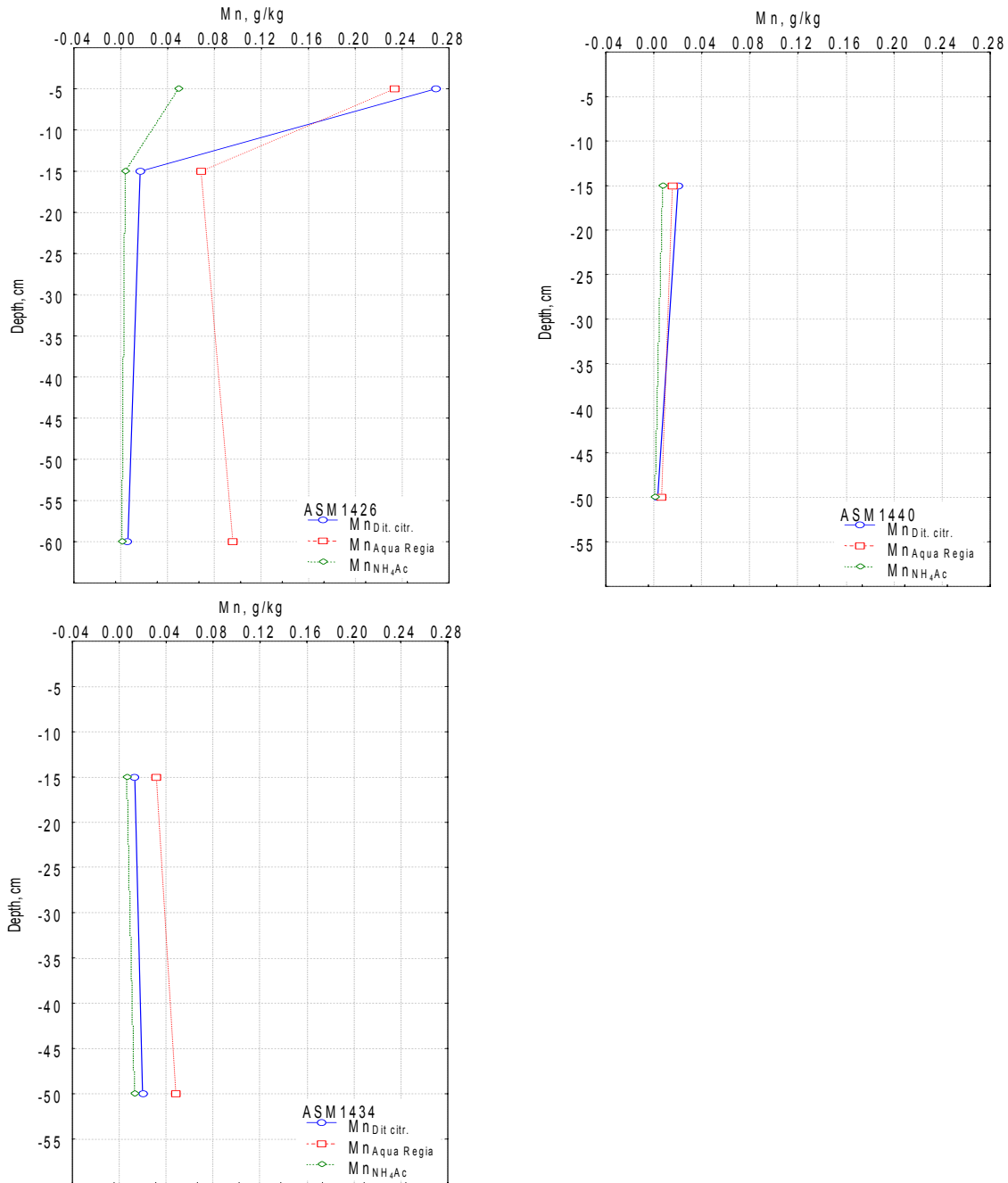
The Al content was lowest in the mineral soil under “oak” with “*Aqua regia*” values on 1–3 g/kg. In the peat sites, values were higher with 6–10 g/kg. The national Swedish inventory gives values for total content on c. 60 g/kg showing a large part of Al not extractable by the used extracts /SoilInfo 2006/. Dithionite citrate extractable values were lower with 3–8 g/kg, being c. 5 g/kg in the upper layer but increasing with depth in the “spruce” site but decreasing in the “alder” site (Figure 5-5 and Table 5-1). Compared to Swedish values extracted with KCl the c. 2.5 g/kg is lower compared to these extractions /SoilInfo 2006/.



**Figure 5-5.** The three site ASM001426 (Oak), ASM001434 (Alder), and ASM001440 (Spruce) aluminium, Al content stratifications with depth at the two extractions “Aqua regia” and \* dithionite citrate.

## Soil Manganese, Mn

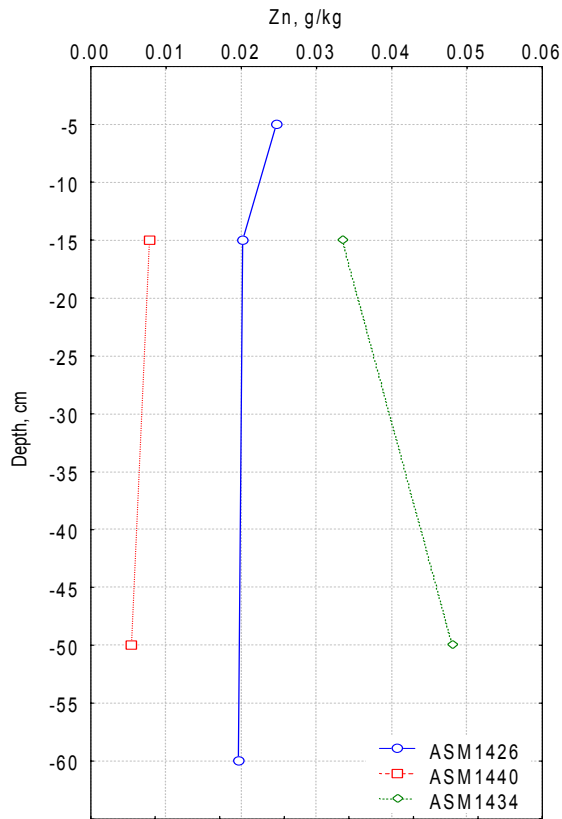
The manganese content was analysed with three extractions, “*Aqua regia*”, dithionite citrate and ammoniumacetate. Patterns were similar for the extractions with  $\text{NH}_4\text{Ac}$  being lowest and mainly “*Aqua regia*” highest, however with fairly small differences between the three extractions. In the mineral soil site, “oak”, the highest values on c. 0.25 g/kg was found in the top soil, with lower values in the 10 cm lower layer and in the deeper mineral soil, < 0.1 g/kg (Figure 5-6 and Table 5-1). In the peat soil values were lower and more similar for the different extractions and stratifications were small (Figure 5-6 and Table 5-1). In /SoilInfo 2006/ total values are given around 0.7 g/kg.



**Figure 5-6.** The three site ASM001426 (Oak), ASM001434 (Alder), and ASM001440 (Spruce) manganese, Mn content stratifications with depth at the three extractions “*Aqua regia*”, dithionite citrate and  $\text{NH}_4\text{Ac}$ .

### Soil Zinc, Zn

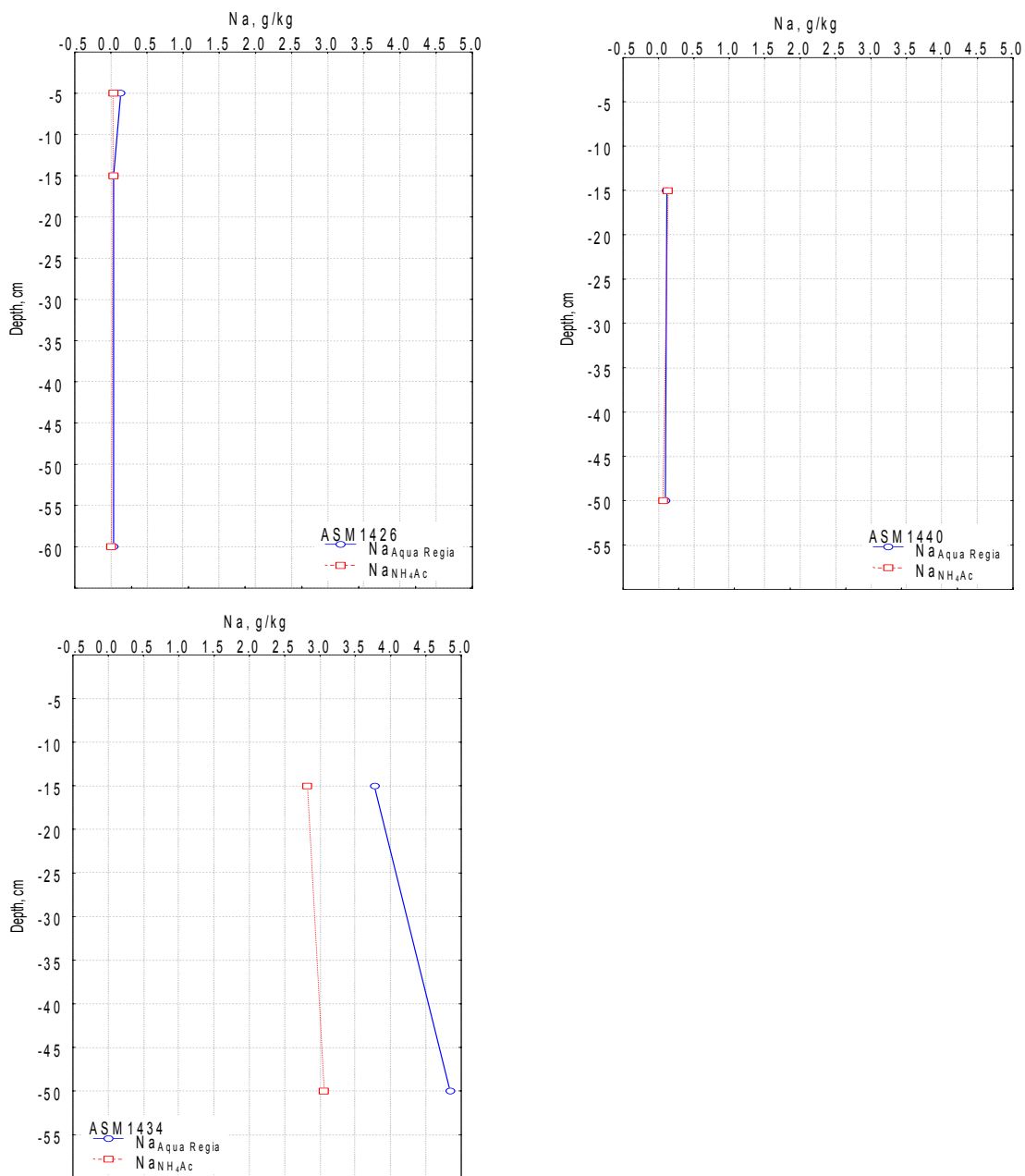
The zinc content was only analysed with “*Aqua regia*”. In the mineral soil, values decreased somewhat from the uppermost layer where the content was 0.05 g/kg. In the “alder” site higher values were found and increasing with depth to almost 0.05 g/kg while the values were low in the “spruce” site, i.e. < 0.01 g/kg (Figure 5-7 and Table 5-1). In Sweden total zinc values on 0.08 g/kg are average /SoilInfo 2006/.



**Figure 5-7.** The three site ASM001426 (Oak), ASM001434 (Alder), and ASM001440 (Spruce) zinc, Zn content extracted by “*Aqua regia*”, stratifications with depth.

### Soil sodium, Na

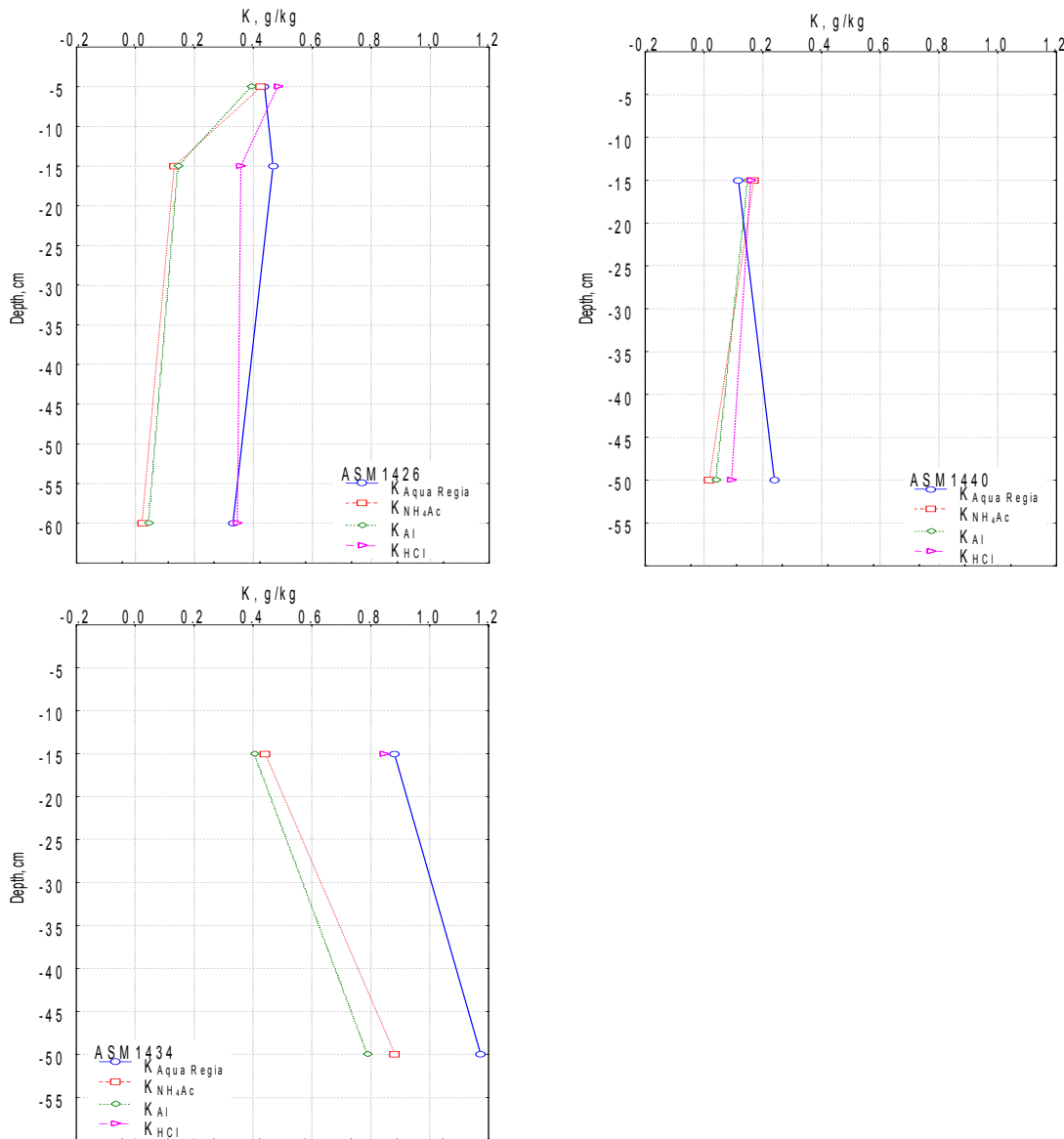
The sodium content was low in two sites, the “oak” and the “spruce” with values mainly below 0.1 g/kg and decreasing with depth. In the “alder” site values were higher being 3–4 g/kg in the upper layer and higher in the deeper one (Figure 5-8 and Table 5-1). Compared to total contents of c. 2 g/kg, two sites showed very low values but the “alder” site much higher, mainly dependent on the high organic content.  $\text{NH}_4\text{Ac}$  extractable contents of Na in Sweden are c. 0.3 g/kg in the B-horizon and compared to this the sampling sites mainly were on low levels /SoilInfo 2006/.



**Figure 5-8.** The three site ASM001426 (Oak), ASM001434 (Alder), and ASM001440 (Spruce) sodium, Na content stratifications with depth at the two extractions “Aqua regia” and  $\text{NH}_4\text{Ac}$ .

## Soil potassium, K

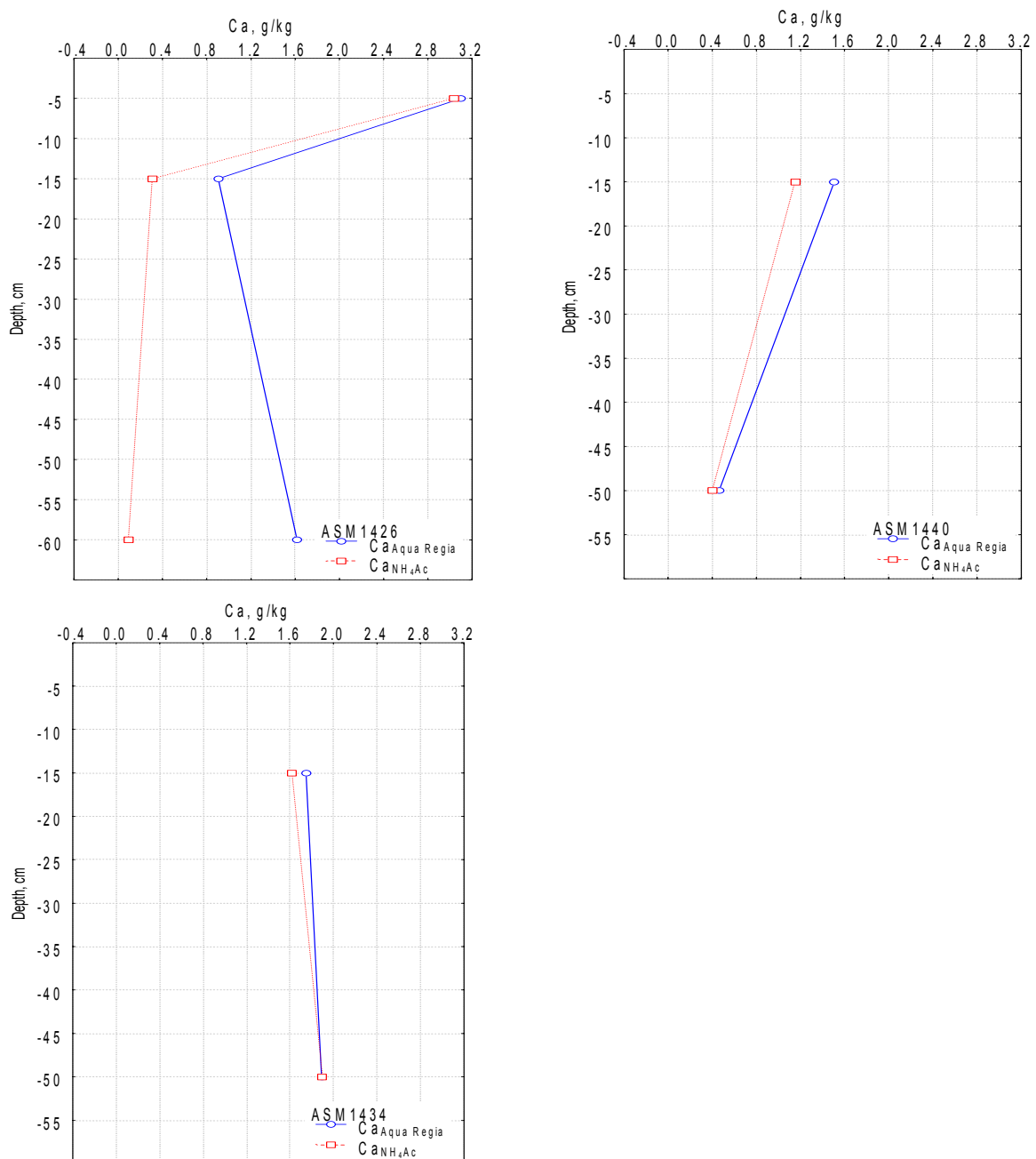
Potassium was analysed in four extractions where  $\text{NH}_4\text{Ac}$  and ammonium lactate showed similar values and “*Aqua regia*” and HCl also were quite similar. In the peat on the “spruce” site the lowest values were found being fairly similar both between extractions and with soil depth, i.e. 0.1–0.2 g/kg. In the mineral soil on the “oak” site easily extractable K was c. 0.4 g/kg, similar to the stronger extractions, but decreased with depth to below 0.1 g/kg while the slightly stronger bound K in the deeper layer stayed on fairly high levels, c. 0.3 g/kg. In the soil on the “alder” site K content increased with depth from 0.4 g/kg for easily extractable K to 0.6 g/kg in 0.6 m depth. Corresponding values for the stronger bound fraction was 0.9 g/kg in the upper layer and almost 1.2 g/kg in the deeper layer (Figure 5-9 and Table 5-1). Comparable total K contents could be 20 g/kg and  $\text{NH}_4\text{Ac}$  extractable for Sweden are on the level of 0.8 g/kg in the organic layer and c. 0.1 g/kg in the mineral soil /SoilInfo 2006/.



**Figure 5-9.** The three site ASM001426 (Oak), ASM001434 (Alder), and ASM001440 (Spruce) potassium, K content stratifications with depth at the four extractions “*Aqua regia*”, HCl, ammoniumlactate and  $\text{NH}_4\text{Ac}$ .

## Soil calcium, Ca

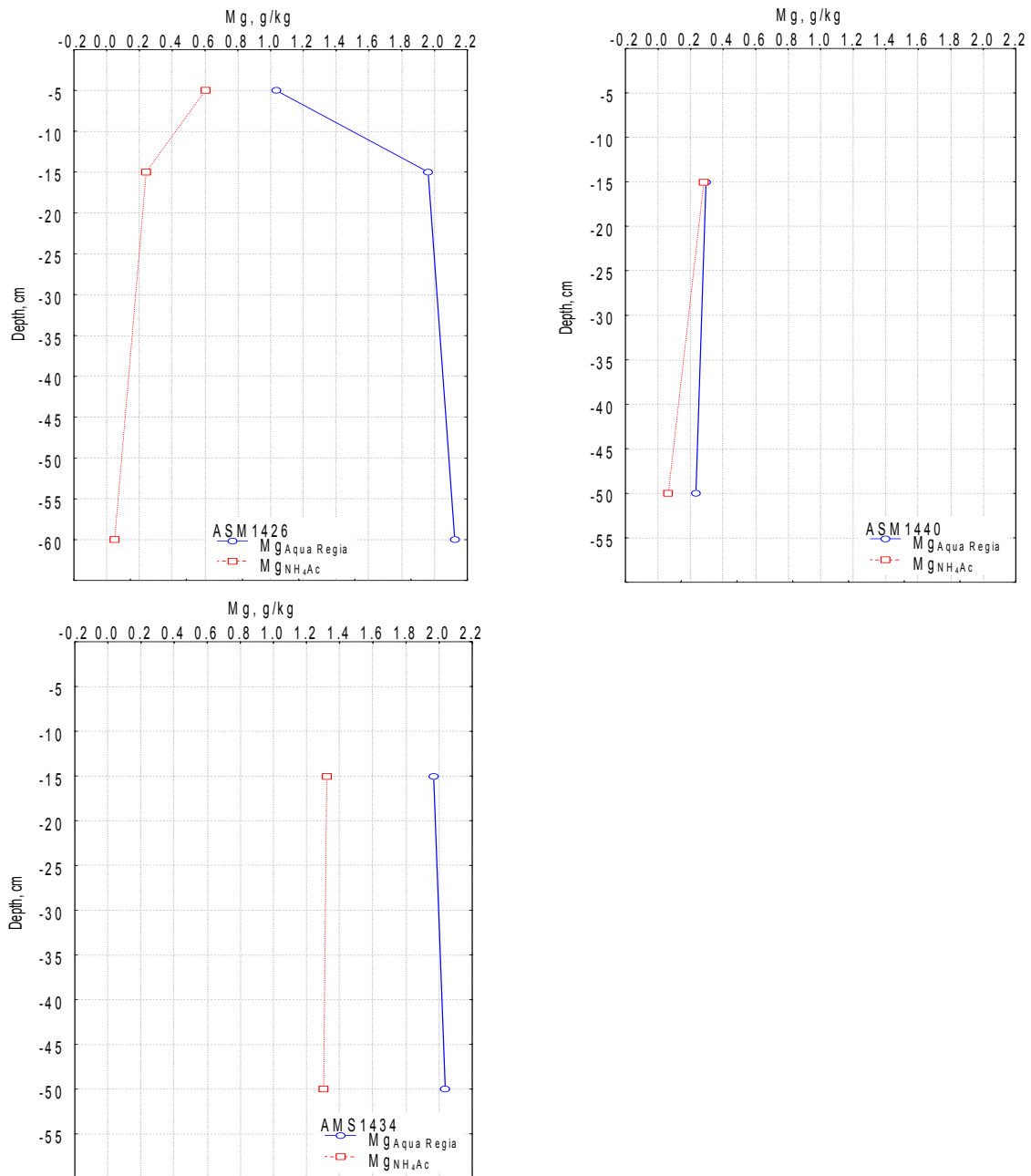
The calcium content differed less between sites compared to most other elements. Values ranged mainly from 0.4 to 2.0 g/kg with exception for  $\text{NH}_4\text{Ac}$  extracted in the deeper mineral soil horizon, i.e. 0.1 g/kg. Higher values were observed in the organic rich horizons and decreasing with depth, however on the “alder” site quite equal contents in the two layers, i.e. c. 1.7 g/kg. The highest values were noticed in the topsoil of the “oak” site with c. 3 g/kg and being equal for  $\text{NH}_4\text{Ac}$  and “Aqua regia” (Figure 5-10 and Table 5-1). In relation to ordinary Swedish forest soils the organic contents of c. 2.4 g Ca/kg, the peat contents, were fairly low but the top mineral soil content high. In the mineral B-horizon of Sweden contents of 0.2 g/kg would be fairly low compared to the Oskarshamn site. Total contents of Ca in Sweden in the mineral soil are around 20 g/kg /SoilInfo 2006/.



**Figure 5-10.** The three site ASM001426 (Oak), ASM001434 (Alder), and ASM001440 (Spruce) calcium, Ca content stratifications with depth at the two extractions “Aqua regia” and  $\text{NH}_4\text{Ac}$ .

### Soil magnesium, Mg

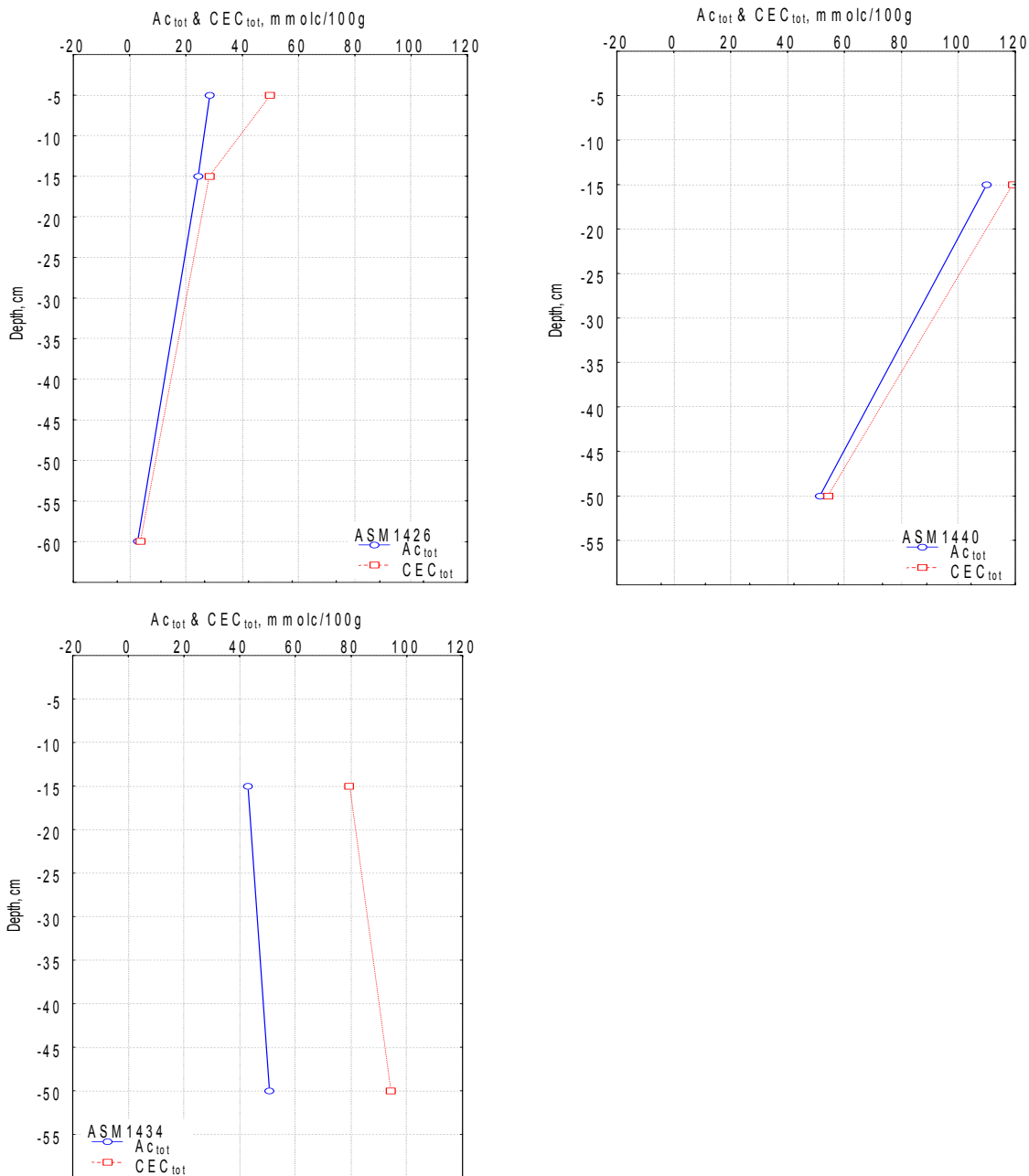
The magnesium content furnished different stratification patterns for the three sites. In the “oak” mineral soil site there were big differences between “*Aqua regia*” and  $\text{NH}_4\text{Ac}$  extractions also with increasing “*Aqua regia*” content with depth while the easily extractable Mg content decreased (Figure 5-11 and Table 5-1). In the “spruce” site values were fairly similar between extractions and also in depth stratification, i.e. 0.2 g/kg. For the “alder” site even differences between extractions were noticed with c. 0.7 g/kg where “*Aqua regia*” was slightly increasing with depth from a little less than 2 g/kg while the content was a little above 2 g/kg in the deeper layer (Figure 5-11 and Table 5-1). For Swedish forest soils, values are on 0.5 g/kg in the mineral soil B-horizon. Total Mg contents reach c. 20 g/kg /SoilInfo 2006/.



**Figure 5-11.** The three site ASM001426 (Oak), ASM001434 (Alder), and ASM001440 (Spruce) magnesium, Mg content stratifications with depth at the two extractions “*Aqua regia*” and  $\text{NH}_4\text{Ac}$ .

### Soil extractable acidity, $A_c$ and cation exchange capacity, CEC

The cation exchange capacity is very dependent on the organic matter content and for the peat soils higher (60–120 mmolc/100 g) were observed to be compared to 20–50 mmolc/100g in the upper horizons of the mineral soil. In the deeper mineral soil with low organic content (0.5%), CEC was only 4 mmolc/100 g. In both the “oak” and “spruce” site, acidity made up almost all CEC while in the “alder” site acidity only furnished about 50% of CEC (Figure 5-12 and Table 5-1). Base saturation in the “spruce” site was c. below 10% and in the “alder” site about 50%. In the organic top layer of the “oak” site the base saturation was 44% compared to an ordinary Swedish organic top soil value on 20–30%. In the mineral soil base saturation in the “oak” site was 14% in the 10–20 cm layer and 25% in the 0.6 m level to be compared with a Swedish average about 30% in the B-horizon /SoilInfo 2006/.

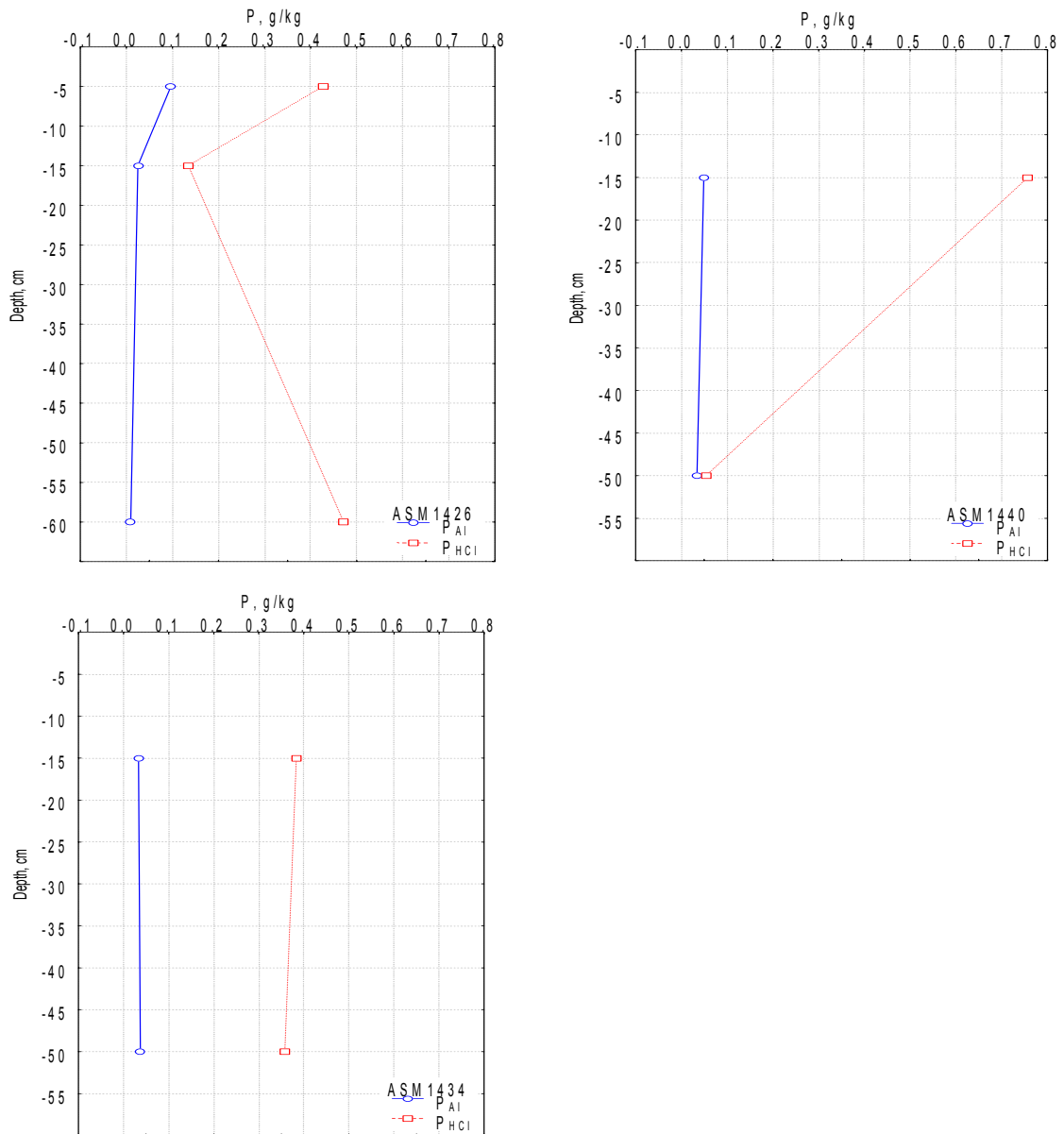


**Figure 5-12.** The three site ASM001426 (Oak), ASM001434 (Alder), and ASM001440 (Spruce) acidity ( $A_c$ ) and cation exchange capacity ( $NH_4Ac$ ) (mmolc/100g).



## Soil phosphorus, P

Phosphorus that is a most important plant nutrient would be bound to calcium rich soils and could also reach fairly high values in organic rich soils as being preferential there. Easily extractable P (ammonium lactate) would reflect a small part of the organically bound P while extraction with HCl furnishes a larger part and also clay bound P in minerals. In the sites differences between extractable contents would reflect organic content but also clay content. Probably, this could be noticed in the “oak” site where big differences occurred in the 0.6 m level. Only small amounts could be extracted easily, c. 0.01–0.1 g/kg where the top organic layer in the “oak” site furnished most. A high value (0.75 g/kg) was noticed in the top layer of the “spruce” site while the “alder” site could provide somewhat harder extractable (HCl) P throughout the profile with values on almost 0.4 g/kg (Figure 5-13 and Table 5-1). Total P content in the mineral forest soil of Sweden is c. 0.7 g/kg /SoilInfo 2006/.



**Figure 5-13.** The three site ASM001426 (Oak), ASM001434 (Alder), and ASM001440 (Spruce) phosphorus, P content stratifications with depth at the two extractions HCl and ammonium lactate.

## 6 Summary and discussions

Comparing the three sites show rather big differences. One, the “oak” site being a mineral soil with in-mixed organic material in the top soil furnishing also rather high pH values both in the upper layer and in the deeper one on 0.6 m depth. Carbon and nitrogen content decrease in ordinary way with depth.

For the two organic soils both having rather high carbon content but as being peat only the top soil layer in the “spruce” site show ordinary high values for peat. Both sites have in-mixed mineral material in the lower layer. The “alder” site is more nutrient rich and the high contents of several element are found throughout the profile while the contents in the “spruce” site decrease with depth. However, statements for the sites should be careful as there is very few sample values included in this evaluation.

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## Appendix 1

### Ditionitratextraktion.

Väg in 4,00 g lufttorr jord i 250 ml skakflaska i plast. Tillsätt 2,00 g  $\text{Na}_2\text{S}_2\text{O}_4$ .  
Tillsätt 100 ml 18 % Nacitrat (180 g/l av  $\text{Na}_2\text{C}_6\text{H}_5\text{O}_7 \cdot 2 \text{H}_2\text{O}$  till 1,000 ml).  
Skaka 16 timmar. Filtrera genom OOK filterpapper över till E-kolv.

E-kolv nr	Plats ID	Horisont	Invägt jord (g)	TS (%)
101	ASM001426	0–10 cm	4.00	95.40
102	ASM001426	10–20 cm	4.00	97.36
103	ASM001426	55–65 cm	4.00	99.51
104	ASM001440	0–30 cm	4.00	89.75
105	ASM001440	40–60 cm	4.00	92.51
107	ASM001434	0–30 cm	4.00	91.53
108	ASM001434	40–60 cm	4.00	92.46

### Ammoniumacetatextraktion.

Löpnr	Namn	Provdjup	Prov (g) som extraherats med 100 ml 1M $\text{NH}_4\text{Ac}$
101	ASM001426	0–10 cm	2
102	ASM001426	10–20 cm	15
103	ASM001426	55–65 cm	15
104	ASM001440	0–30 cm	2
105	ASM001440	40–60 cm	2
107	ASM001434	0–30 cm	2
108	ASM001434	40–60 cm	2

### Kungsvattenextraktion.

30 ml konc.  $\text{HCl}$  + 10 ml konc.  $\text{HNO}_3$  spätt med vatten till 200 ml.

E-kolv nr	Provnr	Plats	Horisont	Invägt (g)
101	101	ASM001426	0–10 cm	2.00
102	102	ASM001426	10–20 cm	3.00
103	103	ASM001426	55–65 cm	6.00
104	104	ASM001440	0–30 cm	1.00
105	105	ASM001440	40–60 cm	3.00
107	107	ASM001434	0–30 cm	2.00
108	108	ASM001434	40–60 cm	3.00