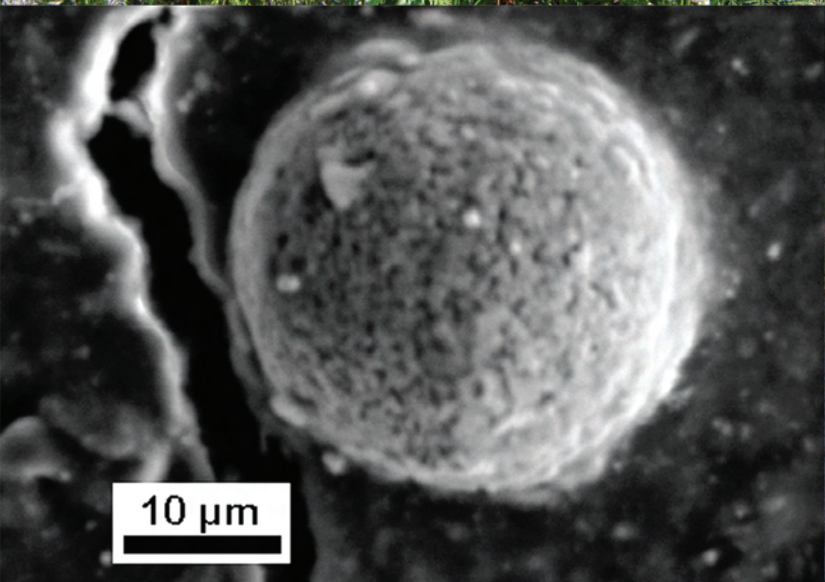
# Mineralogy and chemistry of sandy acid sulfate soils in the Perth metropolitan area of the Swan Coastal Plain




Department of
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# Mineralogy and chemistry of sandy acid sulfate soils in the Perth metropolitan area of the Swan Coastal Plain

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Report to

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## Executive Summary, Finding and Recommendations

Acid sulfate soils (ASS) are a major issue for urban development on the Swan Coastal Plain. Soils on Swan Coastal Plain have the potential to become actual acid sulfate soils unless the watertable is maintained at a suitable level to prevent the oxidation of acid generating sulfide minerals. Up until recently, the management of acid sulfate soils in Western Australia has been based on methodologies and conceptual models developed in Queensland and New South Wales. However, the acidity issue in the Bassendean Dunes is different from most other areas in Australia where sulfide minerals are predominantly associated with silty- or clayey-textured soils. The acid sulfate soil management criteria developed on the eastern seaboard are not appropriate for the Bassendean Dunes. As a consequence of this, the Department of Environment and Conservation (DEC) has carried out a survey of ASS occurrence in the Perth metropolitan area. The purpose of the study reported here was to support the survey by providing detailed characterisation of the identified soil materials. A particular aim was also to characterise sulfidic materials in soils that show ASS field indicators but have sulfur content lower than the current action criteria for ASS management.

All samples and associated field data were provided by DEC for geochemical and mineralogical analysis. Field data and bulk sulfur analysis of the representative samples was interpreted in conjunction with detailed physico-chemical and mineralogical properties measured using a range of modern chemical, X-ray diffraction and electron optical techniques. Physico-chemical measurements included total chemical composition, extractable cations, cation exchange capacity, batch titrations and incubations studies. Synchrotron x-ray diffraction and electron microscopy (SEM and TEM) were used to detect and characterise the nature of sulfidic materials in soils which have bulk sulfur content lower than the current action criteria.

These investigations indicated that sandy soils in the Perth metropolitan area are dominated by quartz, which has no capacity to buffer soil pH. The limited pH buffering capacity present is provided by organic matter, allophane $(Al, Fe)_2O_3(SiO_2)1.3\text{-}2(H_2O)_{2.5\text{-}3}$), kaolin, gibbsite and Fe-oxides which have high surface area with exposed hydroxyl. Primary minerals (feldspar, ilmenite etc) are minor constituents of these soils and are sand-size and essentially insoluble so they do not provide any effective buffering capacity. The poor pH buffering capacity of these sandy soils is also demonstrated by batch titrations and cation exchange capacity measurements. No carbonates were detected in soils developed on the highly leached Bassendean Dune System. Therefore, any acid generating event, such as the oxidation of sulfide minerals, is expected to have a strong impact on lowering the soil pH.

Synchrotron X-ray diffraction (SXRD) investigations of the soil fine concentrates revealed that acidifying sulfur minerals are commonly present in the permanently water-logged soil horizons below the groundwater table. Pyrite is the main acid-generating mineral while elemental sulfur and marcasites also occur as minor constituents in some horizons with high organic matter content. Pyrite occurs in all horizons (including E, B and coffee rock, mud, peat and C horizons) that are water-logged and show low $pH_{FOX}$. No pyrite was detected by SXRD technique in soil horizons above the water table but very small amounts of pyrite were detected by TEM in some of these materials.

Abundant jarosite was found in soil fines of unsaturated zones of soil profiles (mainly the A horizon). Where present, its occurrence was consistent with field observations of low soil pH (~4.0) and yellow brown mottles.

Scanning and transmission electron microscope investigations of the fine fractions were consistent with SXRD investigations. Pyrite is commonly present as particles of various sizes and shapes in water-logged section of the soil profiles. The two most common morphologies present are framboids of 1-10 μm diameter and sub-micron sized single crystals. Both framboids and single crystals appeared to have growth related pores/cavities, suggesting high surface area and thus potentially high reactivity of these pyrites. A combination of high reactivity of pyrite and extremely low pH buffering capacity of these soils makes them prone to acidification during even a short exposure (less than a week) to air during temporary excavation or dewatering.

A subset of samples represented soil profiles with low sulfur content (<0.03%S) while their $pH_{FOX}$ was in the range of 1.8 to 2.5. Based on the experience in other parts of country, soils with such low $pH_{FOX}$ are expected to have sulfur content greater than ASS action criteria (0.03%$S_{CR}$). In the Perth metropolitan area, however, such sandy soils often have sulfur content less than the current action criterion (0.03%$S_{CR}$) which allows these to be disturbed without the requirement of a management plan. Analytical electron microscopy has demonstrated the presence of microcrystalline pyrite in these soils. Low $pH_{FOX}$ is therefore attributed to a combination highly reactive nature of microcrystalline pyrite and extremely poor buffering capacity of the Bassendean sands. Such minor amounts of acid-generation potential would not normally be of concern but the extremely small acid buffering capacity of some Bassendean Dune materials results in significant reductions in pH on oxidation. The $pH_F$ and $pH_{FOX}$ tests are considered helpful in identifying the type of ASS. The $pH_{FOX}$ test provides useful information on the potential acidity of poorly buffered soil samples where Cr-S is not often detected using normal laboratory techniques.

**Findings**

1. Based on the SXRD patterns, acidifying sulfur minerals are commonly present in soil horizons below the groundwater level. The fine fraction samples above groundwater level (mainly A horizon) contain jarosite whereas the fine fraction of samples below groundwater level (including E, B and coffee rock, mud, peat and C horizons) contain pyrite as the main acid-generating mineral. Elemental sulfur and marcasite occur as minor constituents in some horizons which have a high organic matter content.

2. Scanning electron microscope and transmission electron microscope results for the fine fractions show that iron sulfide is present in all water logged soil horizons that recorded $pH_{FOX}$ <3. It occurs as particles of various sizes and shapes including 1-10 μm framboids and single crystal pyrite (≤ 1 μm) which have high surface area and are thus potentially very reactive. Some materials directly above the groundwater level can contain very small amounts of pyrite and can become acidic when oxidized.

3. Some acidifying samples have very low $S_{CR}$ (lower than detection limit <0.005%) and sulfur minerals could not be detected synchrotron x-ray diffraction, we have demonstrated their presence using analytical electron microscopy.

4. Such minor amounts of acid-generation potential would not normally be of concern but the extremely small acid buffering capacity of some Bassendean Dune materials results in significant reductions in pH on oxidation. $pH_F$ and $pH_{FOX}$ tests are helpful in identifying the type of acid sulfate soil. The $pH_{FOX}$ test provides excellent information on the potential acidification of poorly buffered soil samples where Cr-S is not detected.

5. Buffering of acidity is provided by organic matter, allophane $(Al, Fe)_2O_3(SiO_2)1.3\text{-}2(H_2O)_{2.5\text{-}3})$, kaolin, gibbsite and Fe-oxides which have high surface area with exposed hydroxyl. Primary minerals (feldspar, ilmenite etc) are

minor constituents of these soils and are sand-size and essentially insoluble so they do not provide effective buffering capacity.

## Recommendations

The key recommendations for managing pyritic very sandy; quartz-rich soils are as follow:

1. Acid sulfate soils on the Bassendean Dunes system should be managed appropriately, including undertaking chemical analysis before disturbance or drainage. We have established that even when the Cr reducible S content of these soils is at or below the current sandy-textured soil action criterion (0.03%$S_{CR}$), sufficient S compounds are generally present in these soils to trigger acidification on oxidation. These S compounds are responsible for observed low $pH_{FOX}$ and would also cause low soil pH on natural oxidation if these soils are disturbed.
2. An inexpensive and easy method for identifying ASS occurrence is to use the field peroxide ($pH_{FOX}$) test to assess the potential acidity risk. By selecting the soils that record low $pH_{FOX}$ values, further laboratory confirmatory analysis at a detection limit of 0.005%$S_{CR}$ can be undertaken to confirm that these soils contain low levels of sulfide minerals.
3. Based on this investigation, we recommend that a combination of $pH_{FOX}$ <3 and an analytical value of 0.01%$S_{CR}$ or greater are excellent indicators of ASS and can be used as a basis for managing of potential ASS in the Bassendean Dune System.

Summary of $S_{CR}$(%) analyses of some pyrite containing materials and the evaluation of these samples by direct mineralogical methods to determine if the $S_{CR}$(%) value is a reliable indicator of the presence of pyrite.

| Sample No | Site | Horizon | Depth (cm) | $pH_F$ | $pH_{FOX}$ | $S_{CR}$(%) | SXRD | SEM | TEM |
|---|---|---|---|---|---|---|---|---|---|
| N_01 | 616-01-05 | B horizon | 620-630 | 5 5 | 2.7 | 0.014 | × | ✓[d] | ✓[d] |
| N_02 | 616-02-68 | B horizon | 450 | 7.2 | 1.8 | 0.027 | ✓[e] | ✓[e] | ✓[e] |
| N_04 | 616-02-179 | B horizon | 375-400 | 6.1 | 1.6 | 0.013 | ✓[e] | ✓[e] | ✓[e] |
| N_06 | 616-02-78 | B horizon | 400-500 | 4.8 | 1.5 | 0.014 | ✓[e] | ✓[e] | ✓[e] |
| N_07 | 616-02-81 | B horizon | 400-800 | 6.2 | 1.4 | 0.052 | ✓[e] | ✓[e] | ✓[e] |
| N_08 | 616-02-110 | B horizon | 200-500 | 6.3 | 1.8 | 0.036 | ✓[e] | ✓[e] | ✓[e] |
| N_09 | 616-02-174 | B horizon | 250-550 | 5 5 | 2.5 | <0.005 | × | ✓[d] | ✓[d] |
| N_10 | 616-02-65 | B horizon | 200 | 5.7 | 3.0 | 0.005 | × | × | ✓[d] |

× = non detectable pyrite; ✓ = detectable pyrite, d = difficult to detect pyrite, e = easy to detect pyrite

SXRD = synchrotron XRD, SEM = scanning electron microscopy with EDS, TEM = transmission electron microscopy with EDS.

## Acknowledgments

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## 1. Objectives and Aims

The main objectives are to:

1. Characterise and quantify sulfur forms in Bassendean Dune soils that are not detected by the current standard laboratory methods and
2. Understand forms of acidity in the topographic sequence of the Bassendean Dune system in the Perth region, including the Gnangara and Jandakot Mounds

The specific aims of this project as defined by DEC are to:

1. Determine the amounts and forms of acidity and pH buffering of Bassendean soils at non-wetland locations;
2. Characterise forms of sulfur in landscapes with low potential sulfidic acidity ($S_{CR}$) content;
3. Evaluate the adequacy of the current acidity trigger value of 0.03%S for assessing stored acidity in the Bassendean Dune System using a combination of physical and chemical methods for mineral analysis; and
4. Determine the latent acidity in waterlogged horizons of other soil types on the SCP and adjacent Darling Range

## 2. Introduction

Perth, Western Australia, relies heavily on the aquifers in the Bassendean Sand on the Swan Coastal Plain for potable and irrigation water. The two main sources of potable water are the Gnangara Mound to the north of Perth and the Jandakot mound, to the south. These supply about 40 to 45% of metropolitan drinking water. The soils of swales in these mounds are the subject of this report. The various descriptions and discussions below are based on the following literature (Salama *et al*., 2005; McArthur, 2004).

In the Perth region, the Swan Coastal Plain is on the eastern onshore edge of the Perth Basin, extending between Geraldton in the north and Dunsborough in the south. It is bounded to the west by the Indian Ocean and by the Gingin, Darling and Whicher Scarps to the east. The surficial materials of the Swan Coastal Plain are predominately alluvium and three major sand dunes deposits. The youngest and most western dune system is the calcareous Quindalup Dune System. Next in sequence, inland is the Spearwood Dune System with orange earthy sand overlying calcarenite. Finally and most easterly are the purely siliceous Bassendean dunes. The dunes are all from the Quaternary period and all have been deposited adjacent to beaches by aeolian processes

(McArthur, 2004). Between and within the dune systems, inlets, lakes and swamps occur. The swales may be occupied by swamps and lakes so rich in organic matter, that they frequently contain peats (Salama *et al*., 2005).

The Bassendean Dunes have low relief with minor variations in topography, which translate to a variable depth to the water table. Low hills of siliceous sand are interspersed with poorly drained swale areas including both seasonal and permanent swamps. The depth to ground-water varies from close to the surface to at most 10 m below the surface. The water is suitable for irrigation. This dune system originated along a coastline, and probably consisted of calcareous sand, but leaching has continued for so long (about 800,000 years old) that all carbonate has been lost and the steep relief characteristic of beach dunes has been modified. The highly leached soils are infertile and acidic. Three types of Bassendean sand soil profiles have been identified reflecting depth to watertable: the Jandakot, Gavin and Joel sands (McArthur, 2004).

Acid sulfate soils (ASS) are a major issue for urban developments on Swan Coastal Plain regions. Soils on Swan Coastal Plain have the potential to become actual acid sulfate soils unless the watertable is maintained at a suitable level to prevent the oxidation of acid generating minerals. Management of acid sulfate soils has been based on Queensland and New South Wales models; however, the acidity issue in the Bassendean Dunes are different from other areas with clayey soils. To manage poorly buffered, pyritic quartz-rich soils special criteria that are suitable for Bassendean Dunes system soil types need to be developed.

During the past ten years in has been recognised that the cause of acidification in drying Bassendean Dune podosols is the oxidation of pyrite and possibly other reduced minerals present in these soils. Unfortunately the nature and distribution of these minerals is poorly understood and is the focus of the present investigation. The very low acid buffering capacity of Bassendean Dune soils is unable to neutralise the acidity produced by oxidation so the nature of the buffering capacity also requires investigation.

The extent to which pyrite containing soil materials may occur in wet horizons under other landscape elements of the Bassendean Dunes, and particularly “downstream” of organic-rich wetlands is unknown.

During recent years it has become evident that drying of humic podosols in Bassendean Dune soils in and adjacent to swale positions due to lowered water table levels has caused acidification of groundwater. This is of concern because:

(i) acidification degrades metals, concrete and other infrastructure and the acid impact of dewatering and excavation can extend to considerable distances from the site of operations

(ii) acid groundwater kills vegetation and irrigation with acid water containing dissolved Al, As and possibly other toxic elements is undesirable.

(iii) Bassendean Dune aquifers provides a considerable proportion of Perth's drinking water and must not be contaminated by acid water from oxidised podosols.

(iv) the ecologically unique lakes within and adjacent to the Bassendean Dunes become acid and inhospitable as they dry and the organic sediments and adjacent soils are aerated resulting in catastrophic damage to the ecology of the lakes.

(v) the standard chemical methods for assessing the amounts of pyrite in soils are unsuitable for detecting the low concentrations of pyrite present in humus podosols. It is important to critically evaluate the validity of the chemical methods and to develop more appropriate criteria for use by developers and regulators.

# 3. Materials and methods

## 3.1 Soil selection

Sites for investigation were selected and sampled by Department of Environment and Conservation staff. The main geological formations of the superficial units are the Tamala Limestone, Bassendean Sand, Guildford Formation and Safety Bay Sand. All soil samples were selected and sampled soils in swales and were mostly below ground water level. The total samples represent 41 profiles, with 186 samples including A horizon (25 samples), E horizon (64 samples), B horizon (39 samples), coffee rock (31 samples), mud (6 samples), peat (10 samples) and C horizon (11 samples). All studied sites are shown in Appendix Table 1 and Figure 1. Soil samples from sites 003, 005, 009, 011, 014, 018, 019, 031, 032, 058, 065, 068, 071, 078, 080, 081, 082, 085, 087, 094, 099, 100, 113, 122, 127, 136, 145, 158 174, 179 and Ellenbrook were collected from the Bassendean Sand, soil samples from sites 023, 024, 101, 105, 106, 110, 112, 131 were from acidic sandy swales in the Tamala Limestone mapping unit. Soil profiles at sites 028, 155 were from Guildford Formation (Figure 1) (Thierrin *et al*., 1991).

## 3.2 Soil reaction (pH), electrical conductivity (EC) and $H_2O_2$ oxidation

After collection all soils were kept in a cool room and enclosed so as to exclude air and remain wet. However in many instances this did not prevent partial oxidation during extraction, transport and storage of cores. Soil pH and EC were determined in water for a soil: solution ratio of 1: 5 and soil pH $CaCl_2$ was measured in 0.01N $CaCl_2$ at a 1: 5 solid to solution ratio. Sodium fluoride solution (1N NaF) was adjusted to pH 8.5, and used to measure soil pH at a solid to solution ratio of 1: 5. The pH $H_2O_2$ reaction with soil was done with 4 mL of peroxide solution and 2 g of soil samples (1: 2 soil to solution). The pH of the 30% hydrogen peroxide solution was adjusted to 5.5 with 0.1M NaOH. The contents were stirred with a glass rod for 30 minutes before measuring the pH with a standardized pH meter (National Soil Survey Centre, 1996).

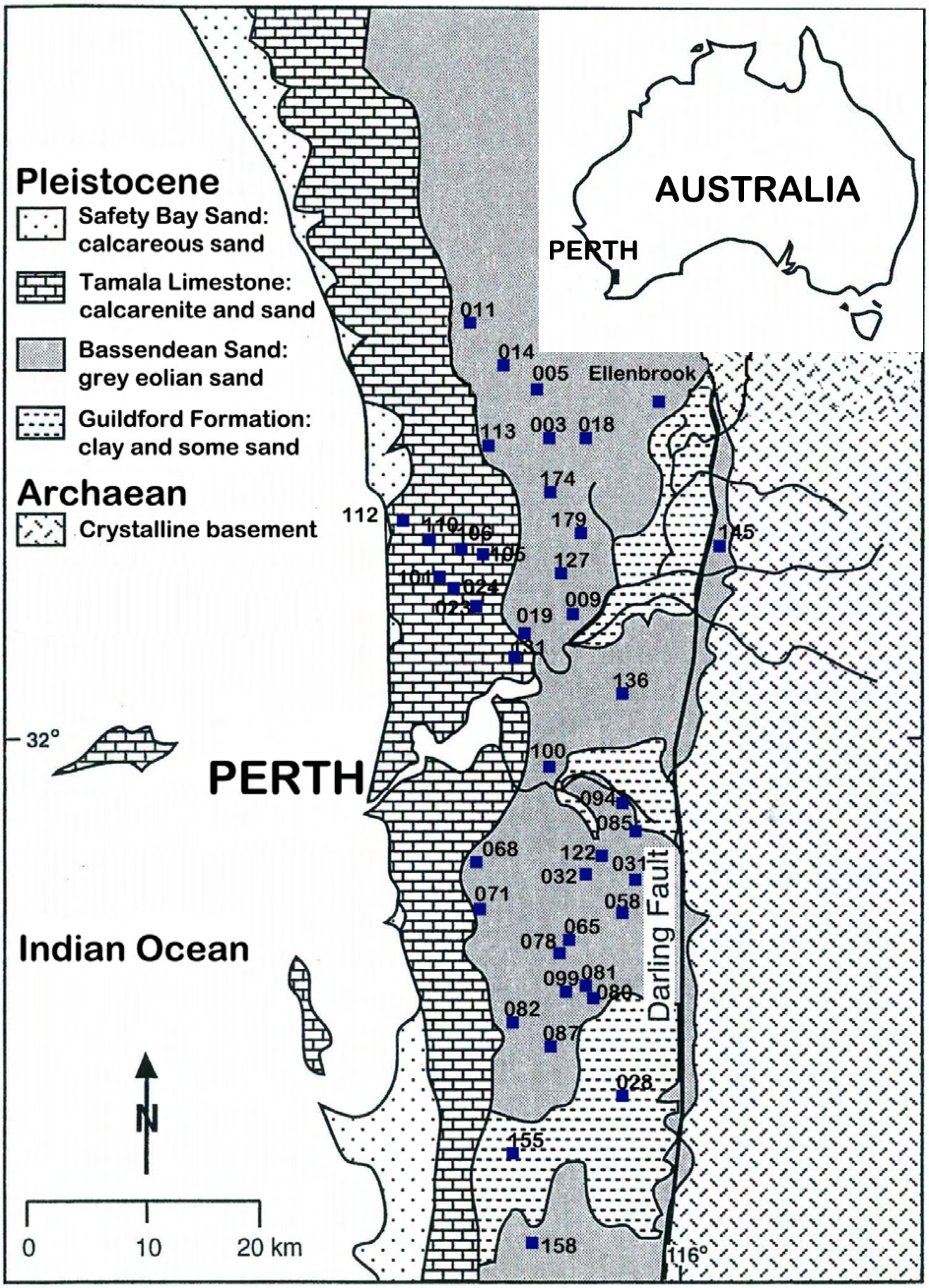



**Figure 1** Sampling locations for podosols on the Bassendean Dune System on the Swan Coastal Plain, WA. Note that several locations investigated in this research are acidic sandy swales in the Tamala mapping unit or alluvium belonging to the Guildford Formation.

## 3.3 Total C and N

Ground oven dried soil weighing 300 mg was placed on tin foil and total carbon and nitrogen determined using a Vario Macro elemental analyzer.

## 3.4 Cation exchange capacity (CEC)

One to two grams of whole wet soil (<2 mm) depending on texture was placed in a 50 mL screw-top centrifuge container and least two blank samples were prepared. Forty mL of 0.01M silver thiourea $(AgTU)^+$ was added, stoppered securely and mechanically shaken end-over-end at approximately 25°C for 16h. The extract was centrifuged until a clear supernatant was obtained. The supernatant was diluted depending on the CEC value. An aliquot (0.100 mL) of original supernatant soil extract was pipetted into a 10 mL polypropylene screwtop tube, and 9.9 mL of MQ water added from a calibrated dispenser. The same procedure was followed with the $(AgTU)^+$ standard. Ag absorbance at 338.3 nm was measured by AAS. CEC-AgTU values are reported on a 105°C oven-dry basis.

## 3.5 Extractable Fe, Al, Mn, Si

### 3.5.1 Dithionite-Citrate-Bicarbonate (DCB) extractable Fe, Al, Mn, Si

The amounts of Fe, Al, Mn, Si extracted from soils by various dissolution methods (so called specific reagents) are commonly taken to indicate particular solid state forms of these elements in soil. The results are useful in studies of soil classification, soil genesis and soil behaviour. The DCB extractant removes virtually no Fe, Al or Mn from most crystalline silicate minerals, and thus provides an estimate of "free oxide" (e.g. non layer silicate mineral Fe, Al, Mn, Si) in soils.

One gram of whole wet soil (< 2 mm) was weighed into a 50 mL centrifuge tube to which 45 mL of buffer solution (0.3 M Na-citrate + 0.1 M Na bicarbonate) were added. The tube was then placed in a water bath at 70°C. One gram of Na-dithionite powder was added to the tube, the mixture was stirred constantly for 1 minute and occasionally during next 15 minutes. The tube contents were centrifuged for 15 minutes at 2000 rpm. Clear supernatant was decanted into a 250 mL volumetric flask. This extraction procedure was repeated twice, then the volume was made up to 250 mL with deionized water and the solution was kept for further analysis. For deteminination of Fe, Al, Mn, Si by atomic absorption spectrophotometry (AAS), standard solutions of these elements were prepared in a matrix of extracting solution.

### 3.5.2 Oxalate extractable Fe, Al, Mn, Si

A sample of one gram of whole wet soil (<2 mm) was weighed into a 25 mL centrifuge tube, 10 mL of 0.2 M ammonium oxalate solution at pH 3.0 were added to the tube, the tube was shaken for 4 h in darkness. Next five drops of 0.4% Superfloc were added to the tube, which was swirled and then centrifuged, clear supernatant was kept for further analysis by AAS. Predicted allophane content was calculated from $Si_o$ (g $kg^{-1}$) x 100)/13.3.

### 3.5.3 Pyrophosphate extractable Fe, Al, Mn, Si

Various organic complexes of Fe, Al, Mn, Si occur in soils. Pyrophosphate solution has been used to extract these organic complexes. A subsample of 1 g of whole wet soil (<2 mm) was weighed into a 50 mL shaking tube and 30 mL of 0.1M sodium pyrophosphate solution was added before shaking overnight.

The tube contents were centrifuged for 15 minutes at 2000 rpm and the clear supernatant was kept for measurement of Fe, Al, Mn, Si by AAS.

## 3.6 Extractable sulfate (Turbidimetric method)

A sample of five grams of whole wet soil (<2 mm)was weighed into a 50 mL centrifuge tube, 20 mL of extraction solution (0.5N ammonium chloride + 0.06 g $Ca(OH)_2$) was added to the tube. The tube was shaken for 15 minutes at high speed (250 oscillations per minute). The extract was filtered using Whatman 42 filter paper. A 5 mL aliquot of supernatant soil extract was pipetted into a 10 mL polypropylene screwtop tube, 1 mL of seed solution (210 mL of 100 ppm $SO_4$ stock solution + 2 mL conc. HCl + 13.87 g $NH_4Cl$ in 500 mL) was added and 1 mL of precipitation solution (225 g barium acetate + 100 mL acetic acid in 1 L), contents were mixed by slow inversion. The extracts were poured into polystyrene cuvets and allowed to stand for 10 minutes. The extract was analysed on a spectrophotometer at 550 nm.

## 3.7 Chromium-reducible sulfur method ($S_{CR}$)

The standard chromium-reducible sulfur method of (QASSIT *et al.*, 2004) was used for $S_{CR}$ determinations (detection limit = 0.005%).

### 3.8 Total element analysis (X-ray fluorescence)

The element composition (total analysis) of Si, Al, Ti, Fe, Mn, Ca, K, Mg, Na, P, S, V, Ni, Cu, Zn, Rb, Sr, Ba, Zr, Co, As, La and Pb was determined for some samples using a Philips P1400 XRF spectrometer fitted with a rhodium tube. Soil samples were finely ground and heated at 105°C overnight then 0.700 g of sample was fused with 7.000 g of lithium meta/tetraborate flux at 1050°C in a platinum crucible and cast into a disc for analysis.

### 3.9 Mineralogical properties

A sample of twenty grams of whole wet soil was weighed into a 50 mL centrifuge tube, 20 mL of DI water and a few drop of chloroform was added to the tube to suppress microbial activity. The fine fraction was dispersed by ultrasonic treatment and separated by sedimentation.

#### 3.9.1 Synchrotron XRD

Powder samples of the fine fraction of soils were mounted into glass capillaries, and analysed over an angular range of 4 - 60° 2Theta. The wavelength was set at ~1.0Å to provide for adequate dispersion/resolution and provided a high peak/background for identifying minor constituents.

#### 3.9.2 Conventional XRD

Minerals were determined by X-ray diffraction (XRD) analysis using a Philips PW- 3020 diffractometer with a graphite diffracted beam monochromator (CuKα, 50 kV, 20 mA). The fine fraction of soils was scanned from 4 to $65^o$ 2θ, using a step size of $0.02^o$ 2θ and a scan speed of $0.04^o$ 2θ $sec^{-1}$.

#### 3.9.3 Differential X-ray powder diffraction (DXRD)

X-ray powder diffraction (XRD) patterns of the fine fraction of samples before and after oxalate treatment were obtained with a Philips PW 3020 diffractometer using monochromated CuKα radiation. Differential XRD patterns (DXRD) were obtained using the Traces program.

### 3.10 Inductively coupled plasma optical emission spectrometry

The chemical composition of strong acid extracts of whole oven dried soil samples was determined using inductively coupled plasma optical emission spectrometry (ICP-OES). For this aqua regia digestion, 0.25 g of fine ground whole dried soil was dissolved in 2 mL of conc. $HNO_3$ and 5 mL of conc. HCl at 130°C for 1 h. The volume was made to 20 mL mark with MQ water. Supernatant was transferred into suitable clean and marked vials and analysed by ICP-OES. Data were assessed for accuracy and precision using a rigorous control system including reagent blanks and a certified international reference material (STSD-1). The aqua regia digestion only dissolves a small part of the resistant sand size minerals (particularly quartz), thus the results represents amounts of trace elements present in the fine fraction. For fusion acid digestion method, 0.1 g of fine ground whole dried soils was fused with 1 g of lithium meta/tetraborate flux at 1050°C in a platinum crucible and then dissolved in 100 mL 10%HCl. The solution was transferred into suitable clean vials and analysed by ICP-OES.

### 3.11 Transmission electron microscopy (TEM)

For analytical transmission electron microscopy (TEM), specimens were prepared from dispersed samples. A highly diluted suspension of the fine fraction was prepared in distilled water and dispersed by ultrasonic treatment. A drop of the suspension was deposited onto a carbon-coated Cu grid and examined using a JEOL 3000 electron microscope operated at 300 kV.

For elemental analysis, electron diffraction and morphology of particles single crystals on carbon film were investigated using a JEOL 3000 transmission electron microscope operated at 300 kV. Energy dispersive spectra (EDS) for well separated single crystals were collect at 500-1500 counts per second for 100 live seconds.

### 3.12 Scanning electron microscopy (SEM)

#### 3.12.1 Thin section preparation

This was done by putting the soil sample in an aluminium tray and impregnating with a polyester resin. When the resin polymerized, it hardened to produce a compact block that encompasses the soil sample, conserving its natural structure with no alteration.

To ensure that the resin penetrates well; impregnation of the samples was carried out under vacuum. After the sample had been impregnated and hardened, cutting and polishing was done with oil as a lubricant to avoid dissolving soluble minerals (e.g. gypsum). Firstly, the impregnated soil was cut with a diamond cut-off saw to obtain a flat surface. The cut surface was polished to eliminate traces of cutting and to obtain a flat surface that is as smooth as possible. The polished surface was stuck onto a glass microscope slide with a colourless, isotropic cementing agent, and then cut to obtain a thin slice. The slice was trimmed and polished until it had a thickness of about 30 microns and so was suitable for both optical and SEM examination.

#### 3.12.2 Fine fraction deposited on a stub

A sample of ten grams of whole wet soil was weighed into a 50 mL centrifuge tube, 20 mL of DI water and a few drop of chloroform was added to the tube to suppress microbial activity. The fine fraction was dispersed by ultrasonic treatment and separated by sedimentation. A drop of the suspension was deposited on a carbon tape which adhered to an aluminium stub and was examined using a JEOL 6400 SEM.

#### 3.12.3 Analysis of thin sections

Samples were coated with carbon prior to examination using a backscattered electron image and elemental mapping on a JEOL 6400 SEM operated at a 15 kV electron beam accelerating voltage. Electron microprobe analysis (EMPA) and energy dispersive spectroscopy (EDS) provided quantitative microanalysis to determine the chemical composition of distinct micromorphological features (matrix, grains).

### 3.13 Incubation

Three laboratory incubation methods including standard method (USA/ Australian standard methods) (Isbell, 2002; Soil Survey Staff, 2006), nearly saturated soil and moist soil methods were used for this study. For standard and nearly saturated soil methods, all soil materials had at uniform thickness of 10 mm. The 20 mm thickness of soil samples were used for the moist soil method. All incubation soil materials were incubated for 12 months, the pH measured every day for 8 days, after that pH was measured every week for 8 weeks, and measured every month until 12 months. Water contents were maintained throughout the observation period.

### 3.14 Batch titration

The present investigation is a part of a comprehensive study by DEC in which changes in soil and solution chemistry are being monitored to evaluate progressive acidification. An important component of this work is the assessment of the acid buffering capacity of acidifying materials. The acid buffering capacity of soil materials was investigated in a laboratory titration experiment. Briefly, in the batch titration experiment, 50 ml of water or a $H_2SO_4$ solution (0.0012, 0.0036, 0.0060, 0.0072, 0.0144 and 0.0288M for coffee rock and B horizon corresponding to acid loads of 24-576 mmol $H^+$ $kg^{-1}$ and 0.000005, 0.000010, 0.000025, 0.000050, 0.000075 and 0.00010M for other soil horizons corresponding to acid loads of 0.1-2.0 mmol $H^+$ $kg^{-1}$) was added to a set of 5-g whole wet soil samples in centrifuge tubes, shaken and pH was measured immediately. The pH values after $H_2O_2$ oxidation were then used in conjunction with the titration curves for establishing the amount of $H^+$ required to reach this pH. For the batch titration against alkali experiment, the studied soils were oxidised by $H_2O_2$ before the measurements were made. 50 ml of water or a NaOH solution (0.00001, 0.0012, 0.0024, 0.0048, 0.0072, 0.0120, 0.0144 and 0.0288M for coffee rock and B horizon corresponding to alkali loads of 0.1-288 mmol $OH^-$ $kg^{-1}$ and 0.00001, 0.00002, 0.00005, 0.00010, 0.00015, 0.00020, 0.00030M for other soil horizons corresponding to base loads of 0.1-3.0 mmol $OH^-$ $kg^{-1}$) was added to a set of 5-g whole wet soil samples (after $H_2O_2$ treatment) in centrifuge tubes and pH was measured immediately. The initial pH $H_2O$ of the soil was used for the end point to calculate from the titration curve the amount of $OH^-$ required to neutralise the acidity released by $H_2O_2$ addition.

## 4. Macromorphology and soil classification

Soil morphology properties such as texture and colour can be related to potential acidification. For example, sandy soils have poorly buffering capacity whereas clayey soils have the ability to neutralise acidity. The soil horizons vary in morphology in response to drainage status and in particular depth to groundwater. However, most soil horizons have sand texture (quartz rich soils), except for B and coffee rock horizons which may be loaming sand. Most soil horizons have little buffering capacity due to their sand texture.

Where the relief is very low and where the water table is within 2 m of the surface an iron-humus podosol forms often with the B horizon being partly cemented. In the lowest topographic sites, which are subject to seasonal flooding, the soil is a humus podosol (Isbell, 2002) often with a strong cemented dark brown B horizon (coffee rock) which is a spodic horizon. The soils examined in this project are all located in these low-lying sites. Dr. Balbir Singh selected and sampled all representative podosol materials for the detailed examination of materials described in this report. All studied sites are shown in Appendix Table 1 and Figure 1. The podosols occur in swale sites in Tamala Limestone, Bassendean Sand and Guildford Formation mapping units (Thierrin *et al*., 1991).

Most studied soils are Podosols[1/]. Present models of podzolisation emphasize the mobilization and precipitation of dissolved organic matter, together with Al(-silicates) and Fe. All the soil profiles are deep (Appendix Figure 1). The moisture condition of all soils is aquic[2/] (Isbell, 2002; Soil Survey Staff, 2006). Most studied soils are poorly drained, exhibiting a 2.5YR to 10YR hue with low chroma colour ($\leq 2$) resulting from the reduction/ oxidation cycles imposed over many years (Appendix Figure 1). The distribution of redoximorphic features indicates that many of these soils are permanently saturated with water in all layers.

These profiles represent an extreme stage of leaching reflecting their age, the substantial annual rainfall (about 800 mm at present) and the very high sand content (>95%) of the parent material.

1/ Soil with B horizons dominated by the accumulation of compounds of organic matter, aluminium and/or iron. These soils are recognised world-wide, and Australia is particularly noted for its'giant' forms (Isbell, 2002).

2/ Soils with long-term saturation in the B horizon. The saturation may be caused as in the semiaquic soils but the duration is of the order of months. The period of saturation is sufficient to reduce most iron compounds and move them out of the B horizon, hence Bh horizons are usually prominent (Isbell, 2002).

Soil texture is sand except for some B, coffee rock, alluvial mud and peat horizons. B horizon and coffee rock have a loamy sand texture due to the high organic matter and allophane contents. The sand grains of the Bassendean Dune System are characteristically well rounded and are well sorted which indicates that the sand came ashore after transport and sorting by water and was then was further sorted by wind (Figure 2).

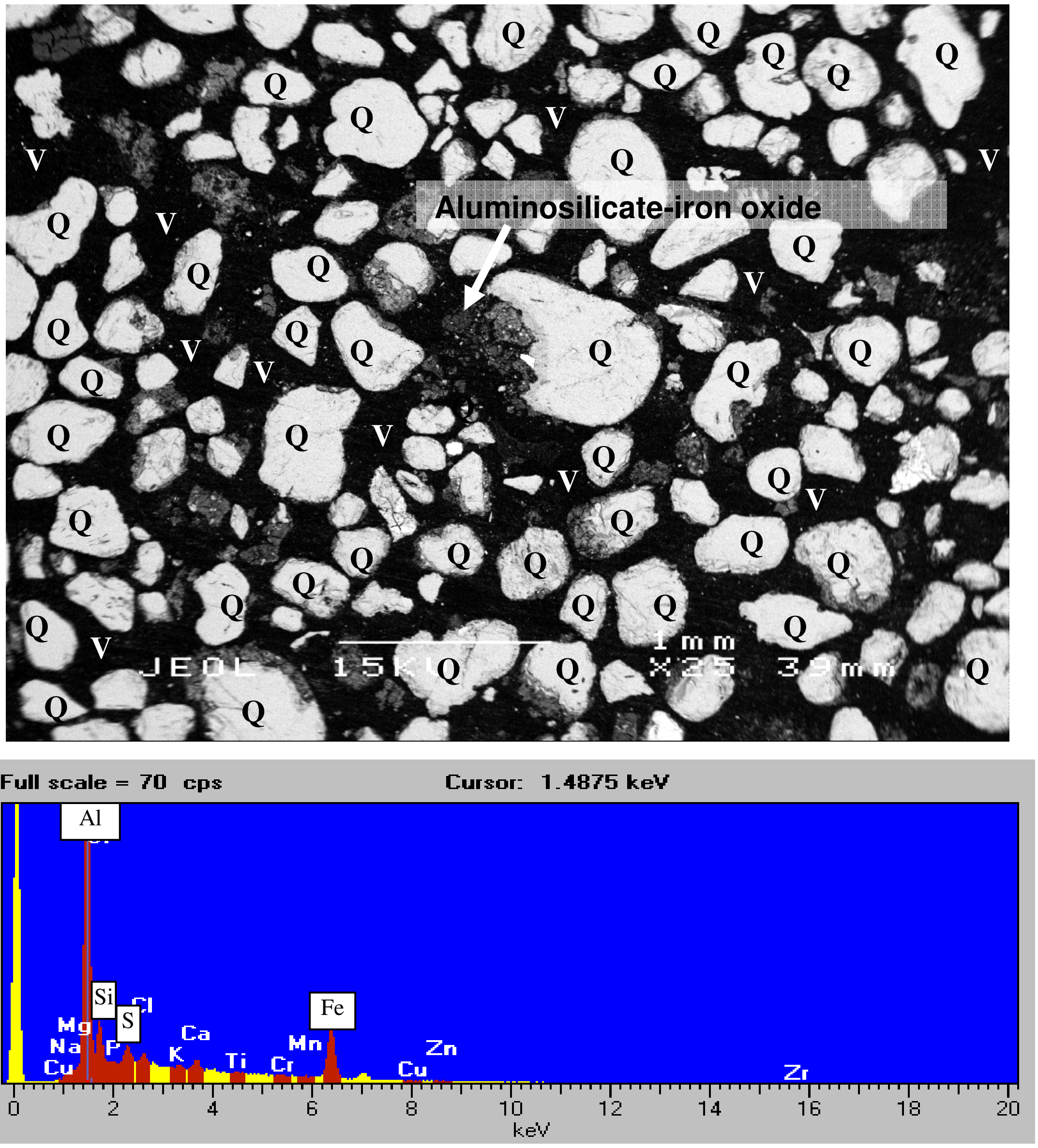



**Figure 2** SEM backscattered electron image and x-ray spectrum of matrix material a thin section from coffee rock (1.8-2.0 m) site 616-01 -03 (Q = quartz, V = void). The matrix material is a complex of amorphous alumino-silicate, iron oxides and organic matter cementing together rounded and well sorted quartz grains.

Some soil profiles (Site 616-01-05, 616-01-18 and 616-02-31) show distinct deep sub-soil horizons (2E horizon and 2coffee rock) which indicates that these soil profiles are buried palaeopodosols. The summary of soil classification (Soil orders) for this study is shown in Appendix Figure 1. Soil profiles have a high diversity in macromorphological properties, descriptions of each soil profile are shown in Appendix Figure 1.

Hand specimens of A horizon, bleached E horizon, brown B horizon, strong dark cemented B horizon (coffee rock), mud, peat and C horizon are shown in Figure 3. This figure is a useful guide to the recognition of podosol materials.

- A horizon: the A horizon of all soils is relatively rich in organic matter.
- E horizon: A horizon is underlain by grey quartz sand which becomes increasingly bleached with depth.
- B1 horizon: below the bleached sand is the illuvial B horizon which is highly porous sand coloured brownish gray to brownish black but which does not contain cemented material.
- B2, coffee rock: the coffee rock is sand which has a dark colour (yellowish brown to black), high organic matter and is strongly cemented. There appears to be a reduced porosity within the coffee rock due to the precipitation of iron oxyhydroxide, organic matter and aluminosilicate-organic complexes. The formation of coffee rock is related to the zone of watertable fluctuation.
- Mud: mud is a wet clayey (dark gray to black) which is soft and adhesive (sometime shelly). It is of rare occurrence and represents Recent alluvium.
- Peat: An unconsolidated deposit of partially decomposed plant matter, in a water-saturated environment. Peat is spongy and has a very dark black colour
- C horizon: the parent material consisting of dune sand (light brownish gray to yellowish brown).

The morphological properties of soil materials are very important for management because the occurrence and oxidation rate of acid generating minerals and acid buffering capacity depend on soil composition. Moreover, soil morphology has a strong relationship with the position of groundwater in the soil profile. For example, coffee rock is formed mainly in the zone of watertable fluctuation.

(NB at some locations buried podsols (palaeosols) are present and contain several horizons)

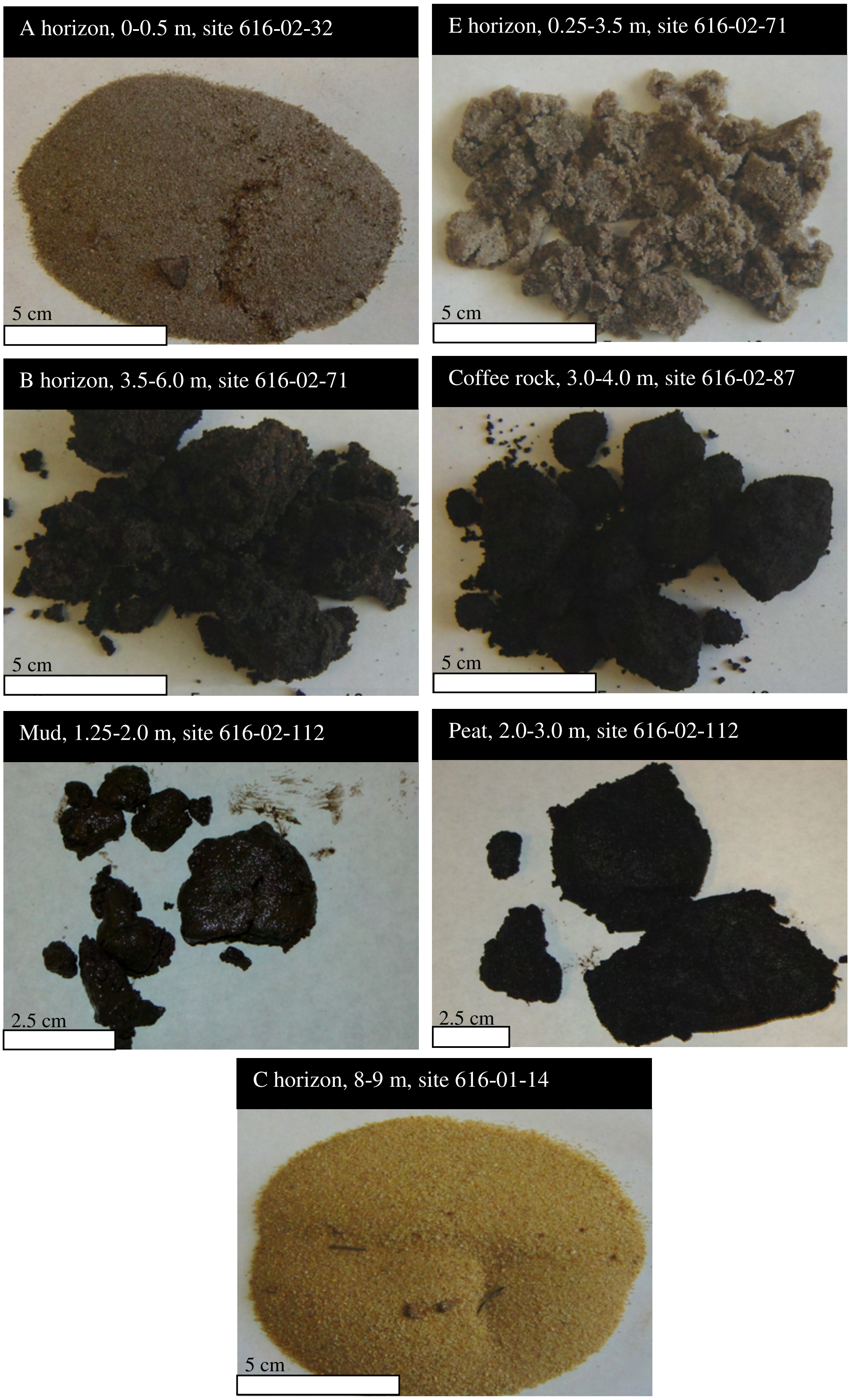



**Figure 3** Hand specimens of representative A, E, B, coffee rock, mud, peat and C horizons.

# 5. Results

## 5.1 Chemical properties

Table 1 shows the chemical properties of these soils. Soil pH in 1: 5 $H_2O$ varies between pH 4.2 - pH 8.8 for the A horizon, pH 2.6 - pH 8.6 for E horizon, pH 2.5 - pH 8.7 for the B horizon, pH 3.6 - pH 6.6 for coffee rock, pH 2.9 - pH 8.9 for mud, pH 2.4 - pH 7.6 for peat and pH 4.7 - pH 8.2 for the C horizon (Table 1 and Appendix Figure 2).

Most values of pH (1: 5) $CaCl_2$ are substantially lower than pH (1: 5) $H_2O$ with an average difference of 0.56. Soil pH in 1: 5 $CaCl_2$ varies between pH 3.2 - pH 7.8 for the A horizon, pH 2.6 - pH 7.5 for E horizon, pH 2.5 - pH 7.9 for the B horizon, pH 3.0 - pH 5.7 for coffee rock, pH 2.6 - pH 8.4 for mud, pH 2.1 - pH 7.6 for peat and pH 4.1 - pH 8.0 for the C horizon (Table 1 and Appendix Figure 3).

The pH of the $H_2O_2$ solution used to extract the soils is pH 5.5. The range of pH ($H_2O_2$) is pH 1.5 - pH 8.1 with the rare high values being for calcareous alluvium. Soil pH $H_2O_2$ varies between pH 2.1 - pH 6.4 for the A horizon, pH 1.9 - pH 7.8 for E horizon, pH 1.8 - pH 8.1 for the B horizon, pH 1.9 - pH 5.3 for coffee rock, pH 1.7 - pH 7.7 for mud, pH 1.5 - pH 6.4 for peat and pH 3.3 - pH 7.6 for the C horizon (Table 1 and Appendix Figure 4). Delta pH (pH $H_2O$-pH $H_2O_2$) ranges from 0.010-4.4 unit, high values being indicative of the presence of sulfide (Soil Survey Staff, 2006).

The pH in sodium fluoride solution ranges upward from pH 8.2 and provides an estimate of the content of exposed hydroxyl on organic matter, sesquioxides and poorly ordered alumino-silicate minerals. It thus provides an indication of acid buffering capacity. Mostly pHNaF of soil samples is higher than pH$H_2O$ except for an A horizon sample (site 616-01-23) where the pH$H_2O$ is higher than pHNaF 0.15 unit. The pHNaF values range from 1.2 - 7.9 unit higher than pH$H_2O$.

Soil pHNaF varies between pH 7.5 - pH 11.5 for the A horizon, pH 7.5 - pH 11.7 for E horizon, pH 6.8 - pH 12 for the B horizon, pH 6.8 - pH 12 for coffee rock, pH 9.2 - pH 11.5 for mud, pH 6.4 - pH 11.5 for peat and pH 8.3 - pH 11.5 for the C horizon (Table 1 and Appendix Figure 5). The pH NaF values range from 1.3 - 5.4 unit (mean = 3.1 unit) higher than pH $H_2O$ for A horizon, 1.2 - 7.3 unit (mean = 4.4 unit) for E horizon, 1.7 - 7.9 unit (mean = 5.3 unit) for B horizon, 2.8 - 7.8 unit (mean = 6.0 unit) for coffee rock, 2.6 - 6.3 unit (mean = 3.9 unit) for mud, 1.2 - 7.3 unit (mean = 4.3 unit) for peat and 2.0 - 5.0 unit (mean = 3.9 unit) for C horizon.

Clearly, coffee rock and B horizon materials have high amounts of surface $OH^-$ which will provide substantial anion and cation exchange sites (buffering capacity).

The organic carbon content is mostly low in E and C horizons ranging between 0.016 - 1.2%. The organic carbon content of A, B, and coffee rock horizons is higher (ranging from 0.05 - 3.6%) (Table 1 and Appendix Figure 6). The organic carbon of the supposed peat samples ranges from 0.41 - 51%, the lower values clearly indicate that some of these materials are not strictly peats (Isbell, 2002) so we have used the term (peat E horizon transition zone; PETZ). The high carbon content in mud and a few C horizon samples may reflect the presence of carbonate. The nitrogen content is mostly low in all samples (0.00046 - 0.85%) except for peat (0.025 - 1.73 %) (Table 1 and Appendix Figure 7). Cation exchange capacity values for A, B, coffee rock, mud and peat horizon are quite high (median between 1.4 - 8.0 meq/ 100 g soil) except for E and C horizons (median 0.60-0.69 meq/ 100 g soil) (Table 1 and Appendix Figure 8). There are close positive statistical relationships between C% and N% (Figure 4) and between C% and CEC (meq/ 100 g soil) (Figure 5) as is usual for soils (McArthur, 2004). Most soil samples have a low soluble sulfate content (less than 200 mg $kg^{-1}$) (Table 1 and Appendix Figure 9).

Electrical conductivity (EC 1: 5) values are mostly low (less than 4100 µS/ cm) but some higher values occur including the alluvial mud samples representing slightly to moderately saline materials (Table 1 and Appendix Figure 10). There is no close relationship between soluble sulfate and EC (Table 1).

**Table 1** Chemical properties of soil samples.

| Site | Horizon | Depth (cm) | pH $H_2O$ | pH $CaCl_2$ | pH $H_2O_2$* | ΔpH** | pH NaF*** | C | N | CEC | $SO_4^{2-}$**** | EC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | (--------%-------) | | meq/100g | mg $kg^{-1}$ | (µS/cm) |
| 616-01-003 | A horizon | 0-25 | 6.3 | 5.5 | 4.9 | 1.4 | 8.6 | 0.92 | 0.03 | 3.60 | 11 | 62 |
| 616-01-003 | Coffee rock | 175-200 | 4.6 | 4.0 | 2.8 | 1.9 | 11.7 | 2.58 | 0.07 | 1.93 | 41 | 41 |
| 616-01-003 | C1 horizon | 200-300 | 5.1 | 4.3 | 5.0 | 0.1 | 10.1 | 0.28 | 0.01 | 1.05 | 47 | 18 |
| 616-01-003 | C2 horizon | 300-400 | 5.7 | 4.7 | 5.2 | 0.5 | 9.6 | 0.07 | 0.00 | 1.47 | 39 | 18 |
| 616-01-003 | C3 horizon | 400-600 | 6.3 | 5.7 | 4.7 | 1.6 | 8.3 | 0.02 | 0.00 | 0.96 | 30 | 27 |
| 616-01-005 | B horizon | 620-630 | 5.0 | 4.5 | 2.8 | 2.2 | 10.4 | 0.30 | 0.03 | 0.34 | 127 | 19 |
| 616-01-005 | A horizon | 0-20 | 5.7 | 4.8 | 4.1 | 1.6 | 7.8 | 2.94 | 0.07 | 5.21 | 11 | 44 |
| 616-01-005 | E horizon | 20-180 | 5.4 | 4.0 | 5.2 | 0.3 | 8.2 | 0.11 | 0.01 | 0.57 | 30 | 16 |
| 616-01-005 | Coffee rock | 180-200 | 5.0 | 3.9 | 4.3 | 0.6 | 11.5 | 1.77 | 0.05 | 1.52 | 23 | 23 |
| 616-01-005 | B horizon | 200-250 | 4.9 | 3.7 | 4.3 | 0.6 | 8.8 | 0.48 | 0.01 | 1.39 | 14 | 17 |
| 616-01-005 | 2E1 horizon | 250-260 | 4.4 | 3.3 | 4.0 | 0.4 | 8.1 | 1.18 | 0.03 | 2.79 | 40 | 24 |
| 616-01-005 | 2E2 horizon | 260-400 | 4.2 | 3.1 | 3.8 | 0.4 | 7.7 | 1.11 | 0.03 | 2.34 | 46 | 27 |
| 616-01-005 | 2E3 horizon | 400-500 | 5.1 | 3.5 | 3.4 | 1.6 | 7.8 | 0.08 | 0.00 | 0.61 | 42 | 14 |
| 616-01-005 | 2E4 horizon | 500-830 | 4.6 | 3.8 | 2.6 | 2.0 | 8.1 | 0.18 | 0.00 | 0.49 | 19 | 29 |
| 616-01-005 | 2Coffee rock1 | 830-900 | 5.3 | 4.1 | 4.8 | 0.4 | 10.6 | 0.53 | 0.01 | 0.92 | 24 | 36 |
| 616-01-005 | 2Coffee rock2 | 900-1000 | 5.5 | 4.2 | 4.9 | 0.6 | 11.2 | 0.62 | 0.01 | 1.04 | 19 | 31 |
| 616-02-009 | E1 horizon | 225-250 | 3.8 | 3.8 | 3.0 | 0.8 | 10.4 | 0.06 | 0.01 | 0.35 | 79 | 80 |
| 616-02-009 | E2 horizon | 325-350 | 2.9 | 2.9 | 2.5 | 0.4 | 9.3 | 0.05 | 0.01 | | | 792 |
| 616-01-011 | A horizon | 0-75 | 5.7 | 4.7 | 4.0 | 1.7 | 7.8 | 1.32 | 0.05 | 2.94 | 11 | 36 |
| 616-01-011 | E1 horizon | 75-500 | 6.0 | 4.4 | 5.2 | 0.8 | 8.0 | 0.04 | 0.00 | 0.07 | 20 | 16 |
| 616-01-011 | E2 horizon | 500-600 | 6.1 | 4.5 | 4.4 | 1.6 | 8.0 | 0.04 | 0.00 | 0.73 | 16 | 16 |
| 616-01-011 | E3 horizon | 600-700 | 4.0 | 3.8 | 2.6 | 1.4 | 8.0 | 0.05 | 0.00 | 0.35 | 85 | 90 |
| 616-01-014 | A horizon | 0-50 | 6.4 | 5.7 | 4.8 | 1.7 | 8.3 | 0.41 | 0.01 | 1.23 | 11 | 37 |
| 616-01-014 | E1 horizon | 50-300 | 6.1 | 5.2 | 5.2 | 0.9 | 8.0 | 0.09 | 0.00 | 0.39 | 48 | 23 |
| 616-01-014 | E2 horizon | 300-650 | 6.4 | 5.6 | 5.5 | 0.9 | 10.3 | 0.07 | 0.01 | 1.01 | 18 | 19 |
| 616-01-014 | Coffee rock | 650-800 | 6.3 | 5.7 | 5.3 | 1.0 | 10.4 | 0.10 | 0.01 | 1.00 | 28 | 61 |
| 616-01-014 | C1 horizon | 800-900 | 6.3 | 5.4 | 5.4 | 0.9 | 10.3 | 0.07 | 0.00 | 1.33 | 18 | 17 |
| 616-01-014 | C2 horizon | 900-1000 | 6.4 | 5.5 | 5.4 | 1.0 | 10.8 | 0.13 | 0.01 | 0.41 | 25 | 20 |
| 616-01-014 | C3 horizon | 1000-1200 | 6.3 | 5.2 | 5.4 | 0.9 | 9.1 | 0.02 | 0.00 | 0.30 | 32 | 16 |
| 616-01-014 | C4 horizon | 1200-1300 | 5.0 | 4.1 | 4.9 | 0.2 | 9.3 | 0.02 | 0.00 | 0.69 | 32 | 23 |
| 616-01-018 | A horizon | 0-25 | 7.4 | 6.6 | 5.3 | 2.1 | 8.7 | 0.31 | 0.01 | 2.14 | 11 | 40 |
| 616-01-018 | E1 horizon | 25-200 | 4.4 | 3.6 | 3.7 | 0.6 | 7.9 | 0.55 | 0.01 | 2.02 | 32 | 39 |
| 616-01-018 | E2 horizon | 200-300 | 4.4 | 3.7 | 4.4 | 0.0 | 8.2 | 0.65 | 0.01 | 1.18 | 44 | 32 |
| 616-01-018 | E3 horizon | 300-400 | 4.8 | 3.9 | 4.6 | 0.2 | 8.1 | 0.22 | 0.01 | 0.83 | 44 | 27 |
| 616-01-018 | Coffee rock | 400-450 | 4.2 | 4.0 | 3.8 | 0.3 | 11.5 | 1.40 | 0.03 | 1.15 | 44 | 56 |
| 616-01-018 | 2E horizon | 450-600 | 4.6 | 4.2 | 4.0 | 0.6 | 10.1 | 0.21 | 0.01 | 0.31 | 29 | 39 |
| 616-01-018 | 2Coffee rock1 | 600-700 | 5.3 | 4.5 | 3.0 | 2.3 | 10.7 | 0.30 | 0.01 | 0.76 | 22 | 42 |
| 616-01-018 | 2Coffee rock2 | 700-800 | 5.0 | 4.5 | 3.9 | 1.1 | 11.7 | 0.67 | 0.01 | 0.70 | 46 | 49 |
| 616-01-019 | A horizon | 0-50 | 4.7 | 3.2 | 3.1 | 1.7 | 7.6 | 0.58 | 0.02 | 0.79 | 43 | 26 |
| 616-01-019 | E1 horizon | 50-200 | 5.4 | 3.7 | 4.1 | 1.3 | 8.1 | 0.09 | 0.01 | 0.62 | 11 | 20 |
| 616-01-019 | E2 horizon | 200-250 | 6.1 | 4.5 | 2.8 | 3.3 | 8.4 | 0.14 | 0.01 | 1.11 | 13 | 23 |
| 616-01-019 | B horizon | 250-300 | 4.2 | 4.0 | 3.5 | 0.7 | 12.1 | 2.19 | 0.06 | 1.13 | 74 | 74 |

*pH $H_2O_2$ adjusted to 5.5, ** Δ pH = pH $H_2O$-pH $H_2O_2$, *** pH NaF adjusted to 8.2, **** Turbidimetric method (0.5 N ammonium chloride extraction)

**Table 1** (Cont.) chemical properties of soil samples.

| Site | Horizon | Depth (cm) | pH $H_2O$ | pH $CaCl_2$ | pH $H_2O_2$* | ΔpH** | pH NaF*** | C | N | CEC | $SO_4^{2-}$**** | EC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | (--------%-------) | | meq/100g | mg $kg^{-1}$ | (µS/cm) |
| 616-01-023 | A horizon | 0-25 | 8.8 | 7.8 | 5.9 | 2.9 | 8.7 | 0.13 | 0.02 | 2.30 | 10 | 81 |
| 616-01-023 | E horizon | 25-100 | 6.6 | 5.0 | 4.4 | 2.2 | 8.4 | 0.05 | 0.01 | 0.51 | 46 | 35 |
| 616-01-023 | B horizon | 100-200 | 5.1 | 4.2 | 4.4 | 0.8 | 9.5 | 0.06 | 0.01 | 0.34 | 18 | 22 |
| 616-01-023 | C1 horizon | 200-300 | 5.8 | 4 5 | 4.2 | 1.6 | 10.4 | 0.13 | 0.02 | 0.30 | 15 | 20 |
| 616-01-023 | C2 horizon | 300-500 | 4.7 | 4.3 | 3.8 | 0.9 | 8.8 | 0.02 | 0.01 | 0.07 | 23 | 37 |
| 616-01-023 | C3 horizon | 500-1000 | 4.9 | 4.2 | 3.3 | 1.5 | 8.9 | 0.03 | 0.01 | 0.64 | 34 | 43 |
| 616-01-024 | A horizon | 0-25 | 6.0 | 4.4 | 3.8 | 2.2 | 7.5 | 1.01 | 0.03 | 3.12 | 10 | 35 |
| 616-01-024 | E horizon | 25-150 | 5.4 | 3.8 | 3.8 | 1.7 | 7.9 | 0.20 | 0.01 | 0.78 | 15 | 43 |
| 616-01-024 | B horizon | 150-200 | 4.8 | 3.8 | 3.8 | 1.1 | 9.1 | 0.35 | 0.02 | 1.59 | 13 | 25 |
| 616-01-024 | 2E horizon | 200-400 | 6.0 | 4.7 | 4.5 | 1.4 | 8.6 | 0.03 | 0.01 | 0.10 | 18 | 23 |
| 616-01-024 | 2B horizon | 400-500 | 5.5 | 4.4 | 3.3 | 2.2 | 11.7 | 0.83 | 0.02 | 1.34 | 19 | 39 |
| 616-01-024 | 3E horizon | 500-800 | 5.9 | 4.7 | 4.3 | 1.6 | 8.7 | 0.04 | 0.01 | 0.89 | 19 | 124 |
| 616-02-028 | B horizon | 30-100 | 3.5 | 3 5 | 2.6 | 0.9 | 9.1 | 0.17 | 0.03 | 0.84 | 146 | 383 |
| 616-02-028 | Mud1 | 100-200 | 2.9 | 2.6 | 1.7 | 1.2 | 9.2 | 2.65 | 0.15 | 6.15 | 376 | 5540 |
| 616-02-028 | Mud2 | 200-250 | 7.3 | 7.3 | 6.1 | 1.2 | 11.2 | 4 53 | 0.16 | | | 4420 |
| 616-02-028 | Mud3 | 250-400 | 7.4 | 7.2 | 6.2 | 1.2 | 11.0 | 5.46 | 0.22 | | | 5800 |
| 616-02-028 | Mud4 | 400-600 | 7.4 | 7.2 | 3.5 | 3.9 | 10.8 | 3.02 | 0.17 | | | 5190 |
| 616-02-031 | A horizon | 0-75 | 5.3 | 3 9 | 3.9 | 1.4 | 7.5 | 2.29 | 0.08 | 5.26 | 5 | 23 |
| 616-02-031 | E horizon | 75-200 | 5.5 | 4.0 | 5.1 | 0.4 | 7.9 | 0.08 | 0.00 | 0.48 | 0.48 | 18 |
| 616-02-031 | Coffee rock1 | 200-300 | 5.5 | 4 5 | 3.6 | 1.9 | 11.3 | 2.04 | 0.06 | 5.78 | 51 | 647 |
| 616-02-031 | Coffee rock2 | 200-300 | 5.7 | 4 5 | 3.9 | 1.8 | 11.3 | 1.65 | 0.04 | 3.93 | 96 | 466 |
| 616-02-031 | 2E horizon | 300-400 | 4.1 | 4.1 | 1.9 | 2.3 | 9.0 | 0.08 | 0.00 | 0.16 | 225 | 168 |
| 616-02-031 | 2Coffee rock1 | 400-500 | 5.5 | 4.7 | 2.1 | 3.5 | 10.9 | 0.49 | 0.01 | 1.83 | 367 | 206 |
| 616-02-031 | 2Coffee rock2 | 500-600 | 6.1 | 4.8 | 3.1 | 2.9 | 10.9 | 0.56 | 0.01 | 1.74 | 262 | 135 |
| 616-02-032 | A horizon | 0-50 | 8.4 | 7.3 | 6.0 | 2.4 | 10.0 | 0.72 | 0.02 | 3.02 | 11 | 120 |
| 616-02-032 | E horizon | 50-200 | 4.2 | 3.6 | 4.2 | 0.1 | 7.8 | 0.28 | 0.00 | 0.41 | 45 | 65 |
| 616-02-032 | Coffee rock1 | 160 | 4.0 | 3.0 | 3.0 | 1.0 | 6.8 | 2 99 | 0.05 | 5.46 | 44 | 61 |
| 616-02-032 | Coffee rock2 | 200-300 | 4.1 | 3.6 | 3.0 | 1.1 | 10.5 | 2.62 | 0.05 | 2.38 | 48 | 60 |
| 616-02-032 | 2E1 horizon | 300-350 | 4.1 | 3.2 | 3.1 | 1.0 | 7.5 | 0.84 | 0.02 | 1.66 | 62 | 82 |
| 616-02-032 | 2E2 horizon | 350-400 | 4.6 | 3.4 | 3.1 | 1.5 | 7.6 | 1.03 | 0.02 | 2.01 | 40 | 55 |
| 616-02-058 | B horizon | 300-500 | 5.1 | 3 5 | 2.5 | 2.6 | 6.8 | 3.27 | 0.07 | 4.65 | 30 | 61 |
| 616-02-065 | B horizon | 200 | 5.4 | 4 9 | 3.6 | 1.8 | 10.9 | 2.16 | 0.13 | 5.72 | 115 | 128 |
| 616-02-065 | Peat/ E horizon (PETZ) | 0-20 | 5.6 | 4 9 | 3.9 | 1.8 | 11.5 | 2.60 | 0.13 | 7.29 | 61 | 267 |
| 616-02-065 | Peat/ E horizon (PETZ) | 20-180 | 5.1 | 4 5 | 3.9 | 1.2 | 11.1 | 1.63 | 0.05 | | | 87 |
| 616-02-065 | B1 horizon | 180-350 | 3.2 | 3 5 | 2.2 | 1.0 | 9.5 | 0.19 | 0.02 | | | 167 |
| 616-02-065 | B2 horizon | 350-480 | 3.4 | 3.6 | 2.3 | 1.2 | 9.5 | 0.44 | 0.02 | | | 171 |
| 616-02-065 | Coffee rock1 | 480-560 | 4.5 | 4.2 | 3.0 | 1.5 | 11.5 | 1 91 | 0.04 | 4.75 | 85 | 263 |
| 616-02-065 | Coffee rock2 | 560-650 | 4.8 | 4.4 | 3.3 | 1.5 | 11.7 | 0 92 | 0.02 | | | 136 |
| 616-02-065 | Coffee rock3 | 650-700 | 4.5 | 4.2 | 2.8 | 1.7 | 11.0 | 0.42 | 0.02 | 1.00 | 120 | 136 |
| 616-02-065 | Coffee rock4 | 700-800 | 4.2 | 4.1 | 2.5 | 1.7 | 10.8 | 0.64 | 0.02 | | | 185 |

*pH $H_2O_2$ adjusted to 5.5, ** Δ pH = pH $H_2O$-pH $H_2O_2$, *** pH NaF adjusted to 8.2, **** Turbidimetric method (0.5 N ammonium chloride extraction)

**Table 1** (Cont.) chemical properties of soil samples.

| Site | Horizon | Depth (cm) | pH $H_2O$ | pH $CaCl_2$ | pH $H_2O_2$* | ΔpH** | pH NaF*** | C | N | CEC | $SO_4^{2-}$**** | EC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | (--------%-------) | | meq/100g | mg $kg^{-1}$ | (µS/cm) |
| 616-02-068 | B horizon | 450 | 3.2 | 3.5 | 2.2 | 0.9 | 10.0 | 0.09 | 0.02 | 0.21 | 62 | 173 |
| 616-02-068 | A horizon | 0-75 | 6.0 | 4.5 | 3.8 | 2.2 | 8.0 | 0.24 | 0.02 | 0.82 | 48 | 45 |
| 616-02-068 | E1 horizon | 75-300 | 6.4 | 5.2 | 5.1 | 1.3 | 8.0 | 0.03 | 0.01 | 0.08 | 18 | 35 |
| 616-02-068 | E2 horizon | 300-375 | 6.4 | 5.4 | 2.1 | 4.4 | 8.8 | 0.09 | 0.01 | 0.59 | 74 | 54 |
| 616-02-068 | E3 horizon | 375-600 | 6.3 | 5.1 | 2.2 | 4.1 | 8.4 | 0.04 | 0.01 | 0.53 | 76 | 58 |
| 616-02-068 | A horizon | 0-25 | 5.1 | 4.2 | 3.9 | 1.2 | 9.3 | 0.31 | 0.02 | 0.17 | 77 | 18 |
| 616-02-068 | E horizon | 25-200 | 5.8 | 5.1 | 4.1 | 1.6 | 10.3 | 0.02 | 0.01 | 1.07 | 39 | 14 |
| 616-02-068 | coffee rock | 200-300 | 3.9 | 3.7 | 2.4 | 1.5 | 9.9 | 0.64 | 0.02 | 0.00 | 147 | 280 |
| 616-02-068 | B1 horizon | 300-400 | 3.4 | 3.4 | 2.5 | 0.9 | 10.0 | 0.09 | 0.01 | | 157 | 340 |
| 616-02-068 | B2 horizon | 400-500 | 3.1 | 3.4 | 2.2 | 0.9 | 9.9 | 0.07 | 0.01 | | | 355 |
| 616-02-068 | B3 horizon | 500-600 | 3.0 | 3.4 | 2.3 | 0.7 | 9.2 | 0.04 | 0.01 | 0.37 | 188 | 468 |
| 616-02-068 | B4 horizon | 600-700 | 2.7 | 2.9 | 2.1 | 0.5 | 9.0 | 0.05 | 0.01 | | | 812 |
| 616-02-068 | B5 horizon | 700-800 | 2.6 | 2.9 | 2.1 | 0.5 | 9.0 | 0.04 | 0.01 | | | 865 |
| 616-02-071 | E horizon | 25-350 | 6.9 | 6.1 | 5.3 | 1.6 | 8.1 | 0.06 | 0.01 | 0.44 | 15 | 50 |
| 616-02-071 | B horizon | 350-600 | 5.8 | 4.4 | 1.8 | 4.0 | 8.1 | 0.58 | 0.03 | 1.50 | 75 | 52 |
| 616-02-078 | B horizon | 400-500 | 3.2 | 3.6 | 2.2 | 1.0 | 9.7 | 0.14 | 0.02 | 0.21 | 122 | 142 |
| 616-02-080 | Coffee rock | 200-400 | 6.6 | 5.3 | 4.2 | 2.3 | 10.5 | 1.92 | 0.05 | 6.50 | 60 | 84 |
| 616-02-081 | B horizon | 400-800 | 3.0 | 3.4 | 2.0 | 1.0 | 9.1 | 0.22 | 0.03 | 0.40 | 66 | 341 |
| 616-02-082 | A horizon | 0-75 | 6.1 | 4.5 | 3.7 | 2.4 | 8.4 | 0.05 | 0.01 | 0.95 | 42 | 29 |
| 616-02-082 | E1 horizon | 75-200 | 5.4 | 4.2 | 3.1 | 2.3 | 8.4 | 0.06 | 0.01 | 0.43 | 46 | 31 |
| 616-02-082 | E2 horizon | 200-300 | 4.4 | 4.2 | 1.9 | 2.5 | 8.5 | 0.08 | 0.01 | 0.76 | 368 | 91 |
| 616-02-082 | B horizon | 300-400 | 4.5 | 4.2 | 2.1 | 2.4 | 8.6 | 0.08 | 0.01 | 0.50 | 327 | 121 |
| 616-02-082 | 2E horizon | 400-500 | 4.1 | 4.0 | 2.0 | 2.2 | 8.6 | 0.07 | 0.01 | 0.68 | 303 | 152 |
| 616-02-082 | Coffee rock | 500-600 | 4.1 | 4.1 | 1.9 | 2.2 | 8.8 | 0.10 | 0.01 | 1.00 | 617 | 183 |
| 616-02-085 | A horizon | 0-70 | 6.3 | 6.1 | 5.6 | 0.7 | 10.6 | 2.97 | 0.26 | 11.30 | 71 | 75 |
| 616-02-085 | B1 horizon | 100-300 | 4.6 | 4.2 | 3.0 | 1.6 | 10.0 | 0.16 | 0.03 | 2.53 | 73 | 99 |
| 616-02-085 | B2 horizon | 300-400 | 2.7 | 2.9 | 2.3 | 0.4 | 9.4 | 0.04 | 0.01 | 0.05 | 181 | 1320 |
| 616-02-085 | Mud | 400-600 | 6.5 | 6.1 | 3.1 | 3.5 | 10.4 | 2.55 | 0.14 | 10.15 | 134 | 2290 |
| 616-02-087 | Coffee rock1 | 200-300 | 6.1 | 5.1 | 3.9 | 2.2 | 12.0 | 2.31 | 0.05 | 2.56 | 43 | 77 |
| 616-02-087 | Coffee rock2 | 300-400 | 6.1 | 4.7 | 4.3 | 1.8 | 11.9 | 3.57 | 0.08 | 6.88 | 28 | 71 |
| 616-02-087 | B horizon | 500-600 | 6.0 | 4.8 | 2.2 | 3.8 | 8.3 | 0.25 | 0.01 | 0.78 | 76 | 48 |
| 616-02-094 | A1 horizon | 0-100 | 4.8 | 4.0 | 2.7 | 2.1 | 9.4 | 0.73 | 0.08 | 4.32 | 67 | 91 |
| 616-02-094 | A2 horizon | 100-175 | 4.6 | 3.8 | 3.0 | 1.6 | 9.9 | 0.14 | 0.02 | 2.24 | 61 | 72 |
| 616-02-094 | E horizon | 175-600 | 3.6 | 3.6 | 2.5 | 1.1 | 10.0 | 0.07 | 0.02 | 0.33 | 165 | 432 |
| 616-02-099 | E horizon | 25-200 | 6.2 | 5.4 | 4.9 | 1.3 | 10.2 | 0.53 | 0.06 | 2.08 | 109 | 86 |
| 616-02-099 | B1 horizon | 200-300 | 5.9 | 5.5 | 2.8 | 3.1 | 10.1 | 0.20 | 0.02 | 1.60 | 188 | 141 |
| 616-02-099 | B2 horizon | 300-400 | 2.7 | 2.5 | 2.0 | 0.7 | 9.0 | 0.37 | 0.02 | 0.00 | 389 | 1988 |
| 616-02-099 | 2E horizon | 400-600 | 3.3 | 3.0 | 2.5 | 0.7 | 9.0 | 0.02 | 0.00 | | | 456 |
| 616-02-100 | A horizon | 0-80 | 7.6 | 7.4 | 6.4 | 1.2 | 11.2 | 0.66 | 0.04 | 0.00 | 128 | 271 |
| 616-02-100 | Peat | 80-110 | 6.0 | 5.7 | 2.9 | 3.1 | 9.7 | 6.90 | 0.36 | 8.61 | 634 | 661 |
| 616-02-100 | Peat/ E horizon (PETZ) | 110-200 | 3.2 | 3.2 | 2.3 | 0.9 | 10.5 | 0.41 | 0.03 | 0.46 | 351 | 1189 |
| 616-02-100 | E horizon | 200-600 | 3.5 | 3.4 | 3.1 | 0.4 | 10.3 | 0.03 | 0.01 | 0.23 | 76 | 138 |

*pH $H_2O_2$ adjusted to 5.5, ** Δ pH = pH $H_2O$-pH $H_2O_2$, *** pH NaF adjusted to 8.2, **** Turbidimetric method (0.5 N ammonium chloride extraction)

**Table 1** (Cont.) chemical properties of soil samples.

| Site | Horizon | Depth (cm) | pH $H_2O$ | pH $CaCl_2$ | pH $H_2O_2$* | ΔpH** | pH NaF*** | C | N | CEC | $SO_4^{2-}$**** | EC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | (--------%-------) | | meq/100g | mg $kg^{-1}$ | (µS/cm) |
| 616-02-101 | A horizon | 0-75 | 8.0 | 7.0 | 5.9 | 2.1 | 10.5 | 0.40 | 0.03 | 2.79 | 310 | 92 |
| 616-02-101 | Peat1 | 150-200 | 7.6 | 7.7 | 6.4 | 1.2 | 10.9 | 20.29 | 0.98 | 11.92 | 217 | 858 |
| 616-02-101 | Peat/ E horizon (PETZ) | 200-350 | 6.5 | 6.1 | 4.0 | 2.5 | 8.7 | 7.88 | 0.60 | | | 389 |
| 616-02-101 | E horizon | 350-600 | 3.0 | 3.0 | 2.5 | 0.6 | 9.0 | 0.05 | 0.01 | 0.41 | 192 | 720 |
| 616-02-105 | A horizon | 0-160 | 7.4 | 7.0 | 5.4 | 2.0 | 11.0 | 1.59 | 0.08 | 7.49 | 99 | 101 |
| 616-02-105 | Peat | 250-360 | 2.4 | 2.1 | 1.5 | 0.9 | 6.4 | 34.69 | 1.22 | 8.00 | 667 | 11 |
| 616-02-105 | Peat/ E horizon (PETZ) | 360-480 | 2.9 | 2.7 | 1.8 | 1.0 | 8.9 | 0.51 | 0.03 | 1.24 | 362 | 11 |
| 616-02-105 | E horizon | 480-700 | 5.9 | 6.1 | 5.0 | 0.9 | 10.4 | 0.03 | 0.01 | 0.28 | 47 | 1494 |
| 616-02-106 | A horizon | 0-50 | 4.2 | 3.7 | 2.1 | 2.2 | 8.6 | 3.76 | 0.11 | 3.52 | 137 | 29 |
| 616-02-106 | E horizon | 50-700 | 3.3 | 3.0 | 2.5 | 0.8 | 9.2 | 0.04 | 0.01 | 0.00 | 196 | 547 |
| 616-02-110 | B horizon | 200-500 | 7.2 | 7.2 | 6.5 | 0.7 | 11.4 | 1.76 | 0.02 | 2.94 | 89 | 601 |
| 616-02-112 | B horizon | 25-80 | 8.6 | 7.9 | 8.1 | 0.5 | 11.5 | 0.00 | 0.86 | 4.96 | 115 | 901 |
| 616-02-112 | Mud | 125-200 | 8.9 | 8.4 | 7.7 | 1.2 | 11.5 | 11.44 | 0.11 | 5.57 | 135 | 1691 |
| 616-02-112 | Peat | 200-300 | 6.7 | 7.1 | 3.9 | 2.8 | 7.8 | 50.65 | 1.73 | 11.51 | 239 | 4 |
| 616-02-112 | Bb horizon | 300-400 | 8.0 | 7.7 | 6.8 | 1.2 | 11.1 | 1.51 | 0.04 | 6.83 | 155 | 669 |
| 616-02-112 | C horizon | 400-600 | 8.2 | 8.0 | 7.6 | 0.6 | 11.5 | 3.49 | 0.02 | 3.17 | 102 | 173 |
| 616-02-113 | A horizon | 0-50 | 6.1 | 6.6 | 3.6 | 2.5 | 9.4 | 1.75 | 0.12 | 4.83 | 213 | 118 |
| 616-02-113 | E1 horizon | 50-250 | 3.6 | 3.9 | 3.1 | 0.5 | 10.3 | 0.04 | 0.01 | | | 125 |
| 616-02-113 | E2 horizon | 250-300 | 2.8 | 2.7 | 2.2 | 0.6 | 9.3 | 0.07 | 0.02 | 0.00 | 294 | 1251 |
| 616-02-113 | E3 horizon | 300-600 | 2.8 | 2.6 | 2.2 | 0.6 | 9.0 | 0.04 | 0.01 | | | 1814 |
| 616-02-122 | E horizon | 20-235 | 5.7 | 5.0 | 4.3 | 1.4 | 10.1 | 0.19 | 0.02 | 0.73 | 136 | 49 |
| 616-02-122 | B horizon | 235-315 | 6.6 | 5.8 | 5.6 | 1.1 | 11.7 | 0.51 | 0.03 | 2.30 | 107 | 20 |
| 616-02-122 | 2E1 horizon | 315-375 | 5.0 | 4.7 | 3.4 | 1.6 | 10.5 | 0.06 | 0.01 | | | 40 |
| 616-02-122 | 2E2 horizon | 375-500 | 2.8 | 2.9 | 2.5 | 0.3 | 10.0 | 0.03 | 0.01 | 0.00 | 91 | 430 |
| 616-02-122 | 2E3 horizon | 500-700 | 3.4 | 3.5 | 2.8 | 0.6 | 10.3 | 0.02 | 0.01 | | | 395 |
| 616-02-122 | B/E horizon | 700-900 | 3.5 | 3.9 | 2.9 | 0.7 | 10.9 | 0.11 | 0.01 | 0.08 | 67 | 119 |
| 616-02-122 | 3E horizon | 900-1000 | 2.6 | 2.8 | 2.5 | 0.1 | 9.9 | 0.02 | 0.01 | | | 638 |
| 616-02-127 | E horizon | 40-100 | 5.1 | 4.6 | 4.5 | 0.6 | 11.7 | 0.20 | 0.02 | | | 50 |
| 616-02-127 | Coffee rock | 100-235 | 4.9 | 4.4 | 4.1 | 0.8 | 11.9 | 2.75 | 0.10 | 1.73 | 108 | 78 |
| 616-02-127 | 2E1 horizon | 235-300 | 4.1 | 4.4 | 3.2 | 0.8 | 10.9 | 0.07 | 0.01 | 0.21 | 77 | 50 |
| 616-02-127 | 2E2 horizon | 300-600 | 4.0 | 4.2 | 3.2 | 0.8 | 11.3 | 0.09 | 0.01 | | | 104 |
| 616-02-131 | A horizon | 0-50 | 6.3 | 5.8 | 4.8 | 1.5 | 11.5 | 0.22 | 0.03 | 1.21 | 47 | 22 |
| 616-02-131 | E horizon | 50-325 | 6.4 | 6.3 | 5.0 | 1.4 | 10.6 | 0.03 | 0.01 | 0.07 | 35 | 20 |
| 616-02-131 | B horizon | 325-425 | 5.2 | 4.4 | 3.7 | 1.4 | 10.5 | 0.22 | 0.03 | 6.15 | 69 | 72 |
| 616-02-131 | 2E horizon | 425-600 | 5.1 | 4.6 | 4.1 | 1.0 | 10.5 | 0.03 | 0.01 | 1.36 | 57 | 33 |
| 616-02-136 | A horizon | 0-25 | 5.8 | 5.0 | 4.8 | 1.0 | 9.0 | 0.40 | 0.02 | 1.35 | 167 | 68 |
| 616-02-136 | Coffee rock | 200-260 | 6.3 | 5.1 | 4.9 | 1.4 | 11.8 | 1.88 | 0.06 | 4.93 | 81 | 92 |
| 616-02-136 | E horizon | 260-600 | 3.0 | 2.8 | 2.4 | 0.6 | 9.6 | 0.08 | 0.02 | 0.99 | | 691 |
| 616-02-145 | E1 horizon | 50-300 | 6.2 | 6.3 | 4.9 | 1.3 | 10.5 | 0.02 | 0.02 | 0.00 | 27 | 16 |
| 616-02-145 | E2 horizon | 300-450 | 3.4 | 3.7 | 2.7 | 0.7 | 10.1 | 0.02 | 0.01 | 0.00 | 110 | 163 |
| 616-02-145 | B horizon | 450-475 | 4.9 | 4.8 | 3.6 | 1.3 | 11.1 | 0.50 | 0.03 | 2.10 | 85 | 150 |
| 616-02-145 | 2E horizon | 475-600 | 3.3 | 3.4 | 2.5 | 0.9 | 10.3 | 0.08 | 0.01 | 0.35 | 158 | 387 |

*pH $H_2O_2$ adjusted to 5.5, ** Δ pH = pH $H_2O$-pH $H_2O_2$, *** pH NaF adjusted to 8.2, **** Turbidimetric method (0.5 N ammonium chloride extraction)

**Table 1** (Cont.) chemical properties of soil samples.

| Site | Horizon | Depth (cm) | pH $H_2O$ | pH $CaCl_2$ | pH $H_2O_2$* | ΔpH** | pH NaF*** | C | N | CEC | $SO_4^{2-}$**** | EC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | (--------%------- | ) | meq/100g | mg $kg^{-1}$ | (µS/cm) |
| 616-02-155 | E horizon | 50-150 | 8.6 | 7.5 | 7.8 | 0.8 | 11.1 | 0.57 | 0.02 | 2.52 | 45 | 52 |
| 616-02-155 | 2E horizon | 200-500 | 3.2 | 3.1 | 2.2 | 1.0 | 9.5 | 0.11 | 0.01 | 2.03 | 229 | 699 |
| 616-02-155 | B horizon | 500-600 | 8.7 | 7.4 | 7.4 | 1.4 | 10.7 | 0.04 | 0.02 | 13.60 | 36 | 198 |
| 616-02-158 | E horizon | 25-225 | 4.8 | 4.0 | 4.1 | 0.7 | 10.1 | 0.09 | 0.01 | 0.00 | 41 | 8 |
| 616-02-158 | Coffee rock1 | 225-300 | 4.7 | 4.3 | 3.9 | 0.8 | 11.9 | 3.05 | 0.07 | 1.46 | 55 | 26 |
| 616-02-158 | Coffee rock2 | 300-400 | 3.6 | 3.8 | 2.5 | 1.1 | 10.7 | 2.20 | 0.05 | 2.36 | 125 | 299 |
| 616-02-174 | B horizon | 250-550 | 5.6 | 4.8 | 2.2 | 3.4 | 10.0 | 1.44 | 0.05 | 2.77 | 57 | 58 |
| 616-02-179 | B horizon | 375-400 | 3.9 | 4.3 | 2.8 | 1.1 | 10.7 | 0.09 | 0.02 | 0.46 | 84 | 64 |
| Ellenbrook | E horizon | 0-150 | 4.5 | 4.4 | 4.5 | 0.0 | 10.4 | 0.03 | 0.01 | 0.00 | 56 | 11 |
| Ellenbrook | Coffee rock | 150-200 | 4.0 | 4.3 | 3.1 | 0.9 | 11.9 | 0.77 | 0.03 | 1.92 | 118 | 163 |
| Ellenbrook | B horizon | 200-500 | 2.6 | 2.6 | 1.9 | 0.7 | 8.9 | 0.16 | 0.01 | | | 1069 |
| Ellenbrook | Coffee rock | 200 | 4.3 | 4.2 | 3.0 | 1.4 | 11.8 | 1.20 | 0.03 | | | 163 |
| Ellenbrook | 2B1 horizon | 500-550 | 2.5 | 2.5 | 1.9 | 0.6 | 8.6 | 0.20 | 0.02 | 0.00 | 406 | 1842 |
| Ellenbrook | 2B2 horizon | 500-600 | 2.7 | 2.6 | 1.9 | 0.8 | 8.8 | 0.19 | 0.01 | | | 1252 |
| Ellenbrook | Coffee rock | 150-200 | 4.6 | 4.1 | 2.9 | 1.7 | 11.8 | 1.78 | 0.04 | | | 62 |
| LOC50A | A horizon | 10-20 | 5.2 | 4.6 | 4.4 | 0.9 | 10.6 | 0.16 | 0.02 | 0.23 | 15 | 38 |
| LOC50A | A horizon | 0-100 | 5.4 | 4.3 | 3.7 | 1.8 | 8.9 | 0.16 | 0.01 | 1.19 | 29 | 28 |
| LOC50A | E horizon | 300-400 | 4.8 | 3.9 | 4.2 | 0.6 | 9.4 | 0.34 | 0.01 | 0.88 | 21 | 34 |
| LOC50A | Coffee rock | 400-500 | 3.7 | 3.4 | 3.3 | 0.4 | 7.8 | 0.83 | 0.02 | 1.45 | 53 | 136 |

*pH $H_2O_2$ adjusted to 5.5, ** Δ pH = pH $H_2O$-pH $H_2O_2$, *** pH NaF adjusted to 8.2, **** Turbidimetric method (0.5 N ammonium chloride extraction)

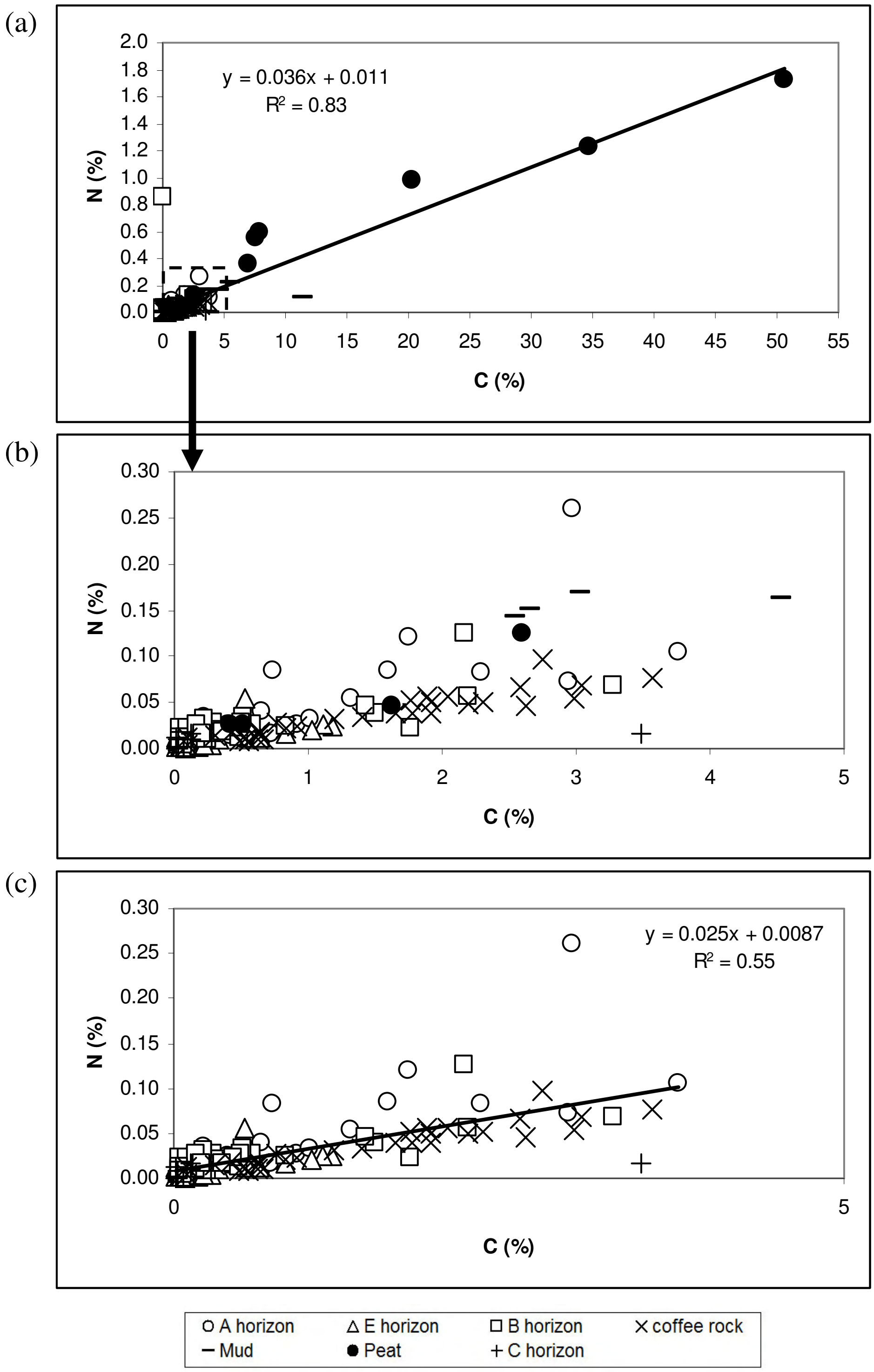



**Figure 4** Bivariate relationships between carbon and nitrogen for (a) all soil samples, (b) soil samples with carbon ranging from 0.0-5.0% and nitrogen ranging from 0.0-0.3% and (c) A, E, B, coffee rock and C horizons.

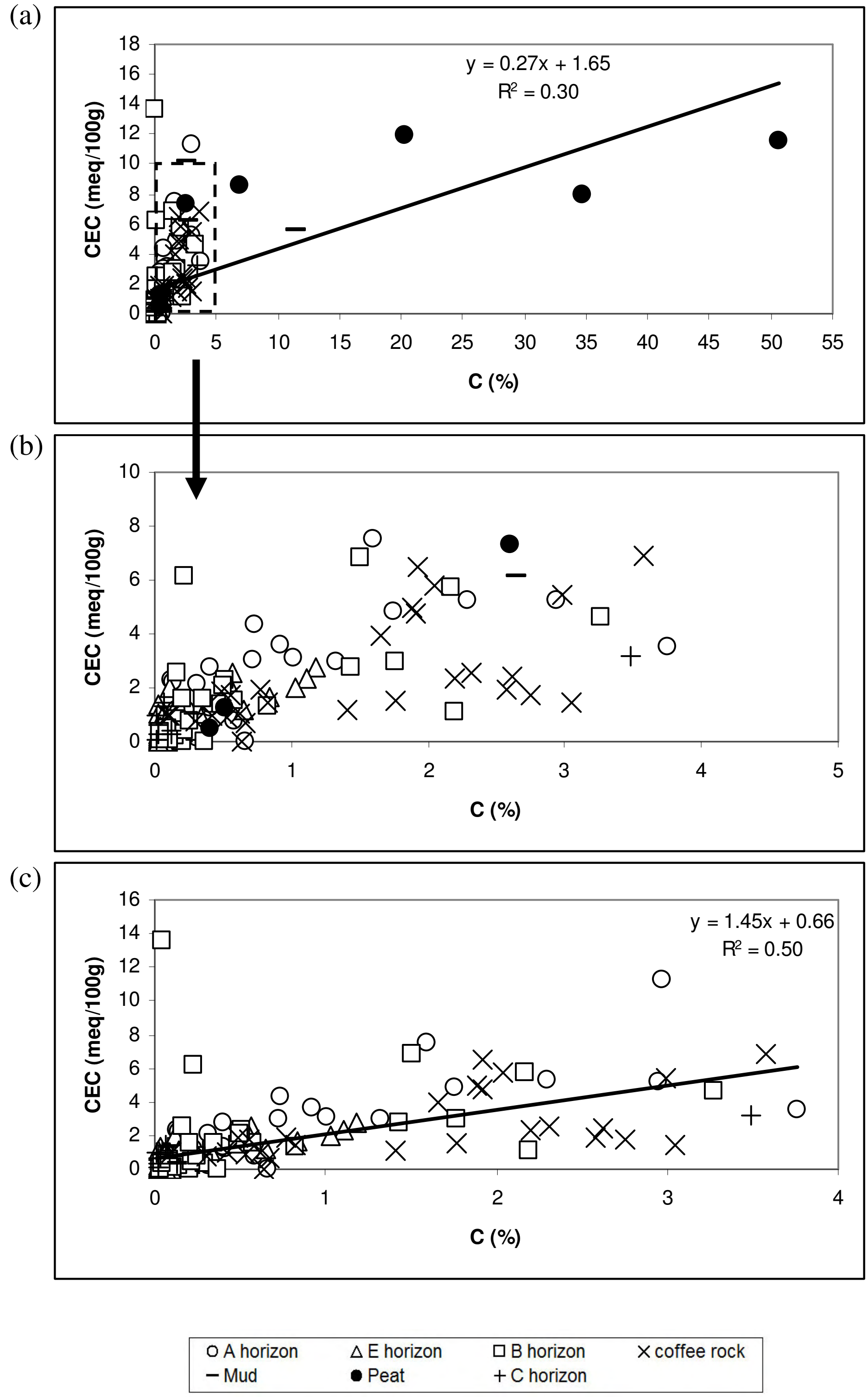



**Figure 5** Bivariate relationships between carbon and cation exchange capacity for (a) all soil samples, (b) some soil samples with carbon ranging from 0.0-5.0% and cation exchange capacity ranging from 0.0-10.0 meq/100g and (c) A, E, B, coffee rock and C horizons.

### 5.2 Micromorphological and mineralogical properties

Scanning electron microscopy showed that all soil horizons consist mainly of rounded quartz grains with some horizons containing various amounts of alumino-silicate organic matter complex which contains small amounts of sulfur (Figure 6). The X-ray spectra of particles indicate that this sulfur is probably mostly present as pyrite; some of the iron content is also in iron oxides and probably iron is also in the structure of the alumino-silicate. Some coffee rock does not contain ferruginous cemented material (Figure 6) as the cemented material consists only of alumino-silicate and organic matter. In some cases coffee rock samples have a matrix mainly consisting of alumino-silicate mixed with organic matter and ferruginous cemented material (Figure 2).

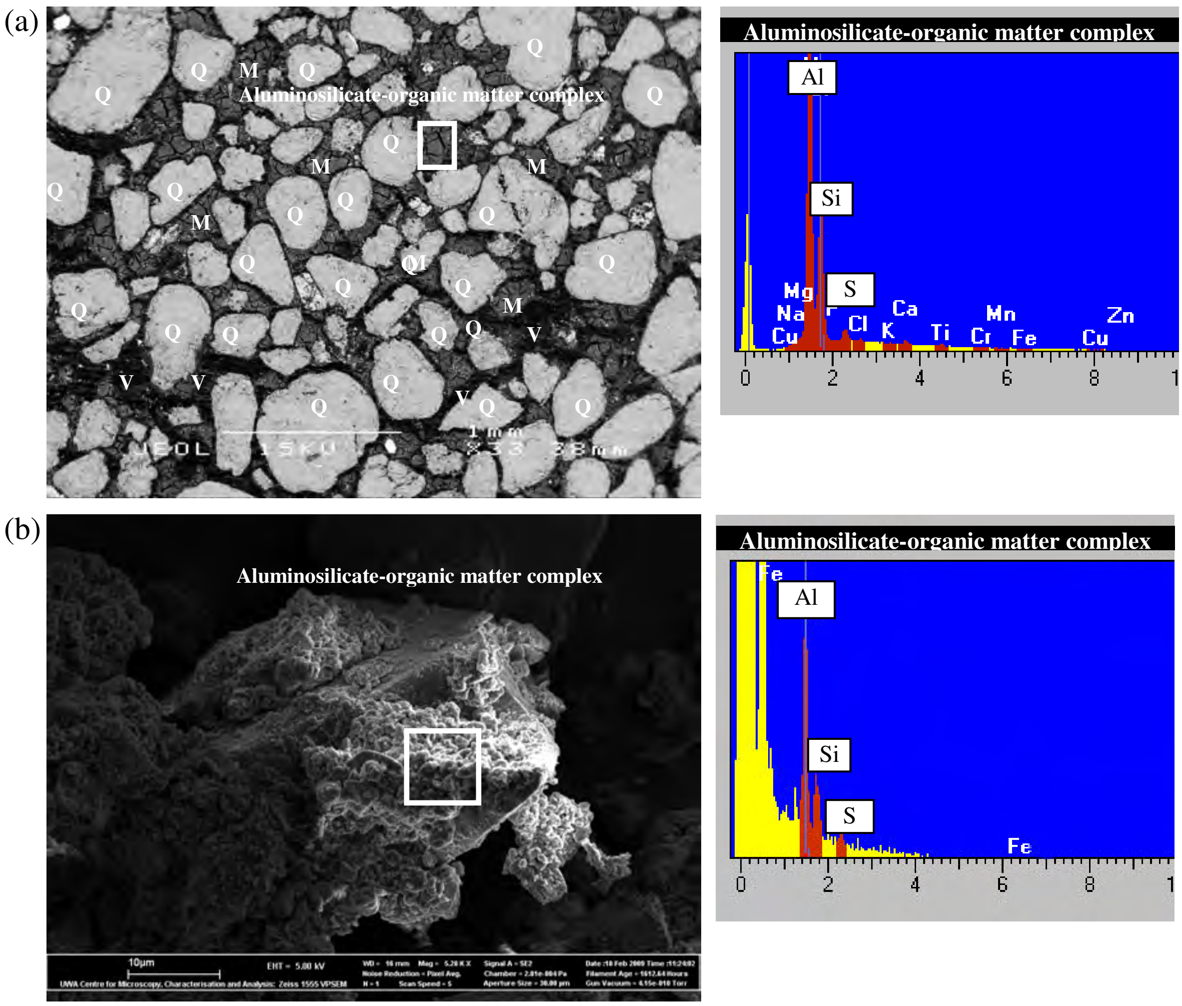
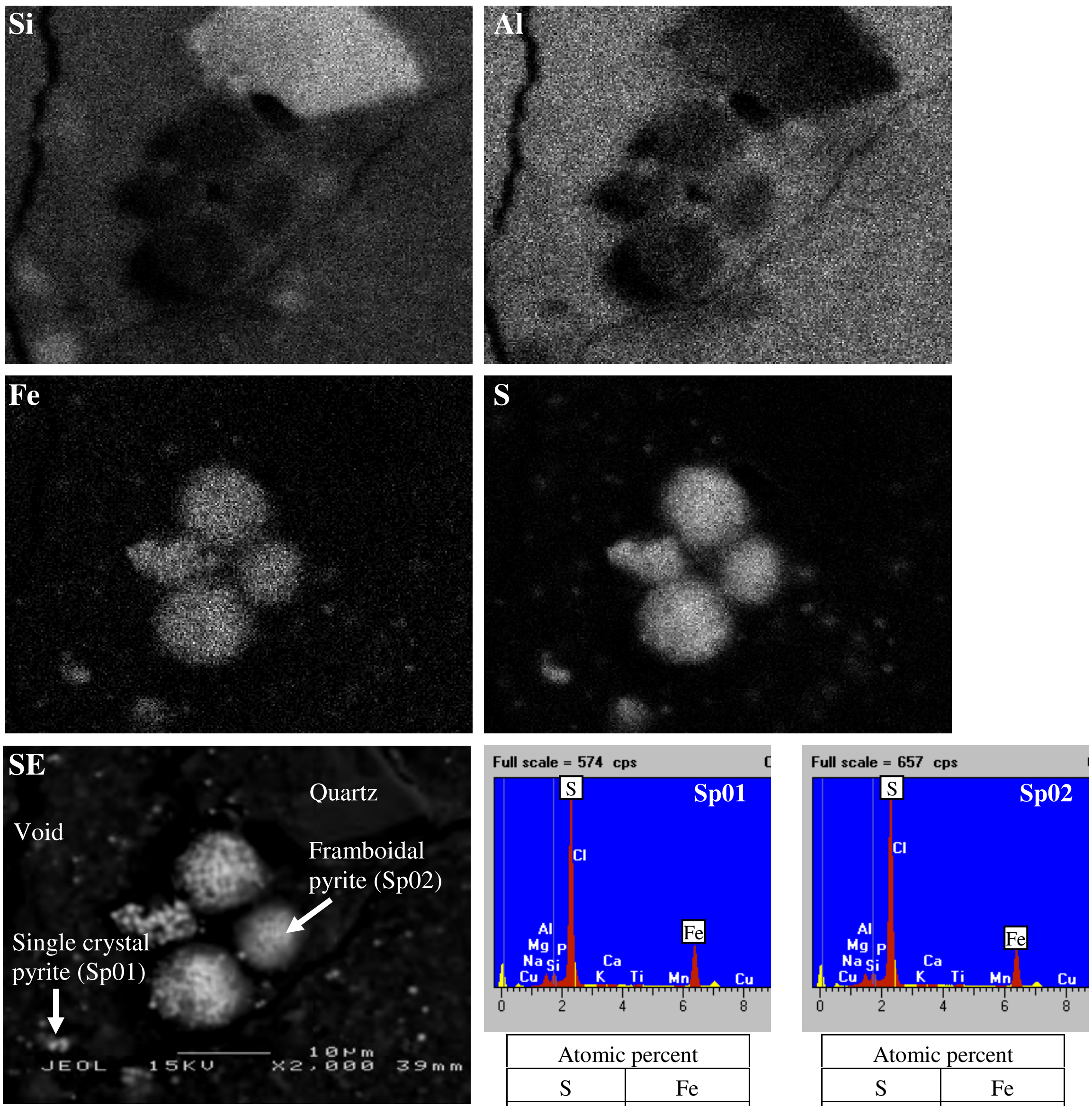



**Figure 6** (a) SEM backscattered electron image and x-ray spectrum of a thin section from coffee rock (9.0-1.0 m) site 616-01-05 (N.B. this is a palaeopodosol-coffee rock horizon) ($pH_F$ = 6.2, $pH_{FOX}$ = 4.5, $S_{CR}$ = <0.02%). (b) SEM secondary electron image and x-ray spectrum of fine fraction from coffee rock (3.0-4.0 m) site 616-02-087 ($pH_F$ = 6.1, $pH_{FOX}$ = 4.1, No $S_{CR}$ data) (Q = quartz, M = matrix, V = void).

Iron sulfide is present in E, B, coffee rock, mud, peat horizons as various size and shape particles including 1-10 μm framboids (Bush and Sullivan, 1999) and single crystal pyrite (≤ 1 μm) (Figure 7). Framboidal pyrite is present in this example of coffee rock (5.0-6.0 m, site 616-02-82) together with single crystals of pyrite, which are very small (≤ 1 μm), have high surface area and are thus potentially very reactive. Pyrite occurs in all E, B and coffee rock horizons examined. The iron to sulfur ratio of these particles is consistent with pyrite (Fe: S ≈ 1: 2) (Figures 7-10) (Shamshuddin *et al*., 2004).




| Atomic percent | |
|---|---|
| S | Fe |
| 63 | 37 |

Atomic ratio Fe: S≈ 1: 2

| Atomic percent | |
|---|---|
| S | Fe |
| 64 | 36 |

Atomic ratio Fe: S≈ 1: 2

**Figure 7** SEM secondary electron image, element mapping and x-ray spectra of the fine fraction from coffee rock (5.0-6.0 m, site 616-02-82) deposited on a stub ($pH_F$ = 6.9, $pH_{FOX}$ = 1.3, $S_{CR}$ = 0.26%).

Transmission electron microscope results for the fine fraction of these soils shows the crystal morphology of pyrite crystals from E, B and coffee rock horizons and x-ray spectra confirm the atomic ratio of Fe: S ≈ 1: 2 indicative of pyrite (Figures 8-10). Elemental sulfur is a minor constituent of some B horizon and coffee rock samples (Figure 11) with an atomic ratio of Fe: S ≈ 0: 1 (Boman *et al*., 2008). The X-ray spectra of single crystals of pyrite obtained by SEM and TEM contain peaks from silicon and aluminium from the soil matrix surrounding the pyrite particles. However, the iron to sulfur ratio is consistently that of pyrite (Fe: S ≈ 1: 2). Electron diffraction patterns obtained for single crystals in the TEM can be indexed by reference to the pyrite unit cell which confirms the identify of pyrite (Figure 12a). Jarosite is present in some A horizon samples (Figures 12b and 13).

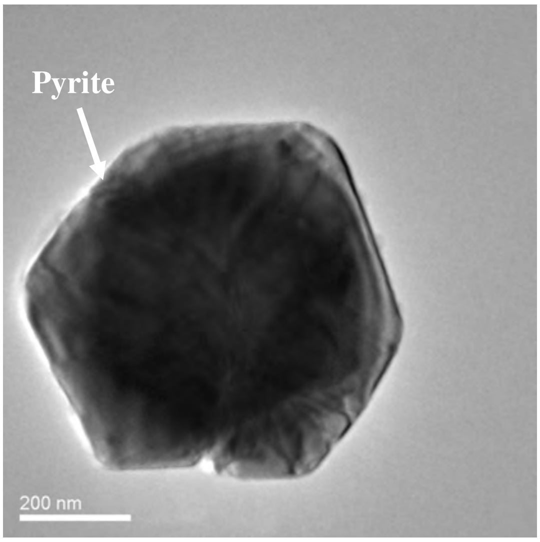
Microcrystalline kaolin crystals occur in E, B and coffee rock horizons (Figures 8-11). A representative TEM micrograph of kaolin crystals from coffee rock (5.25-5.75 m, site 616-02-82) is shown in Figure 10b together with the corresponding EDX spectrum. In this micrograph many platy kaolin crystals are viewed perpendicular to their cleavage. The chemical composition of the indicated crystal is provided by the EDX spectrum and is consistent with kaolin (Al: Si = 1: 1).

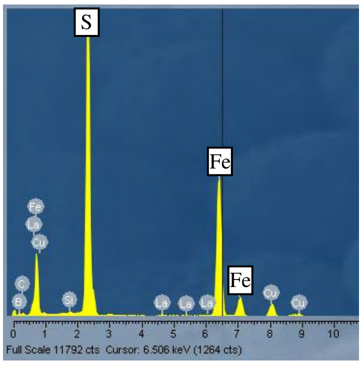
Scanning electron microscope and transmission electron microscope results for the fine fractions show that iron sulfide is present in all water logged soil horizons that recorded $pH_{FOX}$ <3. It occurs as particles of various sizes and shapes including 1-10 µm framboids and single crystal pyrite (≤ 1 µm) which have high surface area and are thus potentially very reactive. Some materials directly above the groundwater level can contain small amount of pyrite and can become acidic when oxidized (Figure 14).

Framboidal pyrite may occur as a result of the activity of bacteria and in association with organic substrate, whereas single crystals (euhedral and anhedral pyrite) may be formed solely by chemical reaction. Therefore, soil horizons with a high organic matter content (including B and coffee rock horizon) contain framboidal pyrite and single crystal pyrite but soil horizons with a low organic matter content (E horizon) contain euhedral and anhedral single crystals of pyrite. All low $pH_{FOX}$ samples investigated in this study contained pyrite while no pyrite was detected in surface horizons where $pH_{FOX}$ was above 3. Pyrite occurred across all horizons where $pH_{FOX}$ was low suggesting pyrite formation is not related to recent pedogenetic processes. Understanding pyrite micromorphology and consequent pyrite oxidation behaviour in acid sulfate soils are very important for management.

E horizon

(a)



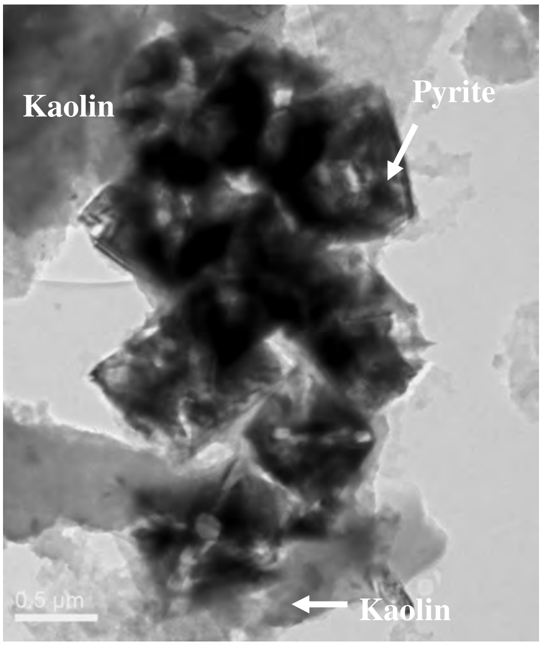



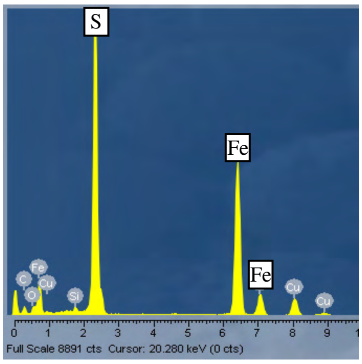

| Atomic percent | |
|---|---|
| Fe | S |
| 30 | 70 |

Atomic ratio Fe: S ≈ 1: 2

E horizon

(b)



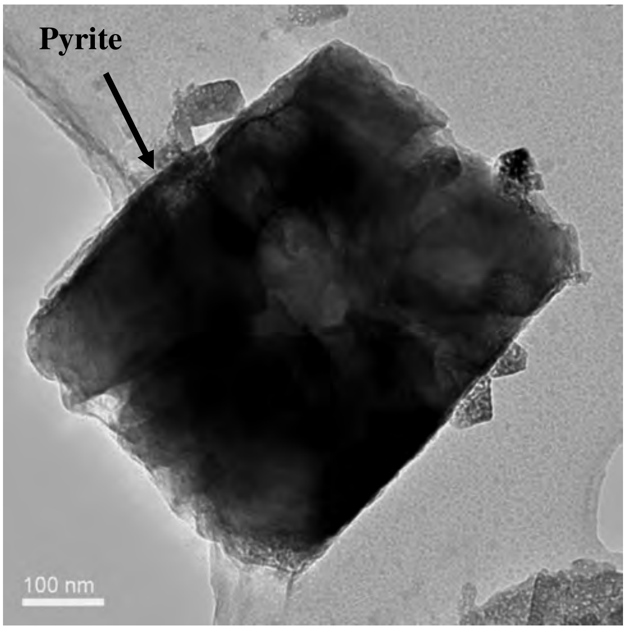

| Atomic percent | |
|---|---|
| Fe | S |
| 37 | 63 |

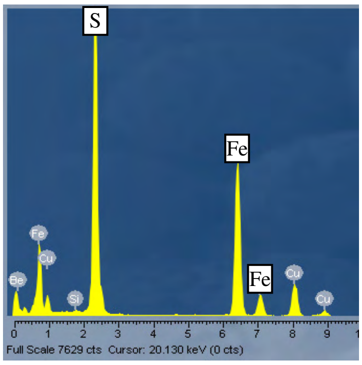
Atomic ratio Fe: S ≈ 1: 2

**Figure 8** TEM transmission electron micrograph and x-ray spectrum of pyrite crystals from the fine fraction from (a) E horizon 1.75-3.5 m, site 616-02-71) ($pH_F$ = 6.5, $pH_{FOX}$ = 4.2, No $S_{CR}$ data) and (b) E horizon (3.0-3.75 m, site 616-02-68) ($pH_F$ = 6.6, $pH_{FOX}$ = 1.7, $S_{CR}$ = <0.02%).

B horizon

(a)



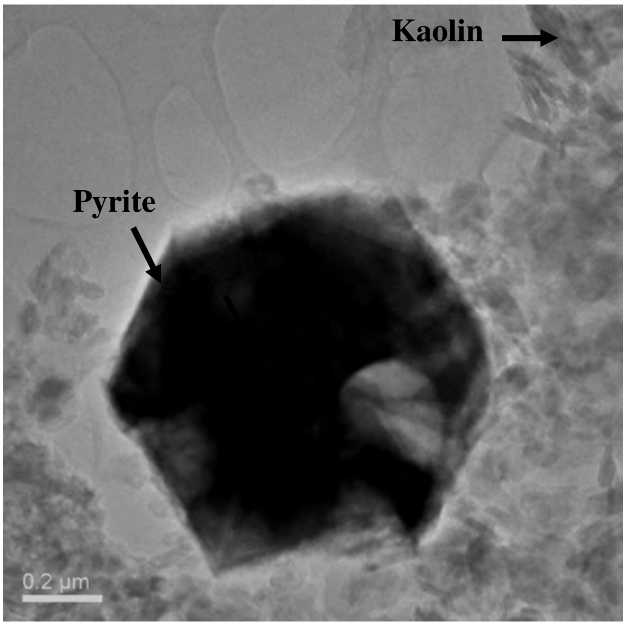



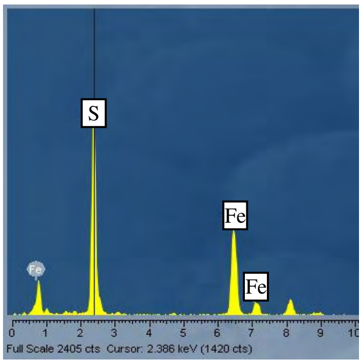

| Atomic percent | |
|---|---|
| Fe | S |
| 30 | 70 |

Atomic ratio Fe: S ≈ 1: 2

Coffee rock

(b)



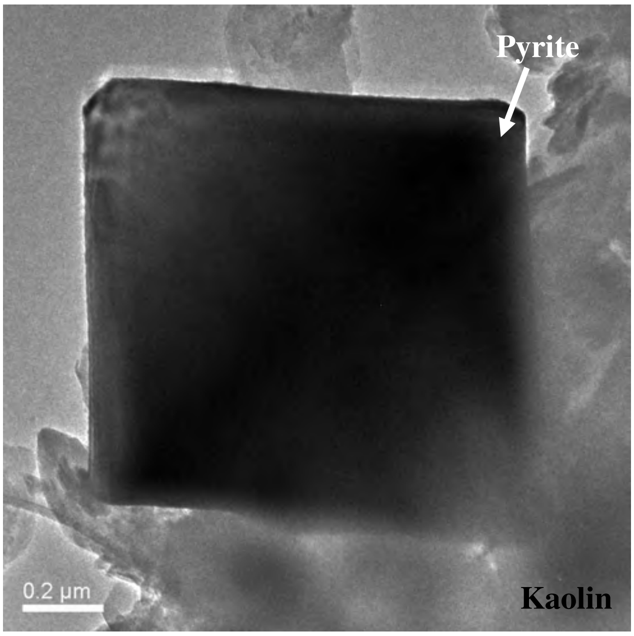

| Atomic percent | |
|---|---|
| Fe | S |
| 40 | 60 |

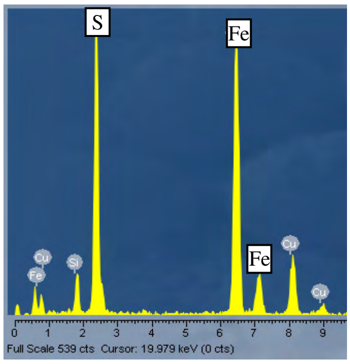
Atomic ratio Fe: S ≈ 1: 2

**Figure 9** TEM transmission electron micrograph and x-ray spectrum of pyrite crystals of the fine fraction from (a) B horizon (3.5-6.5 m, site 616-02-71) ($pH_F$ = 5.9, $pH_{FOX}$ = 2.8, $S_{CR}$ = < 0.10%) and (b) coffee rock (5.0-6.0 m, site 616-02-82) ($pH_F$ = 6.9, $pH_{FOX}$ = 1.3, $S_{CR}$ = 0.26%).

Coffee rock

(a)



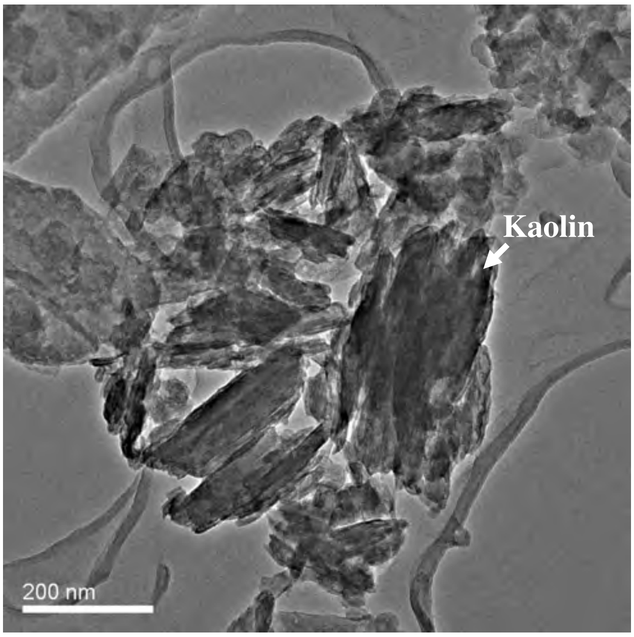



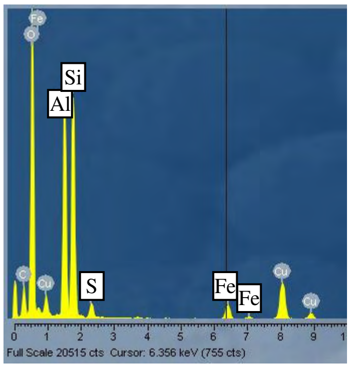

| Atomic percent | |
|---|---|
| Fe | S |
| 35 | 65 |

Atomic ratio Fe: S ≈ 1: 2

Coffee rock

(b)



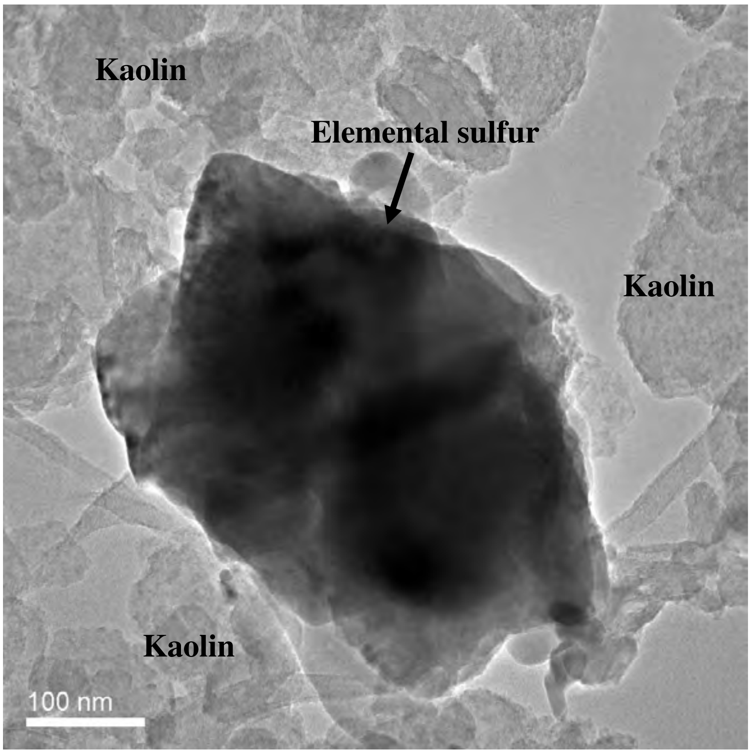

| Atomic percent | | | |
|---|---|---|---|
| Al | Si | S | Fe |
| 47 | 47 | 3 | 3 |

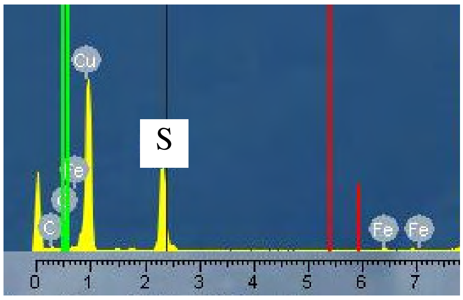
Atomic ratio Al: Si ≈ 1: 1

**Figure 10** TEM transmission electron micrograph and x-ray spectrum of (a) an octahedral pyrite crystal from the fine fraction from coffee rock (2.25-4.0 m, site 616-02-80) ($pH_F$ = 3.9, $pH_{FOX}$ = 2.1, $S_{CR}$ = < 0.02%) and (b) a platy kaolin crystal from coffee rock viewed perpendicular to its cleavage (5.0-6.0 m, site 616-02-82) in an aggregate of kaolin crystals ($pH_F$ = 6.9, $pH_{FOX}$ = 1.3, $S_{CR}$ = 0.26%).

Coffee rock

(a)

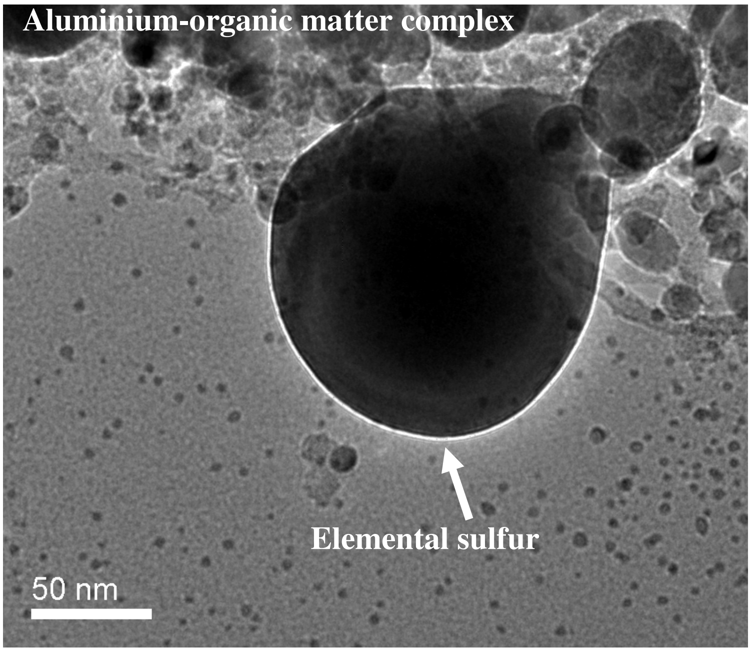



| Atomic percent | |
|---|---|
| S | Fe |
| 100 | 0 |

B horizon

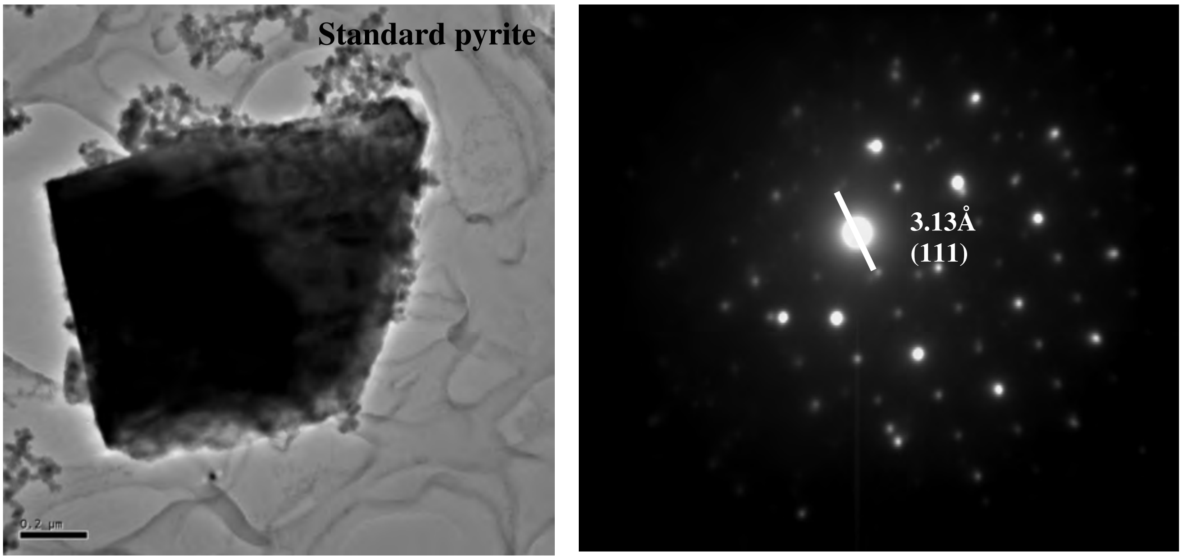
(b)

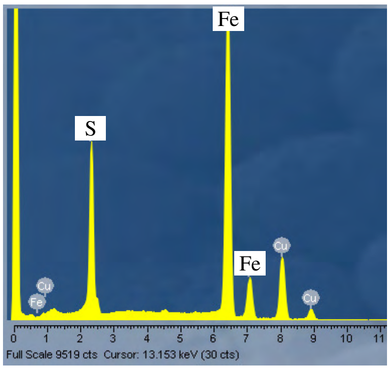



| Atomic percent | |
|---|---|
| S | Fe |
| 100 | 0 |

**Figure 11** TEM transmission electron micrograph and x-ray spectrum of elemental sulfur particles from (a) coffee rock (5.0-6.0 m, site 616-02-82) ($pH_F$ = 6.9, $pH_{FOX}$ = 1.3, $S_{CR}$ = 0.26 %)., (b) B horizon (3.0-5.0 m, site 616-02-58) ($pH_F$ = 4.9, $pH_{FOX}$ = 1.9, $S_{CR}$ = <0.02%). (Cu radiation is from the supporting grid).

(a)

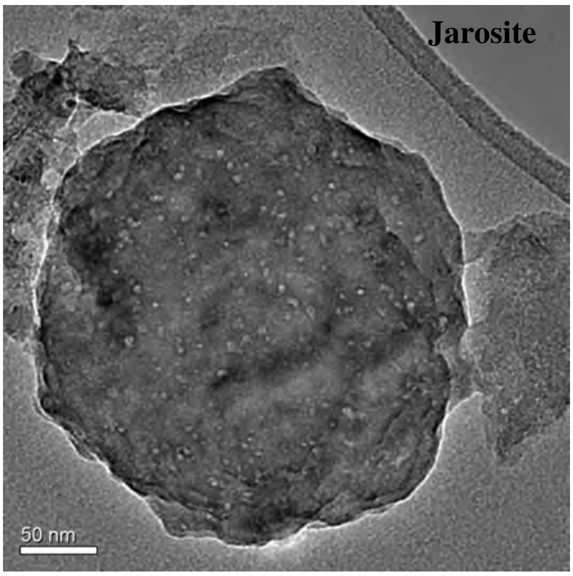


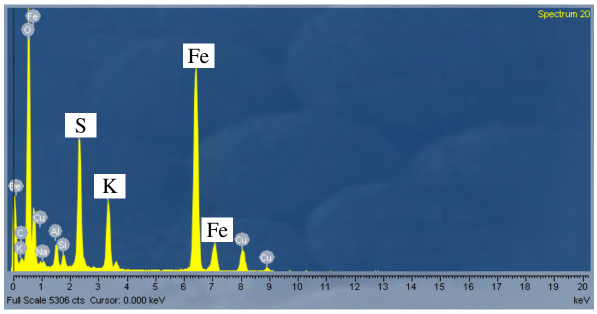




| Atomic Percent | |
|---|---|
| Fe | S |
| 33 | 67 |

Atomic ratio Fe: S ≈ 1: 2

(b)



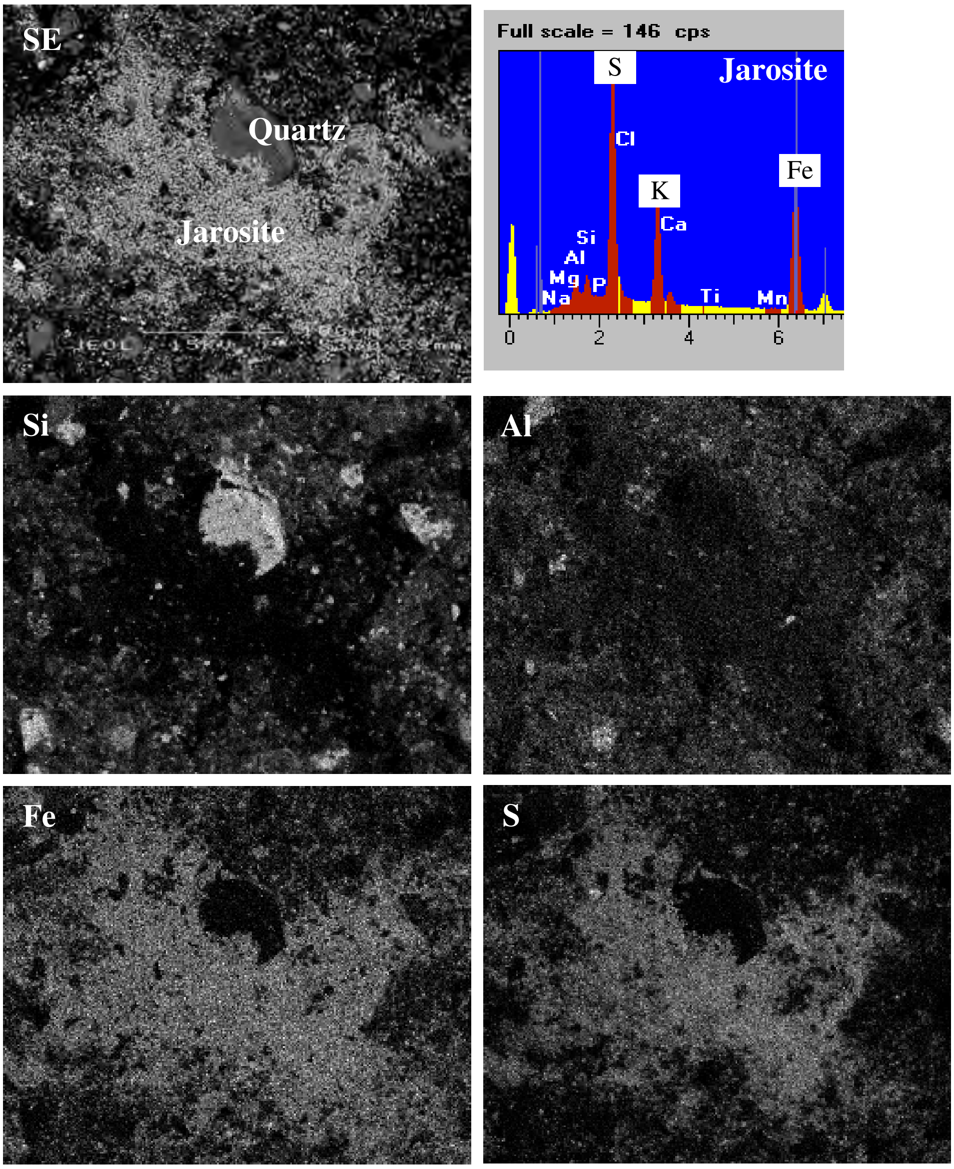



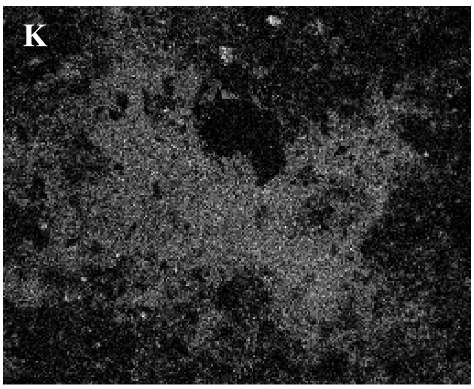

| Atomic percent | | |
|---|---|---|
| K | Fe | S |
| 4.1 | 12.4 | 8.7 |

Atomic ratio K: Fe: S ≈ 1: 3: 2

Jarosite chemical formula = $K_2O$ $3Fe_2O_3$ $4SO_3.6H_2O$

**Figure 12** (a) TEM transmission electron micrograph, x-ray spectrum and electron diffraction pattern of a pyrite crystal from a standard pyrite specimen. Pyrite crystals from the podosols gave the same electron diffraction pattern; (b) TEM transmission electron micrograph, x-ray spectrum of a jarosite crystal from the A horizon (0-100 cm, site 616-02-94) ($pH_F = 4.0$, $pH_{FOX} = 1.9$, $S_{CR} = 0.09\%$).




| Atomic percent | | |
|---|---|---|
| K | Fe | S |
| 16 | 50 | 34 |

Atomic ratio K: Fe : S ≈ 1: 3: 2

Jarosite chemical formula = $K_2O\ 3Fe_2O_3\ 4SO_3.6H_2O$

**Figure 13** SEM secondary electron image, x-ray spectrum and element mapping of jarosite from the fine fraction from A horizon (0-100 cm, site 616-02-94) ($pH_F$ = 4.0, $pH_{FOX}$ = 1.9, $S_{CR}$ = 0.09%).

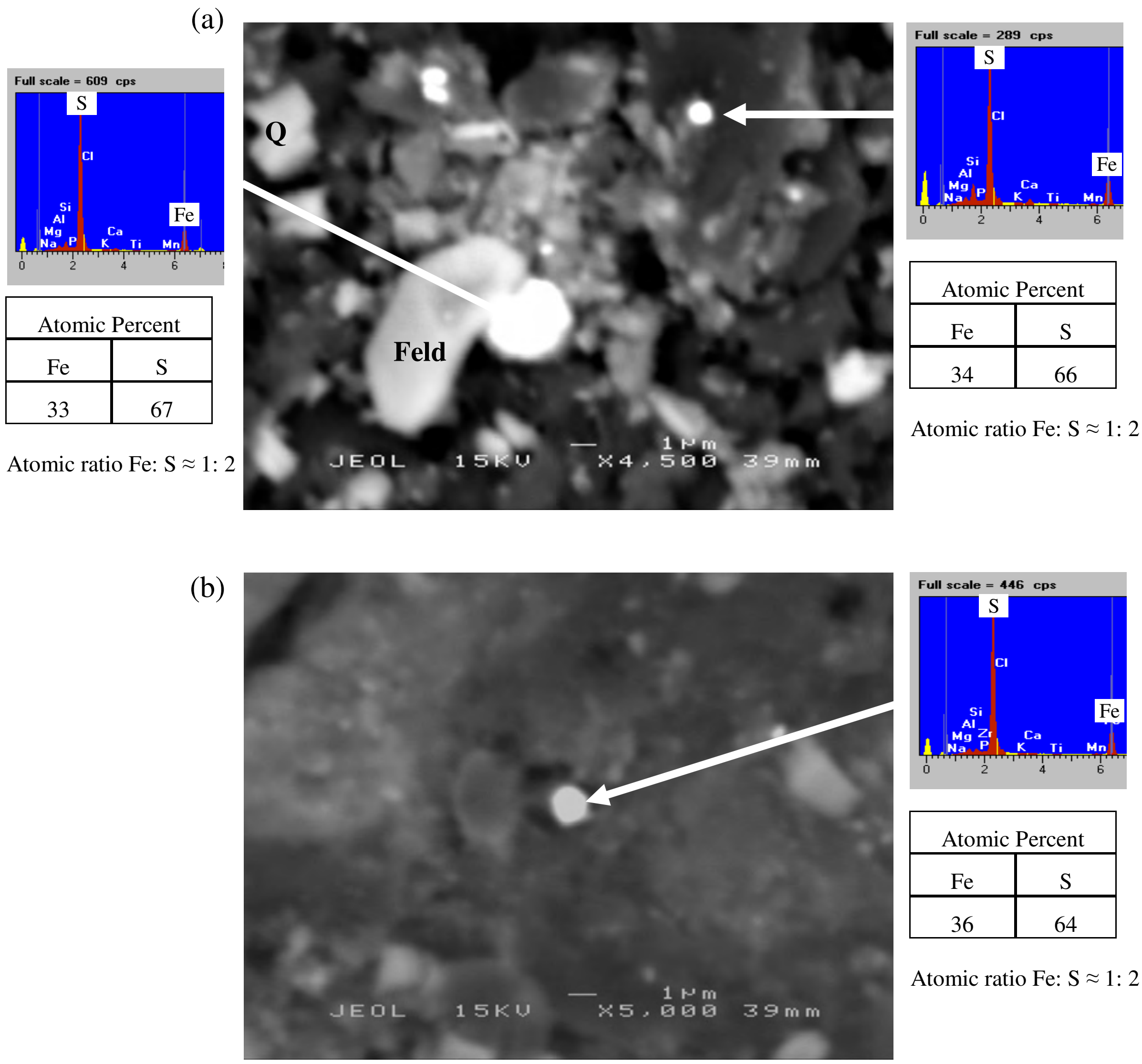



**Figure 14** (a) SEM backscattered electron image and x-ray spectra of a thin section from E horizon (0-150 cm) Ellenbrook site (Q = quartz, Feld = feldspar, laboratory $pHH_2O$ = 4.47, $pHH_2O_2$ = 4.45, SCR no data); (b) SEM backscattered electron image and x-ray spectrum of a thin section from coffee rock (150-200 cm) Ellenbrook site. These horizons were above the watertable at the time of sampling (laboratory $pHH_2O$ = 4.00, $pHH_2O_2$ = 3.10, SCR no data) (Groundwater table level = 7 m).

## 5.3 X-ray diffraction

All studied soils have a very high quartz sand content and small amounts of other minerals that provide acidity and buffering; therefore the fine fraction which contains most of these minor minerals was dispersed by ultrasonic treatment, separated from sand size quartz by sedimentation and used for XRD analysis.

The highly intense monochrome synchrotron X-ray beam provides the sensitivity required for detecting minor quantities of pyrite, sulfur and other crystalline constituents in soil and extracted fine fraction. Conventional XRD of the fine fraction of some podosol fine fraction materials was sensitive enough to provide information on the nature and amounts of sulfides but is inadequate for samples where little sulfide or sulfur is present. It is these materials that are of great concern to DEC as conventional chemical methods to determine S are insensitive. In this case conventional XRD does not recognize low concentrations of some minerals of particular interest such as pyrite, sulfur and jarosite, so synchrotron XRD must be used.

The fine fraction of 93 samples was analysed by synchrotron XRD, 36 samples contain pyrite. The synchrotron XRD patterns of fine fractions extracted from all horizons show that quartz is the dominant mineral of the fine fraction for all horizons with a minor amount of microcline, kaolin and in some samples gibbsite. Halite is present in some subsoils with a high EC level. Resistant minerals, including anatase and ilmenite are present in some samples (Table 2, Appendix Tables 11-25).

The synchrotron XRD patterns of fine fractions extracted from podosol horizons show that jarosite occur in the A horizon (above groundwater level) and in mud and rarely in the B horizon. Pyrite is present in most E, B and coffee rock, mud, peat and C horizons, especially where the samples are located below groundwater level (Table 3). Elemental sulfur occurs as a minor constituent in some horizons which have a high organic matter content. The A horizon samples studied to date do not contain pyrite. Marcasite is present in a few samples. The distribution of pyrite content (semi quantitative %) of the fine fraction of soil samples are shown in Figure 15 (based on synchrotron XRD). Based on data and the origins of these soil samples, pyrite occurs in areas which have the water table at less than 40 metres above mean sea level and there is more pyrite at lower attitudes.

The relationships between sulfur minerals and $S_{CR}$ are shown in Figure 16. Mud sample (site 616-02-028, 200-250 cm) and peat sample (site 616-02-112) have quite high $pH_{FOX}$ (>4) because these samples have high calcite and organic matter contents respectively.

Bivariate relationship between sulfur minerals and $S_{CR}$ for A, E, B, coffee rock, mud and peat horizons and sulfur minerals and $S_{CR}$ of A, E, B and coffee rock horizons are shown in the Figure 16a, b). The Figure 16b plot omits data for the mud and peat samples which makes the relationship nonsignificant showing that the apparently significant relationships in Figure 16a is specious due to the bimodal distribution of these data. One reason for the absence of a relationship is because the sulfur minerals were determined on the fine fraction whereas whole soil samples were used for $S_{CR}$ analysis.

Synchrotron XRD is an excellent technique for identification of minor constituent minerals. However, synchrotron XRD was unable to detect very small amounts of sulfide minerals in some A, E, B, coffee rock, mud, peat samples with with very low $S_{CR}$ contents (less than 0.005%) (Appendix Figures 18, 24 and 25). TEM and SEM enabled the identification very small amount of pyrite in these samples where pyrite was not detected by SXRD (Figures 17-24) indicating that acidification (low $pH_{FOX}$) is generally due to the presence of pyrite (and very low buffering). [The samples shown in Figures 17-24 were also used for the Murdoch University soil column experiment.].

**Table 2** Mineralogical composition (semi quantitative %) of the fine fraction of soil samples (based on synchrotron XRD)*.

| No | Site | Horizon | Depth (cm) | $pH_F$ | $pH_{FOX}$ | $S_{CR}$ (%) | GW (cm) | Ill | Kao | Pyr | S | Jar | Mar | Mac | Micro | Na Ca Feld | Alb | Am | Gib | Goe | Qua | Zir | Ilm | Hal | Cal | Ara |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 003 | 616-01-005 | Coffee rock | 180-200 | 6.3 | 4.7 | no data | 640 | - | 0.8 | - | - | - | - | - | 0.6 | - | - | - | 2.0 | - | 96.6 | - | - | - | - | - |
| 022 | 616-02-031 | Coffee rock1 | 200-300 | 5.3 | 3.2 | < 0.02 | 75 | - | 0.1 | - | - | - | - | - | 0.2 | - | - | - | 0.3 | - | 99.4 | - | - | - | - | - |
| 023 | 616-02-031 | Coffee rock2 | 200-300 | 5.3 | 3.2 | < 0.02 | 75 | - | 0.5 | - | - | - | - | - | 1.8 | - | - | - | 1.9 | - | 95.8 | - | - | - | - | - |
| 034 | 616-01-003 | Coffee rock | 175-200 | 5.0 | 3.6 | no data | 490 | - | 0.5 | - | - | - | - | - | 0.8 | - | - | - | 0.5 | - | 98.2 | - | - | - | - | - |
| 040 | 616-01-014 | C1 horizon | 800-900 | 6.3 | 5.3 | no data | 1350 | - | 0.4 | - | - | - | - | - | 1.3 | - | - | - | 3.2 | - | 95.1 | - | - | - | - | - |
| 052 | 616-02-068 | E3 horizon | 375-600 | 7.2 | 1.8 | <0.02 | 200 | 0.3 | 2.8 | 8.7 | 0.7 | - | - | - | 14.3 | - | - | - | 1.8 | - | 71.4 | - | - | - | - | - |
| 055 | 616-02-080 | Coffee rock | 200-400 | 5.3 | 3.2 | <0.02 | 200 | - | 3.6 | 0.4 | - | - | - | - | - | - | - | - | 1.7 | - | 94.4 | - | - | - | - | - |
| 058 | 616-02-082 | E2 horizon | 200-300 | 5.0 | 1.8 | 0.02 | 50 | - | 1.0 | 2.3 | - | - | - | - | 10.8 | - | - | - | 0.6 | - | 85.3 | - | - | - | - | - |
| 059 | 616-02-082 | B horizon | 300-400 | 5.8 | 1.6 | 0.11 | 50 | - | 33.2 | 3.2 | 0.3 | - | - | - | 4.1 | - | - | - | 0.3 | - | 59.0 | - | - | - | - | - |
| 060 | 616-02-082 | 2E horizon | 400-500 | 6.2 | 1.6 | 0.26 | 50 | - | 0.7 | 8.3 | - | - | 0.2 | - | 10.8 | - | - | - | 0.7 | - | 79.3 | - | - | - | - | - |
| 061 | 616-02-082 | Coffee rock | 500-600 | 6.7 | 1.5 | no data | 50 | - | 1.6 | 6.7 | 0.5 | - | - | - | 8.6 | - | - | - | 1.6 | - | 77.7 | - | - | 3.3 | - | - |
| 062 | 616-02-087 | Coffee rock1 | 200-300 | 6.1 | 3.9 | no data | 150 | - | - | - | - | - | - | - | 1.2 | - | - | - | 0.9 | - | 97.9 | - | - | - | - | - |
| 063 | 616-02-087 | Coffee rock2 | 300-400 | 6.0 | 4.1 | no data | 150 | - | - | - | - | - | - | - | - | - | - | - | 11.7 | - | 88.3 | - | - | - | - | - |
| 069 | 616-01-019 | B horizon | 250-300 | 4.4 | 3.9 | no data | 400 | - | 0.9 | - | - | - | - | - | 2.0 | - | - | - | 0.5 | - | 96.6 | - | - | - | - | - |
| 086 | 616-02-085 | A horizon | 0-70 | 6.1 | 3.9 | no data | 150 | - | 52.7 | - | - | - | - | - | 47.3 | - | - | - | - | - | - | - | - | - | - | - |
| 087 | 616-02-085 | B1 horizon | 100-300 | 6.7 | 2.0 | 0.28 | 150 | - | 4.9 | - | 1.5 | - | - | 3.8 | 3.6 | 3.8 | - | - | - | - | 82.4 | - | - | - | - | - |
| 088 | 616-02-085 | B2 horizon | 300-400 | 7.1 | 2.0 | 0.80 | 150 | 1.8 | 3.5 | 9.0 | - | - | - | - | 9.0 | - | 9.4 | - | 2.5 | - | 64.8 | - | - | - | - | - |
| 089 | 616-02-085 | Mud | 400-600 | 7.4 | 2.6 | 0.40 | 150 | - | 0.7 | - | 0.2 | 3.1 | - | - | 0.7 | 1.7 | - | - | - | - | 91.9 | 1.9 | - | - | - | - |
| 090 | 616-02-028 | B horizon | 30-100 | 4.3 | 2.3 | 0.27 | 150 | - | 0.6 | - | - | 0.6 | 0.8 | - | 0.8 | - | 1.8 | - | - | - | 95.5 | - | - | - | - | - |
| 091 | 616-02-028 | Mud1 | 100-200 | 6.6 | 3.0 | 0.89 | 150 | - | - | 1.5 | - | - | - | - | 4.5 | 3.0 | - | - | - | - | 91.0 | - | - | - | - | - |
| 092 | 616-02-028 | Mud2 | 200-250 | 7.4 | 6.0 | no data | 150 | 0.8 | 1.9 | 16.0 | - | - | - | - | 2.9 | 1.8 | - | 1.4 | - | - | 64.6 | - | 1.4 | - | 9.2 | - |
| 095 | 616-02-094 | A1 horizon | 0-100 | 4.0 | 1.9 | 0.09 | 350 | - | 1.3 | - | - | 5.2 | - | - | 2.0 | - | - | - | - | - | 91.5 | - | - | - | - | - |
| 096 | 616-02-094 | A2 horizon | 100-175 | 4.3 | 2.8 | <0.02 | 350 | - | 0.2 | - | - | 2.0 | - | - | 2.6 | - | - | - | - | - | 95.2 | - | - | - | - | - |
| 097 | 616-02-094 | E horizon | 175-600 | 5.9 | 3.6 | 0.03 | 350 | 0.1 | 0.2 | 0.2 | - | - | - | - | 0.9 | - | - | - | - | - | 98.6 | - | - | - | - | - |
| 098 | 616-02-100 | A horizon | 0-80 | 8.0 | 5.5 | no data | 200 | - | 1.6 | - | 1.5 | - | - | - | 4.7 | - | - | - | 1.8 | - | 77.5 | - | - | - | 12.9 | - |
| 099 | 616-02-100 | Peat | 80-110 | 7.8 | 4.2 | no data | 200 | - | - | - | - | - | - | - | - | - | - | - | - | - | 100.0 | - | - | - | - | - |
| 100 | 616-02-100 | Peat/Ehorizon | 110-200 | 7.1 | 3.3 | 0.08 | 200 | - | 0.7 | 2.6 | - | - | 0.9 | - | 3.2 | - | - | - | - | - | 92.6 | - | - | - | - | - |
| 101 | 616-02-100 | E horizon | 200-600 | 6.4 | 2.1 | 0.02 | 200 | - | 1.0 | 1.0 | - | - | - | - | 8.9 | - | - | - | - | - | 89.1 | - | - | - | - | - |

Ill = Illite, Kao = Kaolinite, Pyr = Pyrite, S = Elemental S, Jar = Jarosite, Mar = Marcasite, Mac = Mackinawite, Micro = Microcline, Na Ca Feldspar, Alb = Albite, Am = Amphibole, Gib = Gibbsite, Goe = Goethite, Qua = Quartz, Zir = Zircon, Ilm = Ilmenite, Hal = Halite, Cal = Calcite, Ara = Aragonite, - = not detected.
* allophane is present in most coffee rock and some other samples but could not be detected by synchrotron XRD due to its diffuse reflections and the nature of background scattering from the glass capillary sample holder.

**Table 2** (Cont.) Mineralogical composition (semi quantitative %) of the fine fraction of soil samples (based on synchrotron XRD)*.

| No | Site | Horizon | Depth (cm) | $pH_F$ | $pH_{FOX}$ | $S_{CR}$ (%) | GW (cm) | Ill | Kao | Pyr | S | Jar | Mar | Mac | Micro | Na Ca Feld | Alb | Am | Gib | Goe | Qua | Zir | Ilm | Hal | Cal | Ara |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 102 | 616-02-099 | E horizon | 25-200 | 7.2 | 3.5 | < 0.02 | 50 | - | - | - | - | - | - | - | - | - | - | - |  | - | 100.0 | - | - | - | - | - |
| 103 | 616-02-099 | B1 horizon | 200-300 | 7.1 | 2.5 | 0.10 | 50 | - | 5.1 | 3.8 | - | - | - | - | 4.3 | - | - | - | - | - | 86.8 | - | - | - | - | - |
| 104 | 616-02-099 | B2 horizon | 300-400 | 7.2 | 1.8 | 0.12 | 50 | - | 0.3 | 3.8 | - | - | - | - | 1.5 | - | - | - | - | - | 94.4 | - | - | - | - | - |
| 105 | 616-02-099 | 2E horizon | 400-600 | 6.8 | 2.1 | 0.05 | 50 | - | 0.4 | 7.6 | - | - | - | - | 1.8 | - | - | - | - | - | 90.2 | - | - | - | - | - |
| 106 | 616-02-101 | A horizon | 0-75 | 7.4 | 3.8 | < 0.02 | 150 | - | 1.2 | - | 0.4 | - | - | - | 6.2 | - | - | - | 1.1 | - | 91.2 | - | - | - | - | - |
| 107 | 616-02-101 | Peat1 | 150-200 | 7.4 | 5.4 | no data | 150 | - | - | 4.7 | - | - | - | - | 6.0 | - | - | - | - | - | 89.3 | - | - | - | - | - |
| 108 | 616-02-101 | Peat2 | 200-350 | 7.1 | 1.6 | 0.74 | 150 | - | - | 4.3 | - | - | - | - | 5.5 | - | - | - | - | - | 82.3 | - | - | - | 7.9 | - |
| 109 | 616-02-101 | E horizon | 350-600 | 8.5 | 2.0 | 0.05 | 150 | - | 0.2 | 1.8 | - | - | - | - | 10.0 | - | - | - | - | - | 88.1 | - | - | - | - | - |
| 110 | 616-02-009 | E1 horizon | 225-250 | 5.8 | 4.9 | no data | 180 | - | 0.3 | - | - | - | - | - | 7.4 | - | - | - | - | - | 92.3 | - | - | - | - | - |
| 112 | 616-02-105 | A horizon | 0-160 | 7.8 | 4.7 | no data | 170 | - | 3.3 | - | - | - | - | - | 6.2 | - | - | - | - | - | 90.5 | - | - | - | - | - |
| 113 | 616-02-105 | Peat | 250-360 | 6.3 | 1.4 | 1.97 | 170 | - | - | 61.9 | - | - | - | - | - | - | - | - | - | - | 38.1 | - | - | - | - | - |
| 114 | 616-02-105 | Peat/Ehorizon | 360-480 | 6.7 | 2.0 | 0.08 | 170 | - | 0.2 | 1.6 | 0.1 | - | - | - | 3.2 | 0.2 | - | - | - | - | 94.6 | - | - | - | - | - |
| 115 | 616-02-105 | E horizon | 480-700 | 7.1 | 3.9 | 0.05 | 170 | - | 0.2 | 0.1 | - | - | - | - | 5.5 | - | - | - | - | - | 93.9 | - | - | 0.4 | - | - |
| 116 | 616-02-106 | A horizon | 0-50 | 4.3 | 2.2 | < 0.02 | 180 | - | 1.1 | - | - | 3.7 | - | - | 3.4 | - | - | - | - | - | 90.7 | - | - | 1.1 | - | - |
| 117 | 616-02-106 | E horizon | 50-700 | 4.9 | 2.1 | 0.04 | 180 | - | 0.3 | 1.2 | 0.4 | - | - | - | 8.2 | 1.3 | - | - | - | - | 88.7 | - | - | - | - | - |
| 119 | 616-02-112 | Mud | 125-200 | 7.7 | 6.4 | no data | 100 | - | - | - | - | - | - | - | 4.1 | - | - | - | - | - | 3.1 | - | - | 11.3 | 81.5 | - |
| 120 | 616-02-112 | Peat | 200-300 | 7.6 | 4.3 | 0.60 | 100 | - | - | 27.5 | - | - | - | - | 8.6 | - | - | - | - | - | - | - | - | 63.9 | - | - |
| 121 | 616-02-112 | B horizon | 300-400 | 7.5 | 3.9 | no data | 100 | - | 0.4 | 1.3 | - | - | - | - | 1.9 | - | - | - | - | - | 59.0 | - | - | - | 37.3 | - |
| 122 | 616-02-112 | C horizon | 400-600 | 7.9 | 6.5 | no data | 100 | - | - | 0.4 | - | - | - | - | 0.9 | - | - | - | - | - | 7.9 | - | - | - | 90.9 | - |
| 123 | 616-02-113 | A horizon | 0-50 | 6.5 | 3.9 | no data | 50 | - | 0.8 | - | - | - | - | - | 6.9 | - | - | - | - | - | 92.3 | - | - | - | - | - |
| 124 | 616-02-113 | E1 horizon | 50-250 | 7.6 | 3.7 | < 0.02 | 50 | - | 0.3 | - | - | - | - | - | 7.1 | - | 0.7 | - | - | - | 92.0 | - | - | - | - | - |
| 125 | 616-02-113 | E2 horizon | 250-300 | 7.6 | 1.6 | 0.10 | 50 | - | 0.3 | 1.9 | - | - | - | - | 5.7 | - | 5.9 | - | - | - | 86.2 | - | - | - | - | - |
| 127 | 616-02-122 | E horizon | 20-235 | 6.3 | 3.6 | <0.02 | 240 | - | 0.2 | - | - | - | - | - | 2.6 | - | - | - | - | - | 97.1 | - | - | - | - | - |
| 128 | 616-02-122 | B horizon | 235-315 | 6.9 | 4.4 | no data | 240 | - | 1.0 | - | - | - | - | - | 5.4 | - | - | - | 0.8 | - | 92.7 | - | - | - | - | - |
| 130 | 616-02-122 | 2E3 horizon | 500-700 | 6.5 | 1.9 | < 0.02 | 240 | 0.2 | 0.3 | - | - | - | - | - | 17.5 | - | - | - | 0.2 | - | 81.8 | - | - | - | - | - |
| 131 | 616-02-127 | E horizon | 40-100 | 5.9 | 4.1 | no data | 200 | - | 0.2 | - | - | - | - | - | 0.5 | - | - | - | - | - | 99.3 | - | - | - | - | - |
| 132 | 616-02-127 | Coffee rock | 100-235 | 5.2 | 3.1 | < 0.02 | 200 | - | - | - | - | - | - | - | 2.7 | - | - | - | - | - | 97.3 | - | - | - | - | - |
| 133 | 616-02-127 | 2E1 horizon | 235-300 | 5.0 | 3.2 | < 0.02 | 200 | - | 0.4 | - | - | - | - | - | 1.8 | - | - | - | - | - | 97.8 | - | - | - | - | - |
| 134 | 616-02-127 | 2E2 horizon | 300-600 | 6.1 | 2.3 | < 0.02 | 200 | - | 0.4 | - | - | - | - | - | - | - | - | - | - | - | 99.6 | - | - | - | - | - |

Ill = Illite, Kao = Kaolinite, Pyr = Pyrite, S = Elemental S, Jar = Jarosite, Mar = Marcasite, Mac = Mackinawite, Micro = Microcline, Na Ca Feldspar, Alb = Albite, Am = Amphibole, Gib = Gibbsite, Goe = Goethite, Qua = Quartz, Zir = Zircon, Ilm = Ilmenite, Hal = Halite, Cal = Calcite, Ara = Aragonite, - = not detected.

* allophane is present in most coffee rock and some other samples but could not be detected by synchrotron XRD due to its diffuse reflections and the nature of background scattering from the glass capillary sample holder.

**Table 2** (Cont.) Mineralogical composition (semi quantitative %) of the fine fraction of soil samples (based on synchrotron XRD)*.

| No | Site | Horizon | Depth (cm) | $pH_F$ | $pH_{FOX}$ | $S_{CR}$ (%) | GW (cm) | Ill | Kao | Pyr | S | Jar | Mar | Mac | Micro | Na Ca Feld | Alb | Am | Gib | Goe | Qua | Zir | Ilm | Hal | Cal | Ara |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 135 | 616-02-131 | A horizon | 0-50 | 7.4 | 4.9 | no data | 200 | - | 1.4 | - | - | - | - | - | 2.4 | - | - | 1.7 | 0.8 | - | 93.7 | - | - | - | - | - |
| 136 | 616-02-131 | E horizon | 50-325 | 7.3 | 4.2 | <0.02 | 200 | - | 0.9 | - | - | - | - | - | 3.1 | - | - | - | 0.4 | - | 95.6 | - | - | - | - | - |
| 137 | 616-02-131 | B horizon | 325-425 | 6.4 | 3.6 | <0.02 | 200 | 0.2 | 0.9 | - | - | - | - | - | 0.8 | - | - | - | - | 0.2 | 97.8 | - | - | - | - | - |
| 138 | 616-02-131 | 2E horizon | 425-600 | 6.3 | 4.2 | <0.02 | 200 | 0.1 | 0.1 | - | - | - | - | - | 0.8 | 0.8 | - | - | - | - | 98.2 | - | - | - | - | - |
| 139 | 616-02-136 | A horizon | 0-25 | 7.0 | 4.4 | no data | 180 | - | - | - | - | - | - | - | 2.2 | - | - | - | - | - | 97.8 | - | - | - | - | - |
| 140 | 616-02-136 | Coffee rock | 200-260 | 6.6 | 3.6 | no data | 180 | - | 9.6 | - | - | - | - | - | 8.5 | - | - | - | - | - | 81.9 | - | - | - | - | - |
| 141 | 616-02-136 | E horizon | 260-600 | 6.3 | 2.0 | 0.02 | 180 | 0.2 | 1.2 | 0.6 | 0.8 | - | 2.5 | - | 16.4 | - | - | - | - | - | 78.3 | - | - | - | - | - |
| 142 | 616-02-068 | A horizon | 0-25 | 5.9 | 4.8 | no data | 200 | - | - | - | - | - | - | - | 2.1 | - | - | - | - | - | 97.9 | - | - | - | - | - |
| 143 | 616-02-068 | E horizon | 25-200 | 6.1 | 4.7 | <0.02 | 200 | - | - | - | - | - | - | - | 19.1 | - | - | - | - | - | 77.6 | - | - | - | 3.3 | - |
| 144 | 616-02-068 | Coffee rock | 200-300 | 5.6 | 2.7 | 0.04 | 200 | - | 0.5 | - | - | - | - | - | 5.0 | - | - | - | 0.2 | - | 94.3 | - | - | - | - | - |
| 145 | 616-02-068 | B1 horizon | 300-400 | 6.3 | 1.2 | <0.02 | 200 | - | 0.9 | 0.4 | 0.4 | - | - | - | 6.3 | - | - | - | 0.8 | - | 91.2 | - | - | - | - | - |
| 146 | 616-02-068 | B2 horizon | 400-500 | 6.7 | 1.4 | <0.02 | 200 | - | 1.3 | 0.8 | - | - | - | - | 7.1 | - | - | - | 1.3 | - | 89.5 | - | - | - | - | - |
| 147 | 616-02-068 | B3 horizon | 500-600 | 7.3 | 1.4 | <0.02 | 200 | - | 1.4 | 2.6 | 0.8 | - | - | - | 12.1 | - | - | - | 1.2 | - | 81.9 | - | - | - | - | - |
| 150 | 616-02-065 | Peat1 | 0-20 | 6.5 | 3.7 | <0.02 | 150 | - | 2.6 | - | - | - | - | - | 2.6 | - | - | - | - | - | 94.8 | - | - | - | - | - |
| 154 | 616-02-065 | Coffee rock1 | 480-560 | 6.0 | 1.6 | <0.02 | 150 | - | 2.9 | 1.9 | - | - | - | - | 1.4 | - | - | - | 4.8 | - | 88.9 | - | - | - | - | - |
| 156 | 616-02-065 | Coffee rock3 | 650-700 | 5.9 | 1.6 | <0.02 | 150 | - | 0.5 | - | - | - | - | - | 2.8 | - | - | - | 1.3 | - | 95.4 | - | - | - | - | - |
| 158 | 616-02-122 | B/E horizon | 700-900 | 6.2 | 2.2 | no data | 240 | - | 0.3 | - | - | - | - | - | 4.5 | - | - | - | 0.6 | - | 94.6 | - | - | - | - | - |
| 159 | 616-02-122 | 2E2 horizon | 375-500 | 6.2 | 1.9 | no data | 240 | - | 1.1 | - | - | - | - | - | 12.6 | - | - | - | 0.6 | - | 85.7 | - | - | - | - | - |
| 161 | Ellenbrook | E horizon | 0-150 | 4.5 | 4.5 | no data | 700 | - | 0.1 | - | - | - | - | - | 0.1 | - | - | - | - | - | 99.8 | - | - | - | - | - |
| 162 | Ellenbrook | Coffee rock | 150-200 | 4.0 | 3.1 | no data | 700 | - | 5.7 | - | - | - | - | - | - | - | - | - | - | - | 94.3 | - | - | - | - | - |
| 163 | Ellenbrook | B horizon | 200-500 | 2.6 | 1.9 | no data | 700 | - | 0.8 | - | - | - | - | - | 7.1 | - | - | - | - | - | 92.1 | - | - | - | - | - |
| 164 | Ellenbrook | Coffee rock | 200 | 4.3 | 3.00 | no data | 700 | - | 7.1 | - | - | - | - | - | 33.9 | - | - | - | 2.1 | - | 56.9 | - | - | | - | - |
| 167 | Ellenbrook | Coffee rock | 150-200 | 4.6 | 1.9 | no data | 700 | - | 1.0 | - | - | - | - | - | 1.2 | - | - | - | 1.0 | - | 96.8 | - | - | - | - | - |
| 169 | 616-02-155 | E horizon | 50-150 | 9.1 | 5.5 | no data | 250 | - | - | - | - | - | - | - | 2.8 | - | - | - | - | - | 77.3 | - | - | - | 18.8 | 1.1 |
| 171 | 616-02-155 | B horizon | 500-600 | 8.3 | 7.1 | no data | 250 | - | 1.6 | - | - | - | - | - | - | - | - | - | 0.4 | - | 98.1 | - | - | - | - | - |
| 174 | 616-02-145 | B horizon | 450-475 | 7.1 | 2.6 | no data | 220 | - | 12.9 | - | - | - | - | - | 2.7 | - | - | - | 4.5 | 2.9 | 77.0 | - | - | - | - | - |
| 178 | 616-02-158 | Coffee rock2 | 300-400 | 5.6 | 2.1 | no data | 290 | - | 0.7 | - | - | - | - | - | 3.4 | - | - | - | 1.8 | - | 94.1 | - | - | - | - | - |

Ill = Illite, Kao = Kaolinite, Pyr = Pyrite, S = Elemental S, Jar = Jarosite, Mar = Marcasite, Mac = Mackinawite, Micro = Microcline, Na Ca Feldspar, Alb = Albite, Am = Amphibole, Gib = Gibbsite, Goe = Goethite, Qua = Quartz, Zir = Zircon, Ilm = Ilmenite, Hal = Halite, Cal = Calcite, Ara = Aragonite, - = not detected.

* allophane is present in most coffee rock and some other samples but could not be detected by synchrotron XRD due to its diffuse reflections and the nature of background scattering from the glass capillary sample holder.

**Table 2** (Cont.) Mineralogical composition (semi quantitative %) of the fine fraction of soil samples (based on synchrotron XRD)*.

| No | Site | Horizon | Depth (cm) | $pH_F$ | $pH_{FOX}$ | $S_{CR}$ (%) | GW (cm) | Ill | Kao | Pyr | S | Jar | Mar | Mac | Micro | Na Ca Feld | Alb | Am | Gib | Geo | Qua | Zir | Ilm | Hal | Cal | Ara |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N1 | 616-01-005 | B horizon | 620-630 | 5.5 | 2.7 | 0.014 | 640 | - | 0.6 | - | - | - | - | - | 0.6 | - | - | - | 0.8 | - | 98.0 | - | - | - | - | - |
| N2 | 616-02-068 | B horizon | 450 | 7.2 | 1.8 | 0.027 | 200 | - | 0.9 | 1.8 | - | - | - | - | 5.3 | - | - | - | 1.1 | - | 90.9 | - | - | - | - | - |
| N4 | 616-02-179 | B horizon | 375-400 | 6.1 | 1.6 | 0.013 | 320 | - | 1.0 | 0.5 | - | - | 0.6 | - | 1.2 | - | - | - | 0.7 | - | 96.1 | - | - | - | - | - |
| N6 | 616-02-078 | B horizon | 400-500 | 4.8 | 1.5 | 0.014 | 200 | - | 0.2 | 1.6 | - | - | - | - | 0.3 | - | - | - | - | - | 97.6 | - | - | 0.3 | - | - |
| N7 | 616-02-081 | B horizon | 400-800 | 6.2 | 1.4 | 0.052 | 300 | - | 0.3 | 1.7 | - | - | 0.7 | - | 3.9 | - | - | - | - | - | 93.4 | - | - | - | - | - |
| N8 | 616-02-110 | B horizon | 200-500 | 6.3 | 1.8 | 0.036 | 180 | - | 1.0 | 12.3 | - | - | - | - | 2.8 | - | - | - | - | - | 26.2 | - | - | - | 57.7 | - |
| N9 | 616-02-174 | B horizon | 250-550 | 5.5 | 2.5 | <0.005 | 310 | - | 0.2 | - | - | - | - | - | 0.2 | - | - | - | - | - | 99.6 | - | - | - | - | - |
| N10 | 616-02-065 | B horizon | 200 | 5.7 | 3.0 | 0.005 | 150 | - | 1.2 | - | - | - | - | - | 2.5 | - | - | - | - | - | 96.3 | - | - | - | - | - |

Ill = Illite, Kao = Kaolinite, Pyr = Pyrite, S = Elemental S, Jar = Jarosite, Mar = Marcasite, Mac = Mackinawite, Micro = Microcline, Na Ca Feldspar, Alb = Albite, Am = Amphibole, Gib = Gibbsite, Goe = Goethite, Qua = Quartz, Zir = Zircon, Ilm = Ilmenite, Hal = Halite, Cal = Calcite, Ara = Aragonite, - = not detected.

* allophane is present in most coffee rock and some other samples but could not be detected by synchrotron XRD due to its diffuse reflections and the nature of background scattering from the glass capillary sample holder.

**Table 3** Semi quantitative SXRD analyses for sulfur minerals in the fine fraction and some soil properties.

| Sample No. | Site | Horizon | Depth (cm) | $pH_F$ | $pH_{FOX}$ | $S_{CR}$ (%) | GW (cm) | Pyr | S | Jar | Mar | Mac |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | (------------------------%-----------------------) | | | | |
| 095 | 616-02-094 | A horizon | 0-100 | 4 50 | 2.13 | 0.09 | 350 | - | - | 5.2 | - | - |
| 096 | 616-02-094 | A horizon | 100-175 | 4.27 | 2.77 | <0.02 | 350 | - | - | 2.0 | - | - |
| 098 | 616-02-100 | A horizon | 0-80 | 8.00 | 5.53 | no data | 200 | - | 1.5 | - | - | - |
| 106 | 616-02-101 | A horizon | 0-75 | 7.43 | 3.77 | <0.02 | 150 | - | 0.4 | - | - | - |
| 116 | 616-02-106 | A horizon | 0-50 | 4.25 | 2.20 | <0.02 | 180 | - | - | 3.7 | - | - |
| 052 | 616-02-068 | E horizon | 375-600 | 7.21 | 1.76 | <0.02 | 200 | 8.7 | 0.7 | - | - | - |
| 058 | 616-02-082 | E horizon | 200-300 | 5.04 | 1.84 | 0.02 | 50 | 2.3 | - | - | - | - |
| 060 | 616-02-082 | E horizon | 400-500 | 6.18 | 1.60 | 0.26 | 50 | 8.3 | - | - | 0.2 | - |
| 097 | 616-02-094 | E horizon | 175-600 | 5.88 | 3.56 | 0.03 | 350 | 0.2 | - | - | - | - |
| 101 | 616-02-100 | E horizon | 200-600 | 6.43 | 2.07 | 0.02 | 200 | 1.0 | - | - | - | - |
| 105 | 616-02-099 | E horizon | 400-600 | 6.76 | 2.06 | 0.05 | 50 | 7.6 | - | - | - | - |
| 109 | 616-02-101 | E horizon | 350-600 | 8 52 | 1.99 | 0.05 | 150 | 1.8 | - | - | - | - |
| 115 | 616-02-105 | E horizon | 480-700 | 7.11 | 3.90 | 0.05 | 170 | 0.1 | - | - | - | - |
| 117 | 616-02-106 | E horizon | 50-700 | 4 90 | 2.13 | 0.04 | 180 | 1.2 | 0.4 | - | - | - |
| 125 | 616-02-113 | E horizon | 250-300 | 7.60 | 1.57 | 0.10 | 50 | 1.9 | - | - | - | - |
| 141 | 616-02-136 | E horizon | 260-600 | 6.32 | 1.97 | 0.02 | 180 | 0.6 | 0.8 | - | 2.5 | - |
| 059 | 616-02-082 | B horizon | 300-400 | 5.78 | 1.55 | 0.11 | 50 | 3.2 | 0.3 | - | - | - |
| 087 | 616-02-085 | B horizon | 100-300 | 6.69 | 2.02 | 0.28 | 150 | - | 1.5 | - | - | 3.8 |
| 088 | 616-02-085 | B horizon | 300-400 | 7.10 | 1.95 | 0.80 | 150 | 9.0 | - | - | - | - |
| 090 | 616-02-028 | B horizon | 30-100 | 4.33 | 2.25 | 0.27 | 150 | - | - | 0.6 | 0.8 | - |
| 103 | 616-02-099 | B horizon | 200-300 | 7.08 | 2.54 | 0.10 | 50 | 3.8 | - | - | - | - |
| 104 | 616-02-099 | B horizon | 300-400 | 7.20 | 1.83 | 0.12 | 50 | 3.8 | - | - | - | - |
| 121 | 616-02-112 | B horizon | 300-400 | 7.45 | 3.93 | no data | 100 | 1.3 | - | - | - | - |
| 145 | 616-02-068 | B horizon | 300-400 | 6.30 | 1.18 | <0.02 | 200 | 0.4 | 0.4 | - | - | - |
| 146 | 616-02-068 | B horizon | 400-500 | 6.73 | 1.40 | <0.02 | 200 | 0.8 | - | - | - | - |
| 147 | 616-02-068 | B horizon | 500-600 | 7.28 | 1.35 | <0.02 | 200 | 2.6 | 0.8 | - | - | - |
| N2 | 616-02-068 | B horizon | 450 | 7.20 | 1.80 | 0.027 | 200 | 1.8 | - | - | - | - |
| N4 | 616-02-179 | B horizon | 375-400 | 6.10 | 1.60 | 0.013 | 320 | 0.5 | - | - | 0.6 | - |
| N6 | 616-02-078 | B horizon | 400-500 | 4.80 | 1.50 | 0.014 | 200 | 1.6 | - | - | - | - |
| N7 | 616-02-081 | B horizon | 400-800 | 6.20 | 1.40 | 0.052 | 300 | 1.7 | - | - | 0.7 | - |
| N8 | 616-02-110 | B horizon | 200-500 | 6.30 | 1.80 | 0.036 | 180 | 12.3 | - | - | - | - |
| 055 | 616-02-080 | Coffee rock | 200-400 | 5.30 | 3.17 | <0.02 | 200 | 0.4 | - | - | - | - |
| 061 | 616-02-082 | Coffee rock | 500-600 | 6.73 | 1.50 | no data | 50 | 6.7 | 0.5 | - | - | - |
| 154 | 616-02-065 | Coffee rock | 480-560 | 6.00 | 1.57 | <0.02 | 150 | 1.9 | - | - | - | - |
| 089 | 616-02-085 | Mud | 400-600 | 7.43 | 2.56 | 0.40 | 150 | - | 0.2 | 3.1 | - | - |
| 091 | 616-02-028 | Mud | 100-200 | 6.63 | 2.98 | 0.89 | 150 | 1.5 | - | - | - | - |
| 092 | 616-02-028 | Mud | 200-250 | 7.35 | 5.98 | no data | 150 | 16.0 | - | - | - | - |
| 100 | 616-02-100 | Peat | 110-200 | 7.06 | 3.24 | 0.08 | 200 | 2.6 | - | - | 0.9 | - |
| 107 | 616-02-101 | Peat | 150-200 | 7.37 | 5.37 | no data | 150 | 4.7 | - | - | - | - |
| 108 | 616-02-101 | Peat | 200-350 | 7.13 | 1.60 | 0.74 | 150 | 4.3 | - | - | - | - |
| 113 | 616-02-105 | Peat | 250-360 | 6.25 | 1.43 | 1.97 | 170 | 61.9 | - | - | - | - |
| 114 | 616-02-105 | Peat | 360-480 | 6.65 | 1.98 | 0.08 | 170 | 1.6 | 0.1 | - | - | - |
| 120 | 616-02-112 | Peat | 200-300 | 7.62 | 4.30 | 0.60 | 100 | 27.5 | - | - | - | - |
| 122 | 616-02-112 | C horizon | 400-600 | 7.86 | 6.46 | no data | 100 | 0.4 | - | - | - | - |

- = not detected, Pyr = Pyrite; S = Elemental S; Jar = Jarosite; Mar = Marcasite; Mac = Mackinawite, $S_{CR}$ = Chromium reducible sulfur; GW = Groundwater level

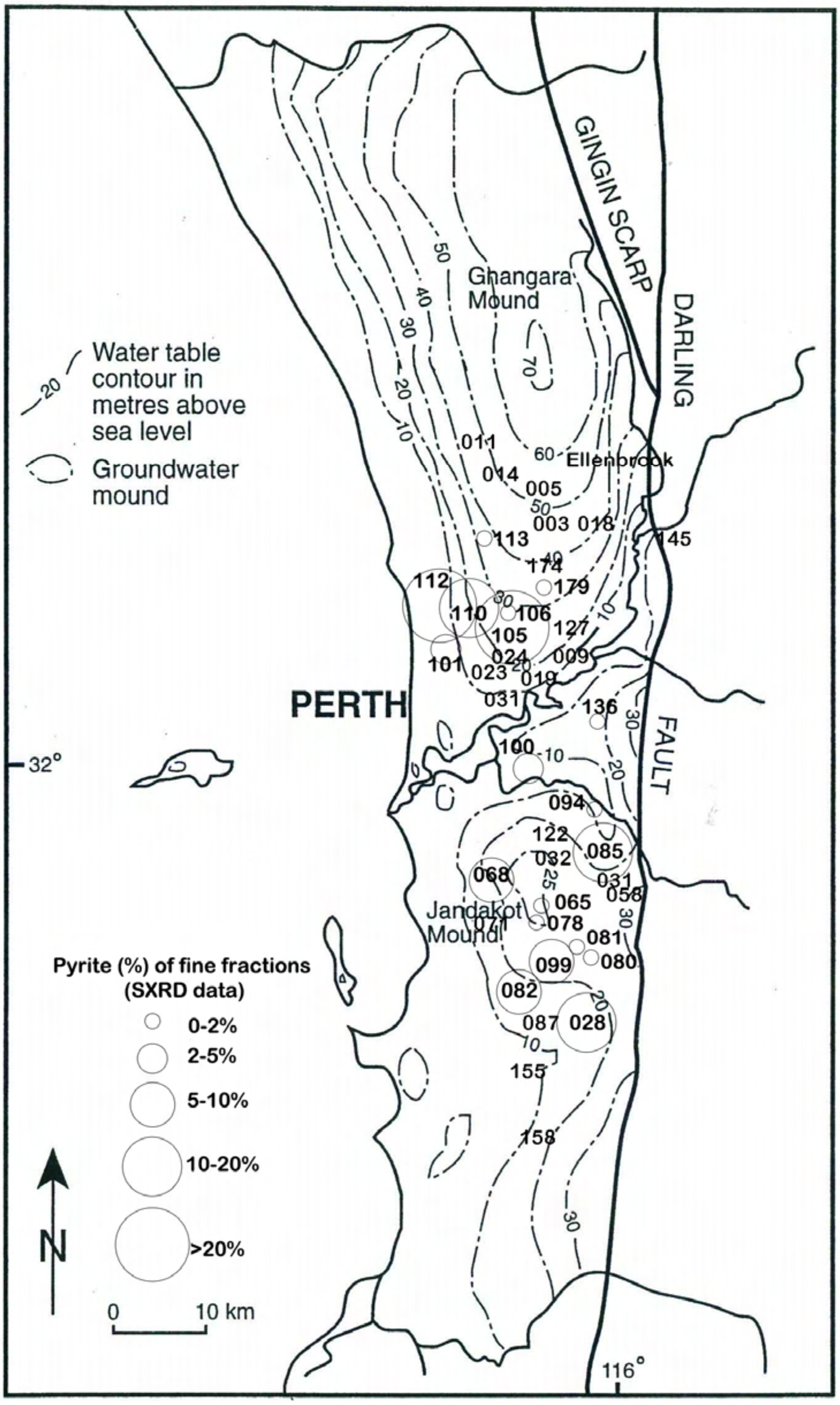



**Figure 15** The spatial distribution of pyrite content (semi quantitative %) of the fine fraction of soil samples (based on synchrotron XRD) related to water table contours for the Perth region.

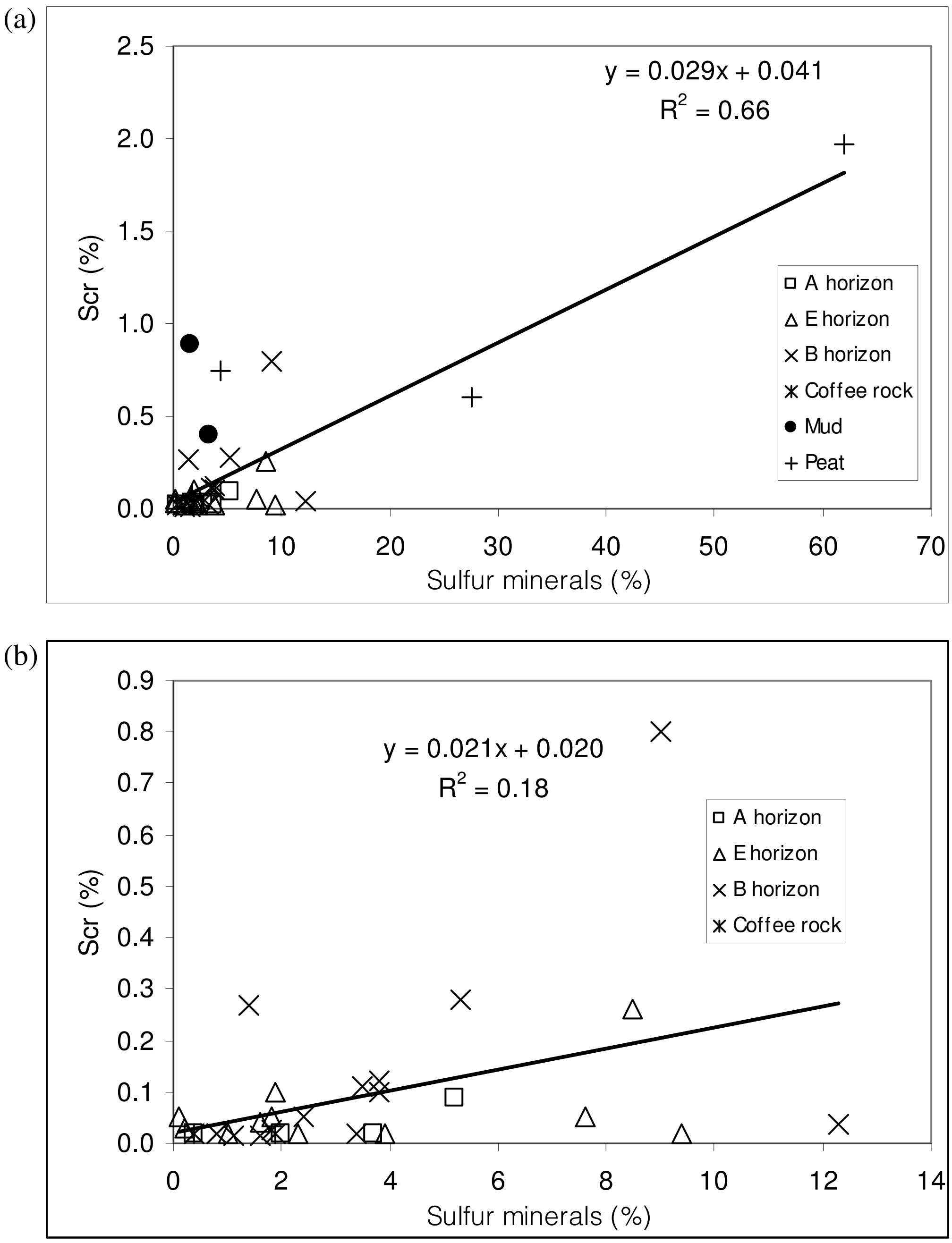



**Figure 16** Bivariate relationship between (a) sulfur minerals (%) and $S_{CR}$ of A, E, B, coffee rock, mud and peat horizons (%), (b) sulfur minerals (%) and $S_{CR}$ of A, E, B and coffee rock horizons. RHS plots omit the mud and peat samples which make the relationship nonsignificant showing that the LHS relationships are specious due to the bimodal distribution of these data.

B horizon (N_01)

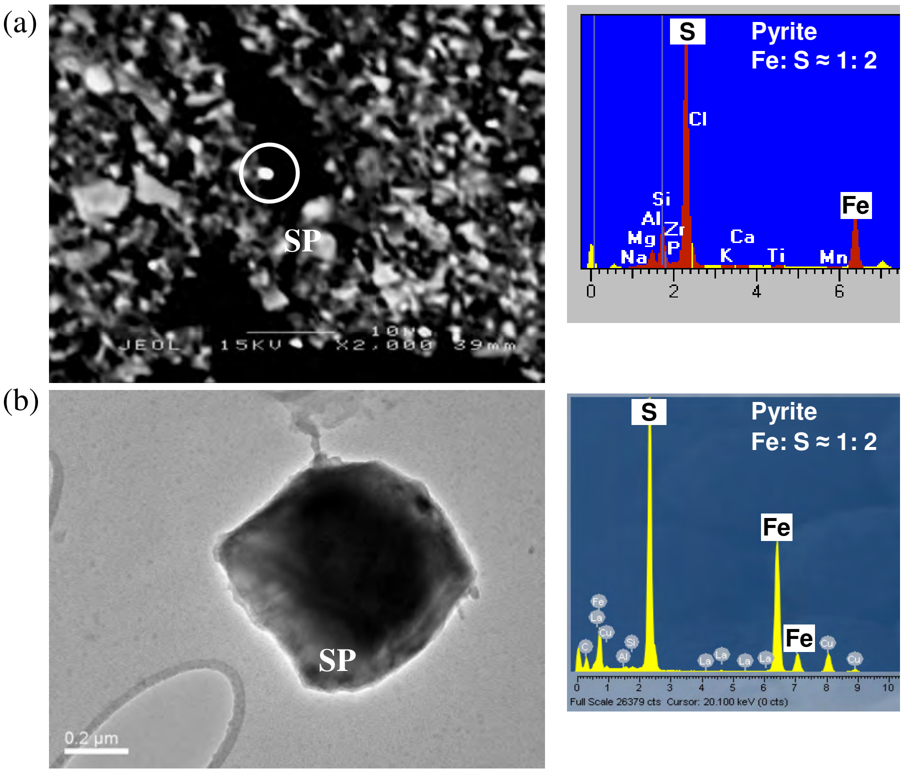



**Figure 17** (a) SEM backscattered electron image (b) TEM transmission electron micrograph and x-ray spectrum of fine fraction pyrite from the B horizon (620-630 cm, site 616-01-005) ($pH_F$ = 5.5, $pH_{FOX}$ = 2.7, $S_{CR}$ = 0.014%), pyrite was not detected by SXRD however at high magnification rare pyrite crystals can be seen (SP = Single crystal pyrite).

B horizon (N_02)

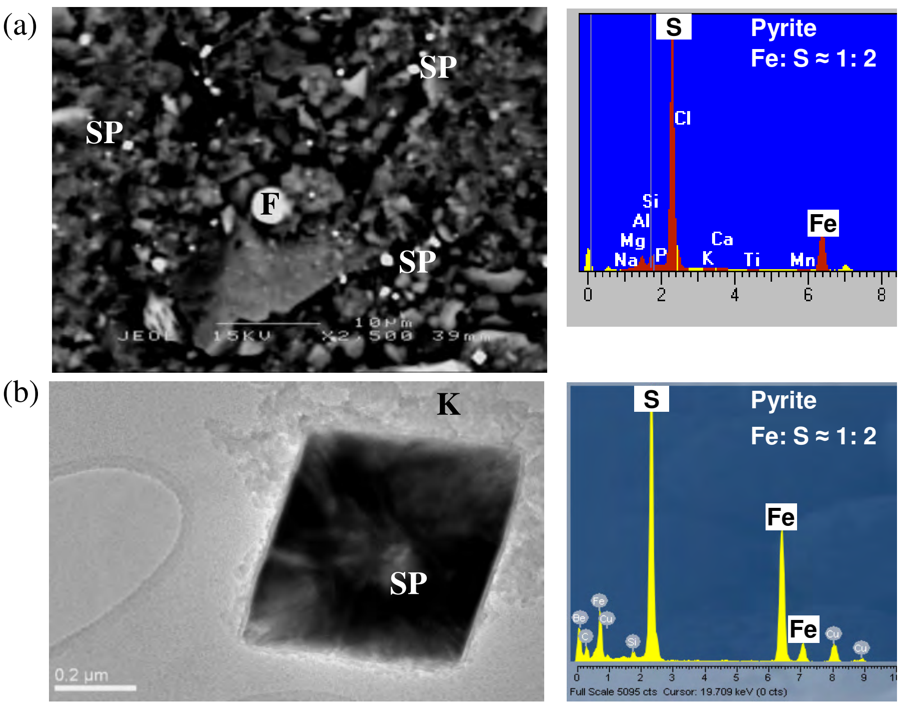



**Figure 18** (a) SEM secondary electron image (b) TEM transmission electron micrograph and x-ray spectrum of fine fraction pyrite from the B horizon (450 cm, site 616-02-068) ($pH_F$ = 7.2, $pH_{FOX}$ = 1.8, $S_{CR}$ = 0.027%) (F = Framboidal pyrite, SP = Single crystal pyrite, K = Kaolin).

B horizon (N_04)

(a)
(b)

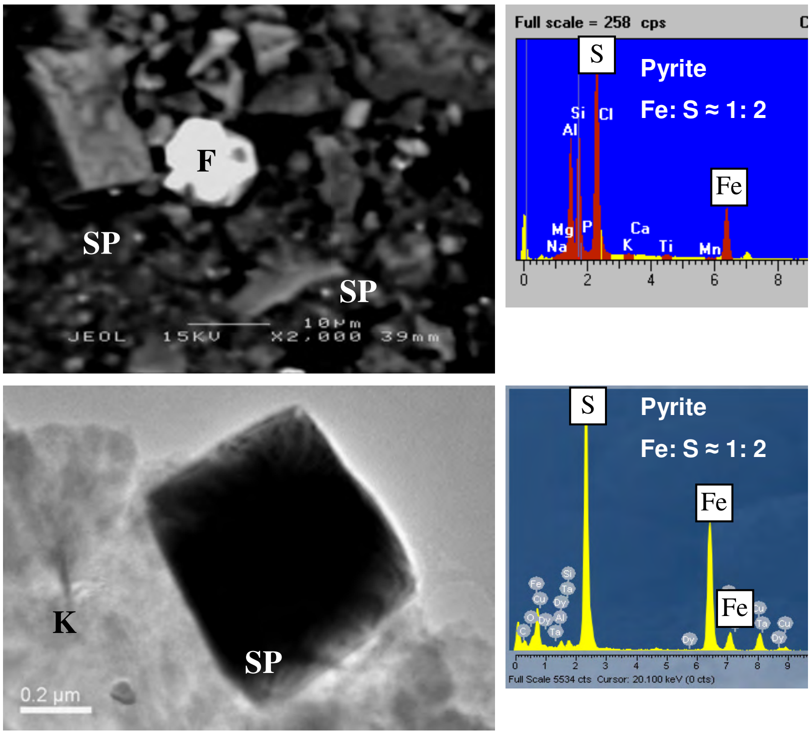



**Figure 19** (a) SEM backscattered electron image (b) TEM transmission electron micrograph and x-ray spectrum of fine fraction pyrite from the B horizon 375-400 cm, site 616-02-179) ($pH_F$ = 6.1, $pH_{FOX}$ = 1.6, $S_{CR}$ = 0.013%) (F = Framboidal pyrite, SP = Single crystal pyrite, K = Kaolin).

B horizon (N_06)

(a)
(b)

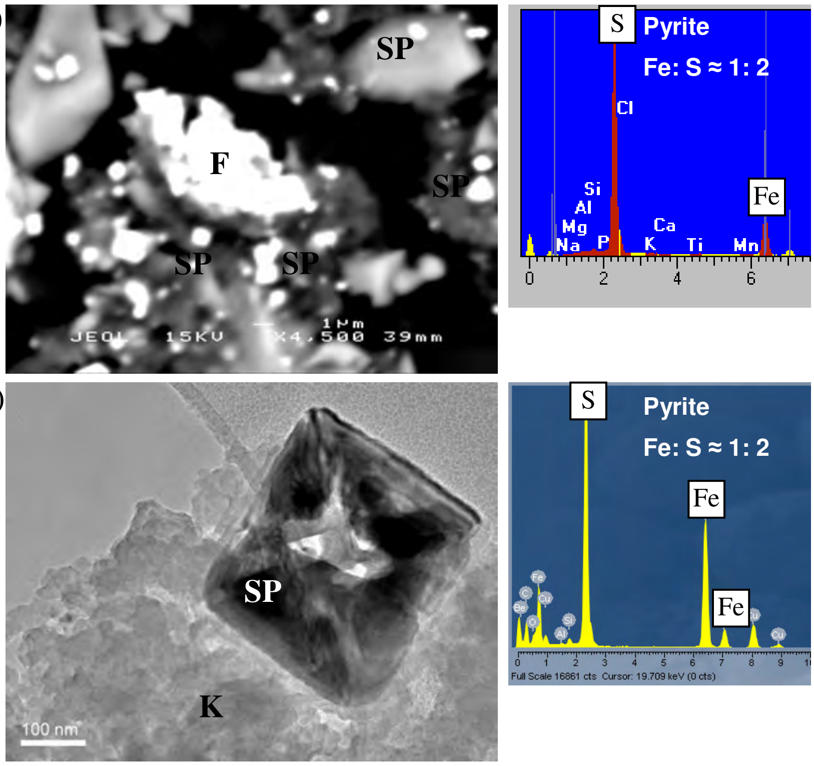



**Figure 20** (a) SEM backscattered electron image (b) TEM transmission electron micrograph and x-ray spectrum of fine fraction pyrite from the B horizon (400-500 cm, site 616-02-078) ($pH_F$ = 4.8, $pH_{FOX}$ = 1.5, $S_{CR}$ = 0.014%) (F = Framboidal pyrite, SP = Single crystal pyrite, K = Kaolin).

B horizon (N_07)

(a)

(b)

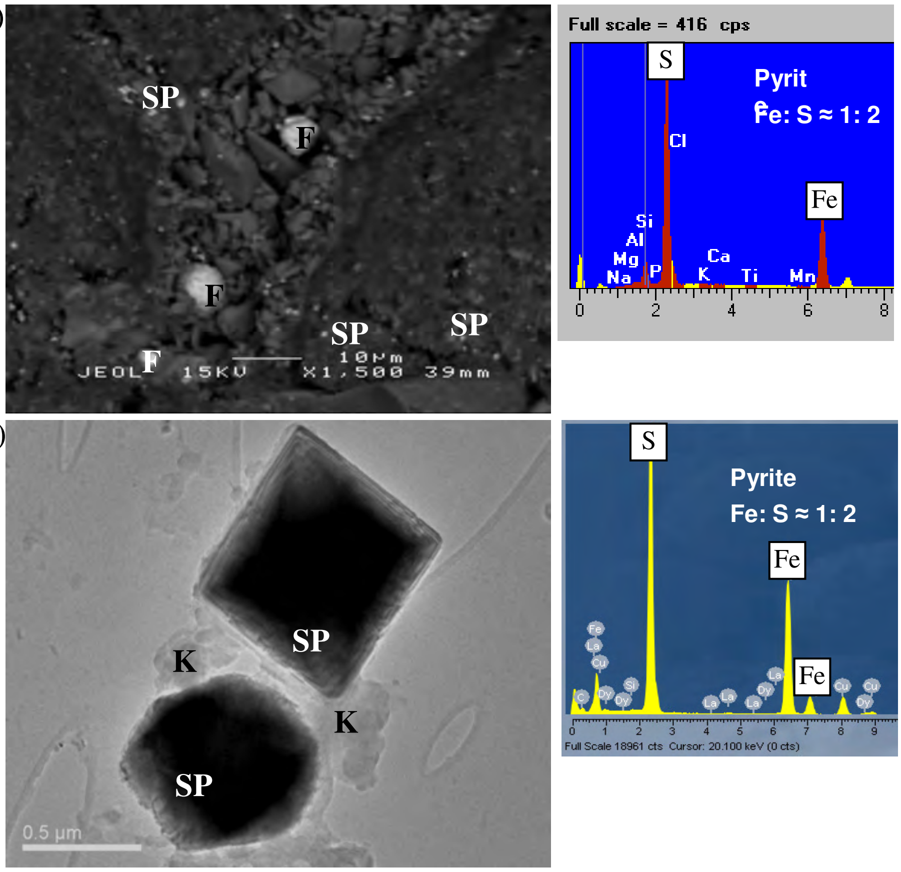



**Figure 21** (a) SEM secondary electron image (b) TEM transmission electron micrograph and x-ray spectrum of fine fraction pyrite from the B horizon (400-800 cm, site 616-02-081) ($pH_F$ = 6.2, $pH_{FOX}$ = 1.4, $S_{CR}$ = 0.052%) (F = Framboidal pyrite, SP = Single crystal pyrite, K = Kaolin).

B horizon (N_08)

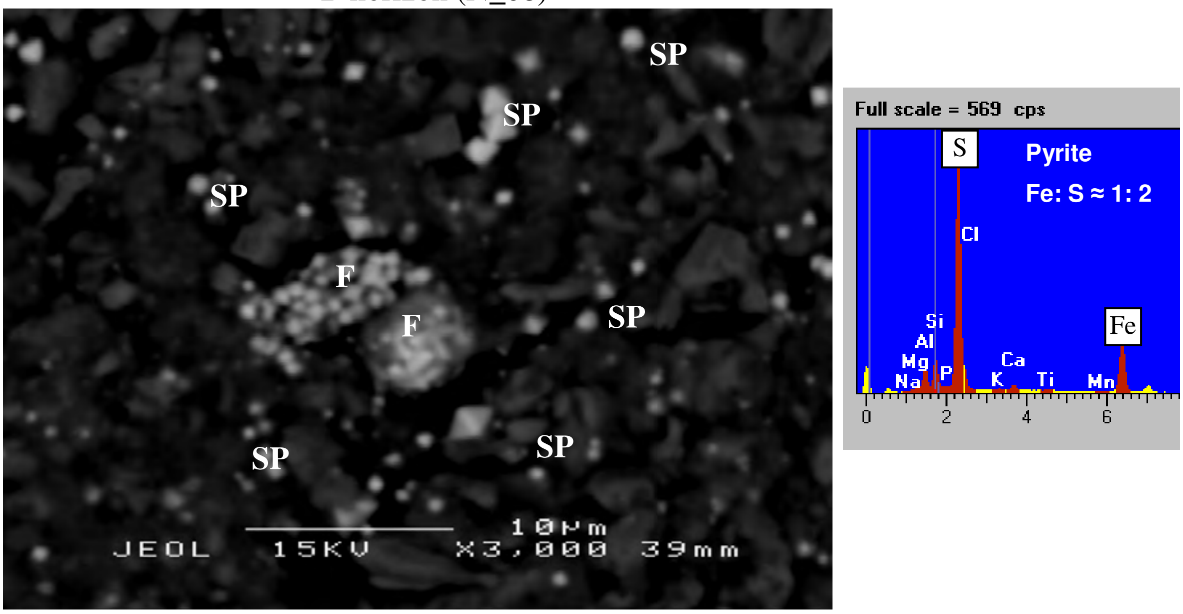



**Figure 22** SEM secondary electron image and x-ray spectrum of fine fraction pyrite from the B horizon (200-500 cm, site 616-02-110) ($pH_F$ = 6.3, $pH_{FOX}$ = 1.8, $S_{CR}$ = 0.036%) (F = Framboidal pyrite, SP = Single crystal pyrite).

B horizon (N_09)

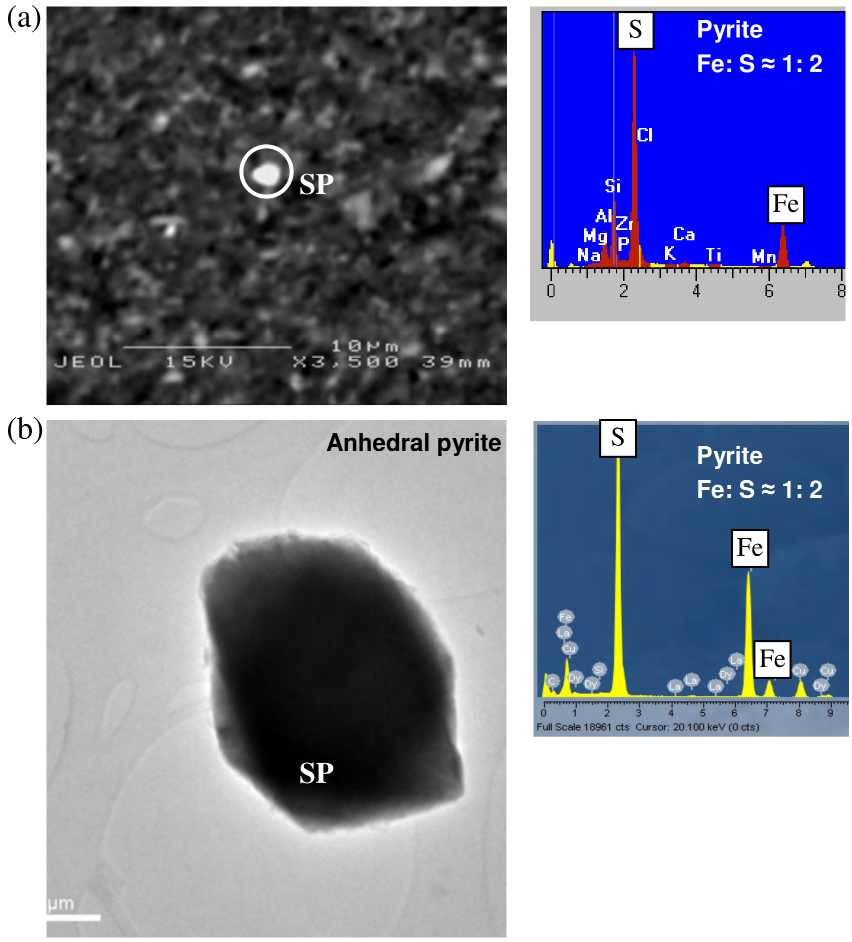



**Figure 23** (a) SEM backscattered electron image (b) TEM transmission electron micrograph and x-ray spectrum of fine fraction pyrite from the B horizon (250-550 cm, site 616-02-174) ($pH_F$ = 5.5, $pH_{FOX}$ = 2.5, $S_{CR}$ = <0.005%). Pyrite was not detected by SXRD however at high magnification rare pyrite crystals can be seen (SP = Single crystal pyrite).

B horizon (N_10)

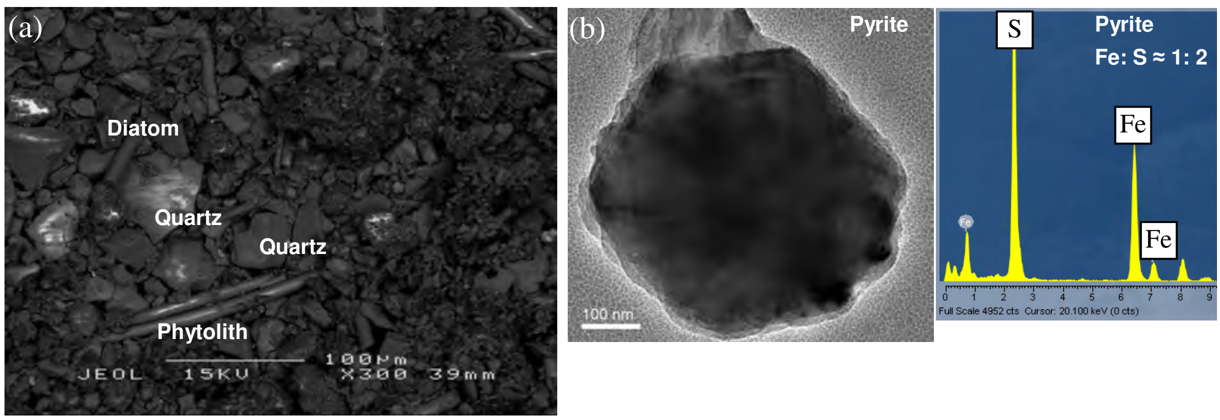



**Figure 24** (a) SEM backscattered electron image with no evident pyrite (b) TEM transmission electron micrograph and x-ray spectrum of fine fraction pyrite from the B horizon (200 cm, site 616-02-065) ($pH_F$ = 5.7, $pH_{FOX}$ = 3.0, $S_{CR}$ = 0.005%). Pyrite was not detected by SXRD and SEM however at high magnification rare pyrite crystals can be seen.

### 5.4 Total chemical composition (ICP and XRF data)

The complete chemical analyses of the whole soils (XRF analysis) are shown in Appendix Table 2. The median and range of minor element concentrations in A, E, B, coffee rock, mud, peat and C horizons (ICP-OES analysis) are given in Appendix Figures 26-59. All soil profiles have quite similar compositions except for a buried soil profile (site 616-02-112) and alluvium

XRF analysis shows that silica dominates in most soil horizons (70-100%) except for mud (8-66%) and peat samples (1-25%). The alumina content of coffee rock is higher than for other horizon (Appendix Table 2). Calcium content is high in mud, peat and C horizons. Sulfur is a very minor constituent of the studied soils. The concentration of iron is highly variable in coffee rock (Appendix Table 2) which is consistent with SEM/EDS data that indicated that iron is not always present at elevated concentrations in coffee rock and that some cemented materials contain little iron (Figures 2 and 6). The Bassendean soil samples have a very high quartz sand content, so that XRF analysis unable to detect some elements in some samples.

For ICP-OES analysis, a combined procedure, involving an aqua regia partial digest and acid digestion of a fusion of whole soil, provides total element compositions. These data enable identification of associations of elements in the fine materials and resistant minerals (Appendix Tables 3 and 4).

Aluminium is relatively abundant in coffee rock (Appendix Figure 27). The Al: Si ratio is always high in coffee rock. Aqua regia dissolves allophane but the Al: Si ratio for this digest is too high for allophane (2: 1) alone and some aluminium comes from kaolin (1: 1), gibbsite (1: 0) and aluminium-organic (1: 0) complex. Iron is relatively abundant in some coffee rock samples; sulfur concentrations are highest in coffee rock and E horizons. Lead and other heavy metals are not present at hazardous concentrations. Arsenic is present in one peat sample at a hazardous concentration (418 mg $kg^{-1}$) (accepted limit 20-50 mg $kg^{-1}$) (Appendix Figure 39). Peat has relatively high sodium content as it is salty (Appendix Figure 30). The sulfur content of E, B, coffee rock and peat horizons is higher than for normal surface soils worldwide (Appendix Figure 38).

The relationships between element concentrations and EC are shown in Table 4. There are very close positive relationships for sulfur, arsenic, iron, C and N (Table 4) however, there are a bimodal distributions of data for the relationships between carbon and arsenic, carbon and sulfur and nitrogen and sulfur (Figure 25) reducing the statistical validity of these relationships. Some elements and soil properties have positive relationships with a more normal distributions of data (Figure 26).

Factor analysis and principal component analysis was carried out on chemical analyses of whole soil using only data for Bassendean sand dune samples (not include alluvium samples). These results show that only 46% of the variation in chemical data for the soils is explained by the first two factors which is a consequence of the diverse nature of these soil materials (Figure 27a). Three affinity groups of elements are recognized. The first group consists of Si ($SiO_2$) which simply relates to the sand fraction of the soils and is not positively related to any other elements. The second group is strongly negatively related to Si, it consists of As, S, C and N which are associated with organic matter. The third group which is also negatively related to Si consists of all remaining elements samples (Al, Ba, Be, Ca, Ce, Co, Cu, Cr, Fe, Ga, Gd, Ge, Hf, K, La, Mg, Mn, Mo, Na, Nd, Ni, P, Pb, Sc, Sr, Th, Ti, V, Y, Zn, Zr) and represents the diverse minerals and adsorbed species in the fine fraction of these soils.

For the cases factor plot, most soil samples are quite similar (group 1) (Figure 26b). All peat samples have relatively high sulfur, arsenic carbon and nitrogen concentrations (group 2) The B horizons are diverse because some B horizons contain relatively high Al and Fe concentrations (group 3).

**Table 4** Correlation matrix (r) showing significant relationships between concentrations of elements for whole soil samples (ICP-OES analysis) ($p<0.05$) (N = 124).

| | C | N | EC | Si | Al | Na | K | Ca | Mg | Fe | Mn | Ti | Zn | Zr | P | S | As | Cu | Cr | Pb | Ni | Ba | Be | Ce | Co | Ga | Gd | Ge | Hf | La | Mo | Nd | Sc | Sr | Th | V | Y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N | 0.99 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| EC | | | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Si | -0.86 | -0.87 | | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Al | | | | -0.30 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Na | 0.60 | 0.59 | | -0.53 | 0.27 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| K | | | 0.29 | -0.19 | 0.62 | 0.43 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ca | 0.22 | 0.22 | | -0.43 | | | 0.21 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mg | 0.79 | 0.81 | | -0.83 | 0.28 | 0.66 | 0.22 | 0.44 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Fe | 0.37 | 0.40 | | -0.63 | 0.59 | 0.24 | 0.31 | | 0.38 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mn | 0.31 | 0.37 | 0.25 | -0.40 | 0.19 | 0.24 | 0.26 | 0.42 | 0.52 | 0.40 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ti | | | | | 0.49 | | 0.34 | | | 0.26 | | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Zn | | | | | | | | | | | | | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | |
| Zr | | | | | | | | | | | | 0.76 | | 1.00 | | | | | | | | | | | | | | | | | | | | | | | |
| P | 0.33 | 0.35 | | -0.46 | 0.34 | | | 0.32 | 0.44 | 0.37 | 0.41 | | | | 1.00 | | | | | | | | | | | | | | | | | | | | | | |
| S | 0.73 | 0.73 | | -0.72 | | 0.20 | | 0.19 | 0.41 | 0.60 | 0.29 | | | | 0.24 | 1.00 | | | | | | | | | | | | | | | | | | | | | |
| As | 0.59 | 0.57 | | -0.58 | | | | | 0.22 | 0.58 | | | | | | 0.96 | 1.00 | | | | | | | | | | | | | | | | | | | | |
| Cu | | | | -0.26 | 0.47 | 0.33 | 0.29 | | 0.23 | 0.47 | 0.21 | 0.29 | 0.37 | | 0.28 | | | 1.00 | | | | | | | | | | | | | | | | | | | |
| Cr | | | | -0.49 | 0.81 | | 0.41 | 0.26 | 0.38 | 0.75 | 0.35 | 0.42 | | 0.22 | 0.47 | 0.29 | 0.28 | 0.39 | 1.00 | | | | | | | | | | | | | | | | | | |
| Pb | | | | | 0.35 | | | | | 0.39 | | | 0.64 | | 0.27 | | | 0.60 | 0.38 | 1.00 | | | | | | | | | | | | | | | | | |
| Ni | 0.45 | 0.49 | 0.27 | -0.56 | 0.24 | 0.34 | | | 0.46 | 0.48 | 0.34 | | | | 0.34 | 0.39 | 0.33 | | 0.39 | | 1.00 | | | | | | | | | | | | | | | | |
| Ba | 0.35 | 0.42 | | -0.58 | 0.47 | 0.35 | 0.35 | 0.46 | 0.58 | 0.59 | 0.69 | 0.21 | | | 0.69 | 0.33 | | 0.52 | 0.57 | 0.32 | 0.37 | 1.00 | | | | | | | | | | | | | | | |
| Be | 0.41 | 0.41 | | -0.53 | 0.25 | | | | 0.18 | 0.77 | | | | | 0.31 | 0.75 | 0.82 | | 0.57 | 0.21 | 0.42 | 0.30 | 1.00 | | | | | | | | | | | | | | |
| Ce | | | 0.20 | -0.33 | 0.62 | 0.24 | 0.61 | 0.25 | 0.30 | 0.44 | 0.25 | 0.53 | | 0.40 | 0.40 | | | 0.42 | 0.63 | 0.33 | | 0.54 | 0.22 | 1.00 | | | | | | | | | | | | | |
| Co | | | | -0.30 | 0.64 | 0.22 | 0.41 | | 0.35 | 0.57 | 0.22 | 0.45 | | 0.35 | 0.28 | | | 0.32 | 0.70 | 0.32 | 0.26 | 0.41 | 0.45 | 0.49 | 1.00 | | | | | | | | | | | | |
| Ga | | | | -0.42 | 0.88 | 0.21 | 0.38 | | 0.31 | 0.81 | 0.36 | 0.49 | | 0.23 | 0.45 | 0.21 | 0.19 | 0.53 | 0.87 | 0.48 | 0.35 | 0.60 | 0.51 | 0.59 | 0.64 | 1.00 | | | | | | | | | | | |
| Gd | | | | | | | 0.29 | 0.42 | | | | 0.21 | | 0.29 | 0.39 | | | | 0.33 | | | 0.27 | | 0.72 | | | 1.00 | | | | | | | | | | |
| Ge | | | | | | | | | | | | | | | | | | | | | - | | | | | | | 1.00 | | | | | | | | | |
| Hf | | | | | 0.26 | | | | | | | 0.20 | | | | | | | 0.18 | | - | | | | | 0.20 | 0.34 | 0.83 | 1.00 | | | | | | | | |
| La | | | 0.19 | -0.36 | 0.70 | 0.22 | 0.57 | 0.30 | 0.35 | 0.43 | 0.25 | 0.57 | | 0.38 | 0.44 | | | 0.39 | 0.72 | 0.33 | 0.19 | 0.55 | 0.23 | 0.94 | 0.53 | 0.63 | 0.73 | | 0.19 | 1.00 | | | | | | | |
| Mo | | | 0.34 | -0.29 | 0.36 | 0.30 | 0.24 | | 0.20 | 0.48 | 0.20 | 0.34 | | | 0.24 | 0.22 | | 0.48 | 0.34 | 0.28 | 0.21 | 0.45 | 0.25 | 0.42 | 0.30 | 0.46 | | | | 0.38 | 1.00 | | | | | | |
| Nd | | | 0.19 | -0.39 | 0.63 | 0.22 | 0.58 | 0.33 | 0.32 | 0.47 | 0.24 | 0.50 | | 0.37 | 0.46 | 0.21 | | 0.39 | 0.68 | 0.31 | 0.19 | 0.55 | 0.31 | 0.98 | 0.49 | 0.61 | 0.77 | | | 0.95 | 0.41 | 1.00 | | | | | |
| Sc | | | | -0.32 | 0.89 | 0.27 | 0.53 | | 0.35 | 0.66 | 0.21 | 0.55 | | 0.27 | 0.24 | | | 0.54 | 0.78 | 0.37 | 0.24 | 0.48 | 0.28 | 0.63 | 0.75 | 0.84 | | | | 0.69 | 0.45 | 0.61 | 1.00 | | | | |
| Sr | | | | -0.30 | | | | 0.86 | 0.39 | | 0.47 | | | | 0.29 | | | | 0.28 | | | 0.42 | | | | | 0.37 | | | 0.28 | | 0.25 | | 1.00 | | | |
| Th | | | | -0.28 | 0.88 | 0.23 | 0.53 | | 0.29 | 0.64 | 0.20 | 0.68 | | 0.43 | 0.22 | | | 0.43 | 0.80 | 0.42 | 0.21 | 0.43 | 0.31 | 0.66 | 0.77 | 0.85 | 0.21 | | 0.18 | 0.73 | 0.44 | 0.65 | 0.94 | | 1.00 | | |
| V | | | | -0.19 | 0.49 | | | | | 0.62 | | | | | 0.31 | | | | 0.60 | 0.44 | 0.31 | 0.30 | 0.56 | 0.26 | 0.53 | 0.66 | | | | 0.27 | 0.30 | 0.27 | 0.52 | | 0.59 | 1.00 | |
| Y | 0.39 | 0.38 | | -0.53 | | | | 0.36 | 0.25 | 0.54 | | | | | 0.31 | 0.74 | 0.76 | | 0.45 | | | 0.33 | 0.73 | 0.45 | 0.33 | 0.27 | 0.41 | | | 0.41 | 0.19 | 0.54 | 0.18 | 0.27 | | | 1.00 |

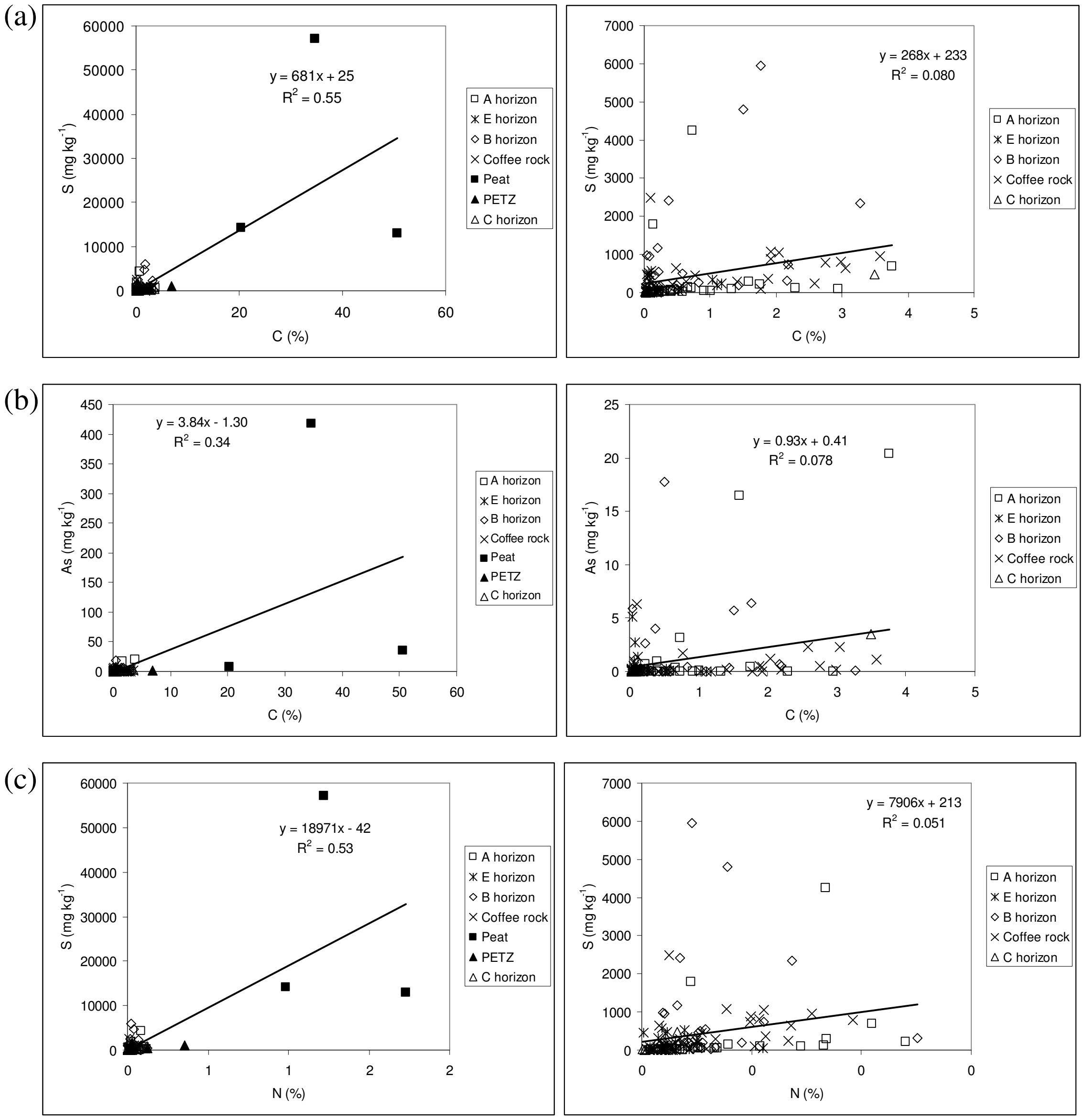



**Figure 25** Some significant bivariate relationships between (a) carbon and sulfur (b) carbon and arsenic and (c) nitrogen and sulfur. RHS plots omit the PETZ and peat samples which make the relationships non significant showing that the LHS relationships are specious due to the bimodal distribution of these data.

NB all data for whole soil samples.

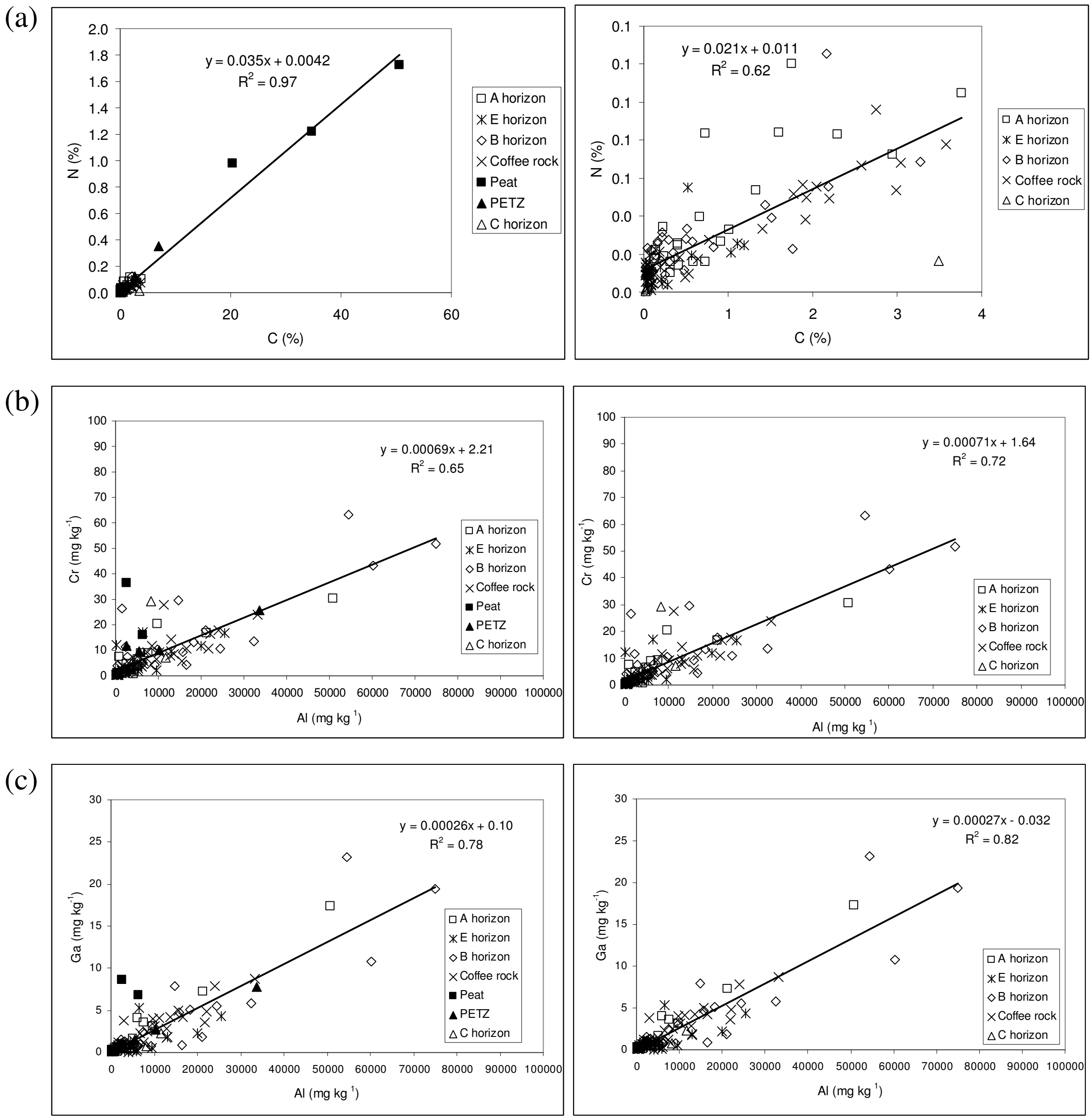



**Figure 26** Some highly significant bivariate relationships (for a more normal distribution of data) between (a) carbon and nitrogen (b) aluminium and chromium and (c) aluminium and gallium. RHS plots omit the PETZ and peat samples but the relationship continue to be highly significant showing that the LHS relationships are not specious due to the abnormal distribution of these data.

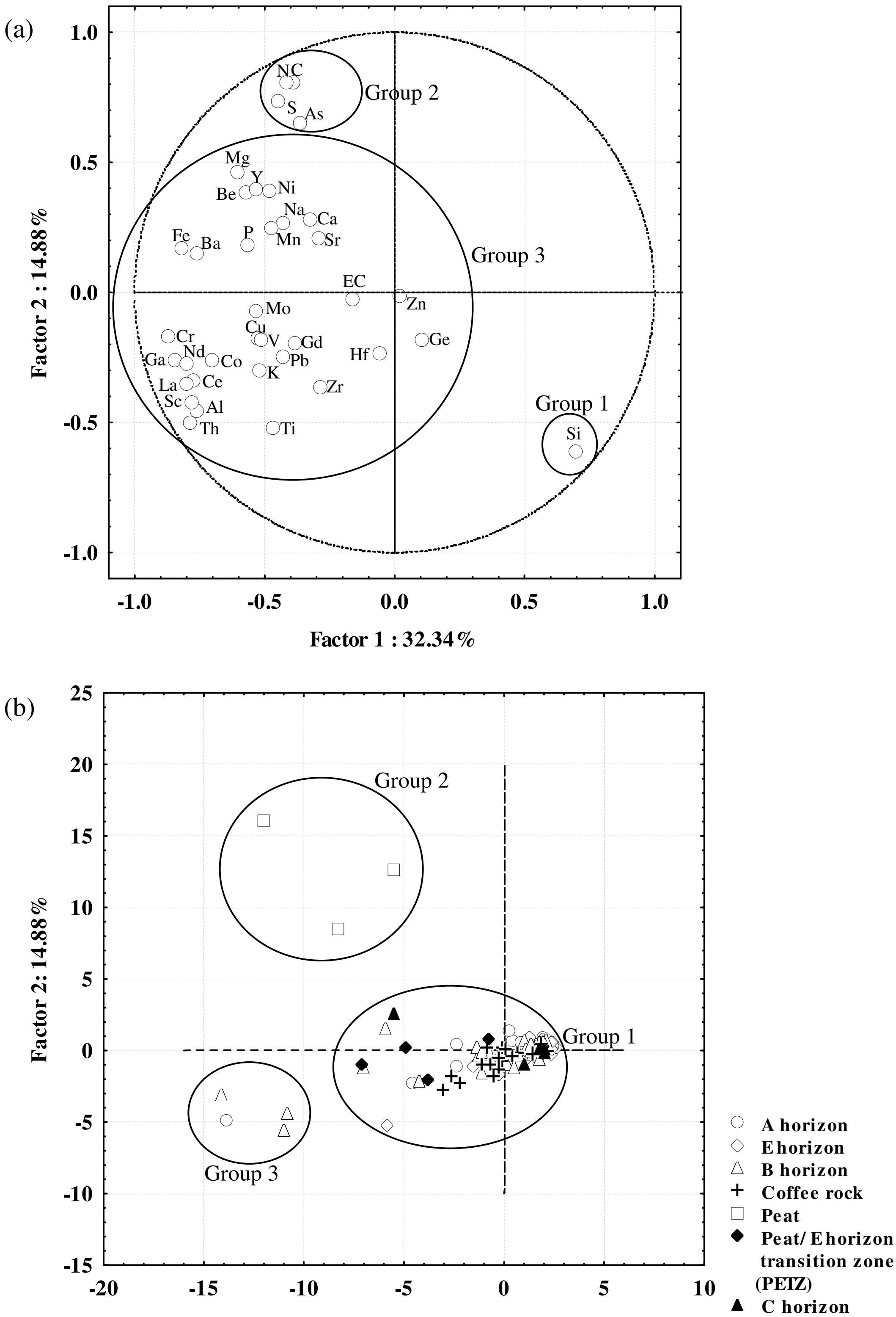



**Figure 27** Factor analysis for chemical analyses by aqua regia digests and fusion acid digestion methods of whole soil samples and some soil properties of whole soil materials (N = 124) (a) distribution of elements and some soil properties (variables) (b) distribution of soil samples (cases).

## 5.5 Extractable silicon, aluminium, iron, manganese

Si, Al, Fe and Mn concentrations of extractable by dithionite-citrate-bicarbonate (d), ammonium oxalate (ox) and pyrophosphate (p) are also given in Appendix Table 5. These extractions estimate the various "reactive" constituents of soils: respectively crystalline oxides, amorphous oxides and OM complexes (García-Rodeja, *et al.*, 2004). Maximum, minimum and median values of extractable Si, Al, Fe, Mn are presented in Appendix Figures 60-71. Si contents of all extractions of coffee rock are higher than for other soil horizons, especially the concentration of silicon extracted by ammonium oxalate which has a close relationship with amorphous minerals, particularly allophane in this instance.

Aluminium (Ald, Alox and Alp) are high in coffee rock and B horizon because of the amorphous alumino-silicate cementing agent between sand grains. The ratio Alox/ Siox of coffee rock and B horizon may indicate the composition of the allophane present in these soils. Figure 28 is a bivariate plot of Siox and Alox which has a slope of 0.4 which is similar to that expected for allophane (García-Rodeja, *et al.*, 2004). A TEM of allophane is shown in Figure 29.

Extractable iron analysis uses three separate techniques to determine the types of ferric minerals present in soil samples. Crystalline iron oxides as estimated by DCB extraction (Fed), whereas the concentration of amorphous iron compounds (active iron) in soils is estimated by oxalate extraction. Organically bound iron and aluminium are extracted with a Na-pyrophosphate solution. The pyrophosphate-soluble iron concentration of B horizon, coffee rock and peat is higher than for other soil horizons, probably because of Fe complexing with the more abundant organic matter. Manganese concentrations for all extractions are very low.

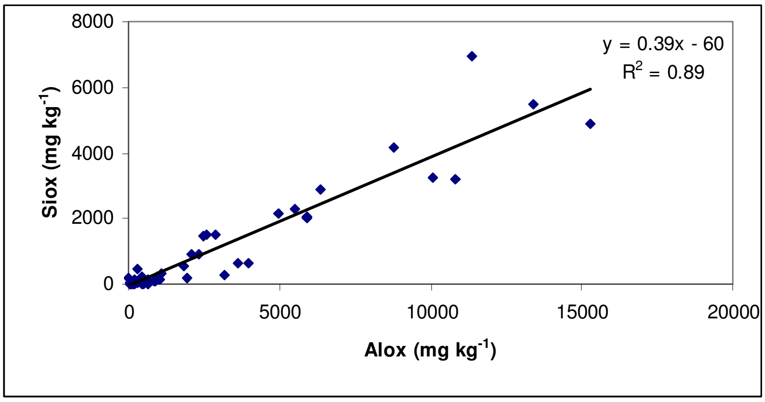
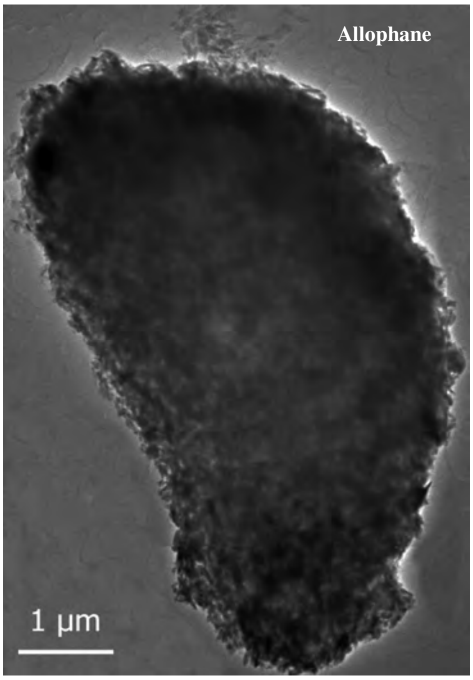
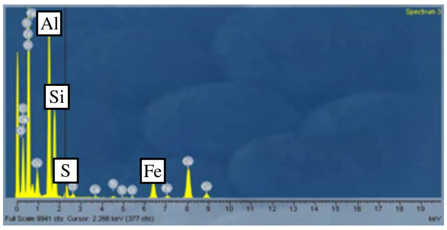



**Figure 28** Bivariate relationship between Alox and Siox of coffee rock and B horizons.

Coffee rock

(a)

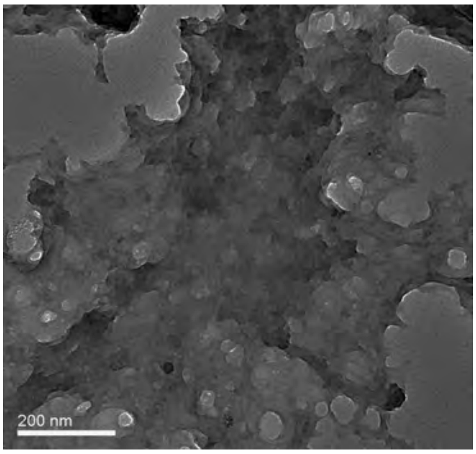


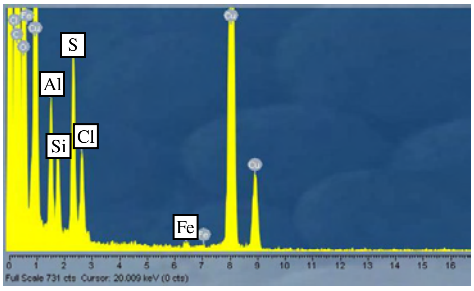




| Atomic percent | | | |
|---|---|---|---|
| Al | Si | S | Fe |
| 53 | 36 | 1 | 10 |

Atomic ratio (Al, Fe) : Si ≈ 2: 1

(b)




| Atomic percent | | | |
|---|---|---|---|
| Al | Si | S | Fe |
| 34 | 20 | 45 | 1 |

Atomic ratio (Al, Fe) : Si ≈ 2: 1

**Figure 29**Transmission electron micrograph and X-ray spectrum of an allophane (Al, Fe)$_2$O$_3$.SiO$_2$.nH$_2$O) particle from (a) coffee rock (5.0-6.0 m, site 616-02-82), (b) coffee rock (3.0-5.0 m, site 616-02-58), this allophanic material contains much elemental or incorporated S.

## 5.6 Incubation

Potential acid sulfate soils can be identified by incubation of soil samples in an open tray. This procedure simulates oxidation under natural conditions. Three incubation methods at different soil moisture contents were used to identify sulfidic materials in this research (Figure 30). Summary details of the incubation study are shown in Table 5. Three soil profiles (17 soil samples), including site 616-02-65, 616-02-68 and 616-02-122, were studied by the incubation method to determine the pH trend as natural (not $H_2O_2$) oxidation takes place. Only sample No 149 (site 616-02-68 B horizon; depth 7.0-8.0 m) was used for all three incubation methods. Some samples from the soil column experiment (site 616-02-05, 616-02-68 and 616-02-179) were also used for the standard incubation method.

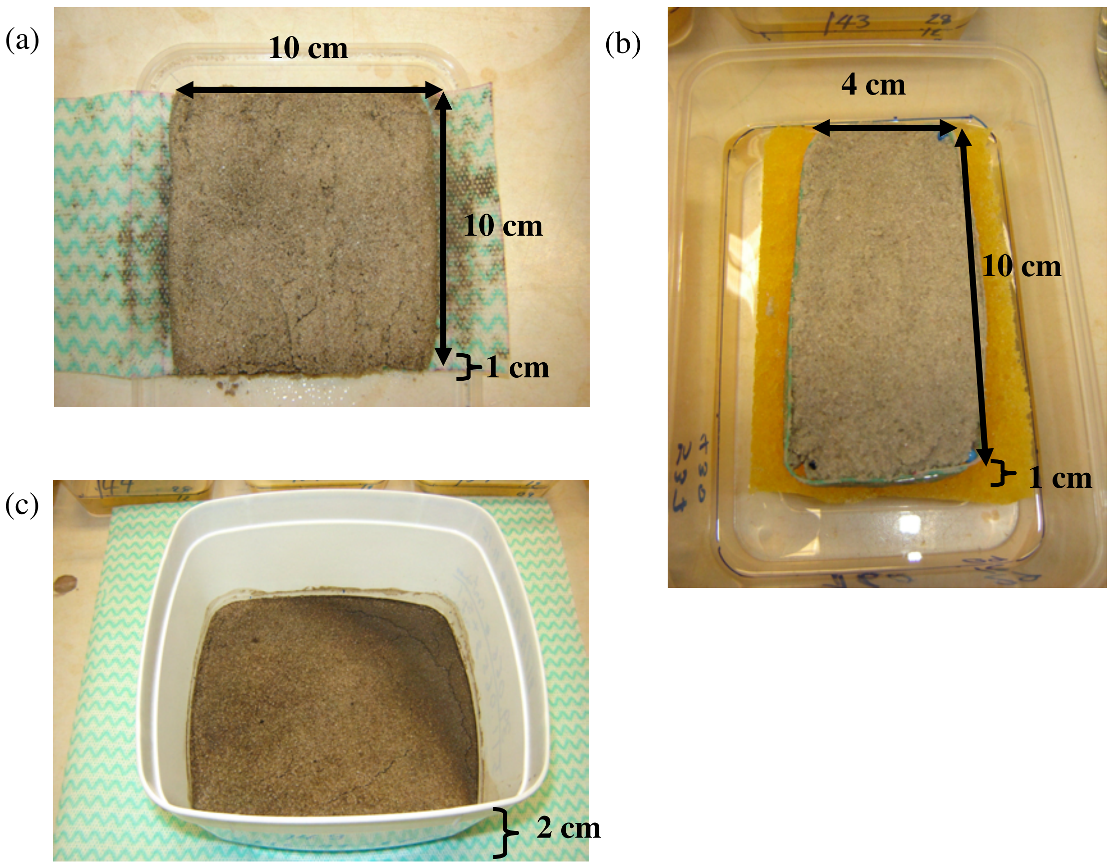



**Figure 30** (a) standard method prescribed by the USDA/ Australian soil classifications (1 cm soil thick); (b) modified standard method for nearly saturated soil (1 cm soil thick) and (c) modified method for moist soil (2 cm soil thick).

All soil pH values decreased by more than 0.5 units therefore all soils are sulfidic material, an accelerated oxidation of sulfide occurred when the pH decreased below pH 4.0 (Soil Survey Staff, 2006) (Figures 31-34). The pH of many samples decreased to low or very low values (Figures 31-34). The pH values for many soil samples appears to have reached a steady state but these steady state values are much higher than those obtained with $H_2O_2$.

For many samples, the starting pH was already lower than field pH measured in water because some oxidation had occurred during sampling and storage consequently incubation commenced with samples that were considerably more acid than their original field condition. For Figure 34 (site 616-02-05, 616-02-68 and 616-02-179), the field pH (water) indicated in this figure is the starting pH (0 day). The pH decreased very quickly but after 2 months, the pH was quite stable and pH($H_2O$) did not decrease to pH($H_2O_2$). pH($H_2O_2$) for the standard and nearly saturated soil methods is higher than field pH($H_2O_2$) ($pH_{FOX}$) possibly because some acid buffering reactions take place during the incubations but did not during the rapid field $H_2O_2$ ($pH_{FOX}$) oxidation (Figures 31-34). Figure 34 compares the pH values produced by incubation and peroxide treatment ($pH_{FOX}$) for B horizon samples.

The actual acidity released from these soils is related to the rate of acidification. Oxidation of organic matter and amorphous iron-aluminosilicate minerals may affect acidification. Comparing soil sample 616-02-65 (mainly coffee rock) and 616-02-122 (mainly E horizon), both materials have a low $S_{CR}$ content (<0.02%), the standard method of assessment shows that pH($H_2O$) of the coffee rock incubated for 13 months was above 4 (Figure 32) whereas, pH($H_2O$) of the E horizon material dropped to less than 4 within 1 day (Figure 33). It is clear that the neutralising behaviours of coffee rock and E horizon are different with the coffee rock having a higher acid neutralising capacity than E horizon material. Thus the morphology of soil profile materials especially depth and thickness of coffee rock and E horizons may be directly related to the potential environmental hazard of acid sulfate soils when they are exposured to air. Some potential acid sulfate materials may be not become a hazard to the environment if the acidity is released at a slow rate and buffering processes are available to neutralise the acidity.

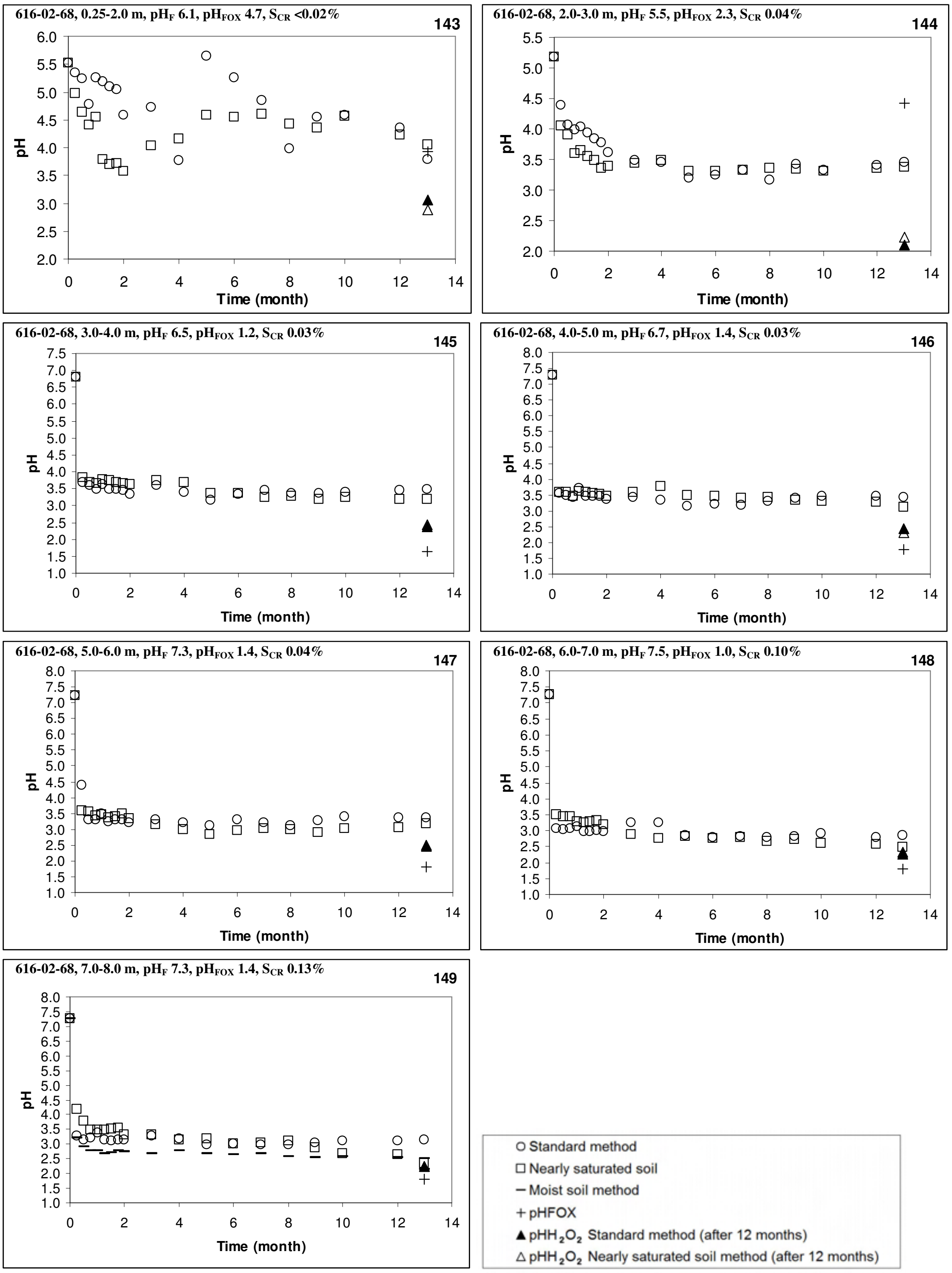



**Figure 31** Changes in pH of soil samples from site 616-02-68 during the 12 month incubation period (the USA/Australian standard methods requires 8 weeks incubation).

N.B. Start pH was already lower than pH$_F$ because some oxidation had occurred during sampling and storage so that incubation commenced with samples that were considerably more acid than their original field condition.

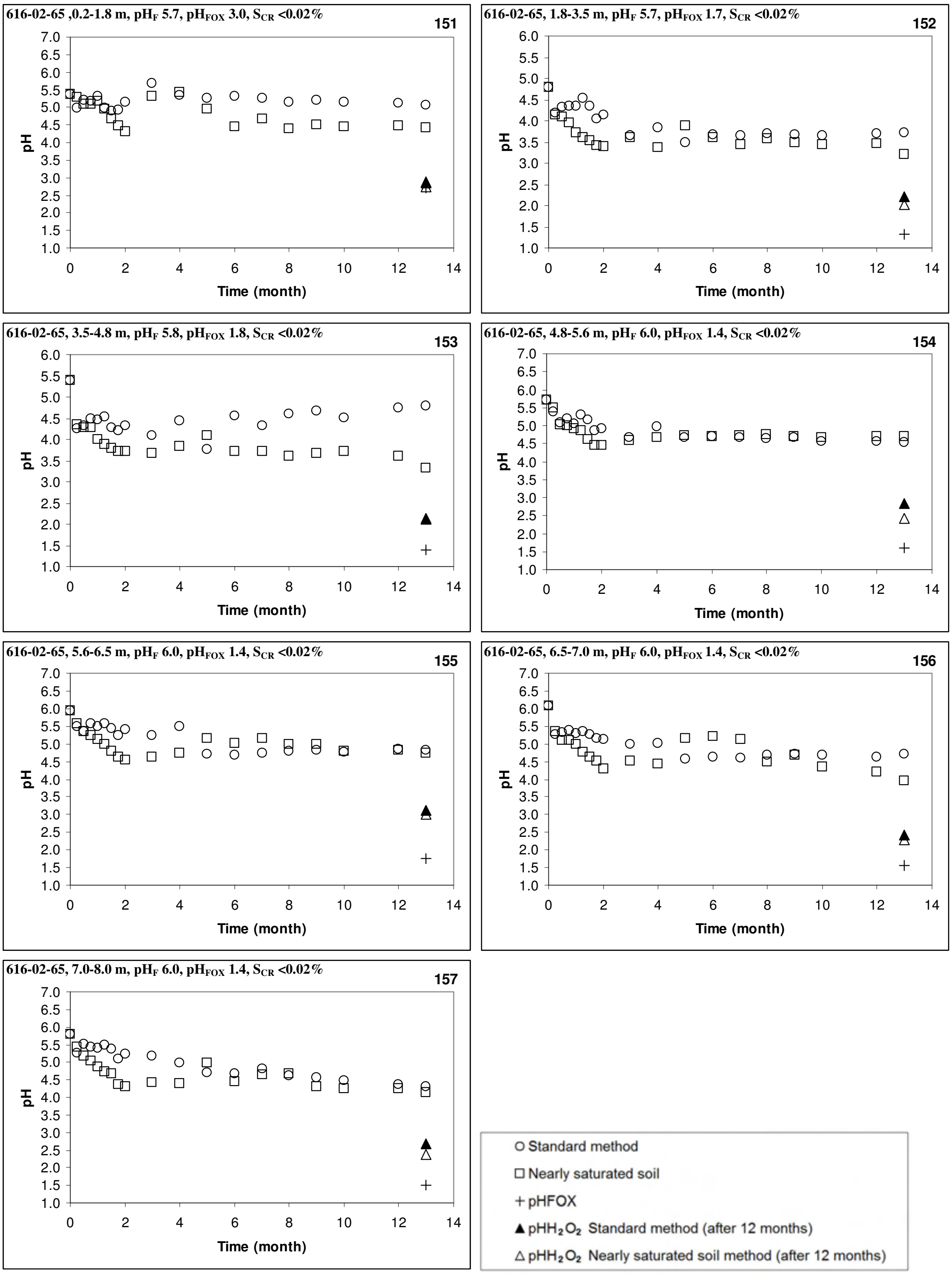



**Figure 32** Changes in pH of soil samples from site 616-02-65 during the 12 month incubation period (the USA/Australian standard methods requires 8 weeks incubation).

N.B. Start pH was already lower than $pH_F$ because some oxidation had occurred during sampling and storage so that incubation commenced with samples that were considerably more acid than their original field condition.

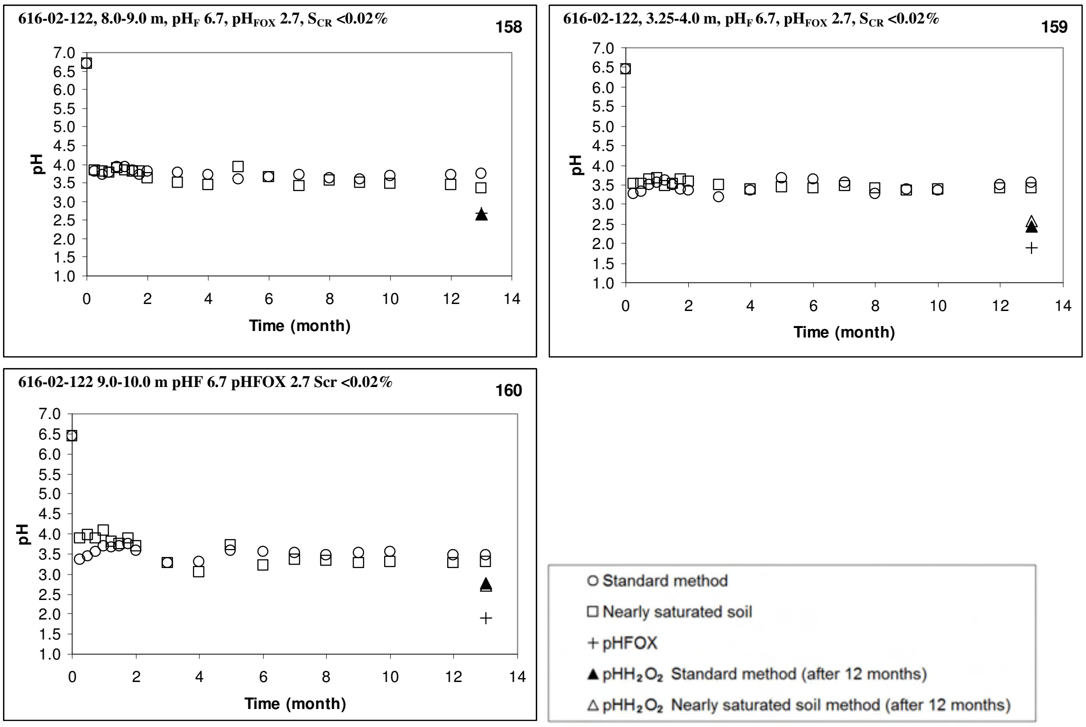



**Figure 33** Changes in pH of soil samples from site 616-02-122 during the 12 month incubation period (the USA/Australian standard methods requires 8 weeks incubation).

N.B. Start pH was already lower than $pH_F$ because some oxidation had occurred during sampling and storage so that incubation commenced with samples that were considerably more acid than their original field condition.

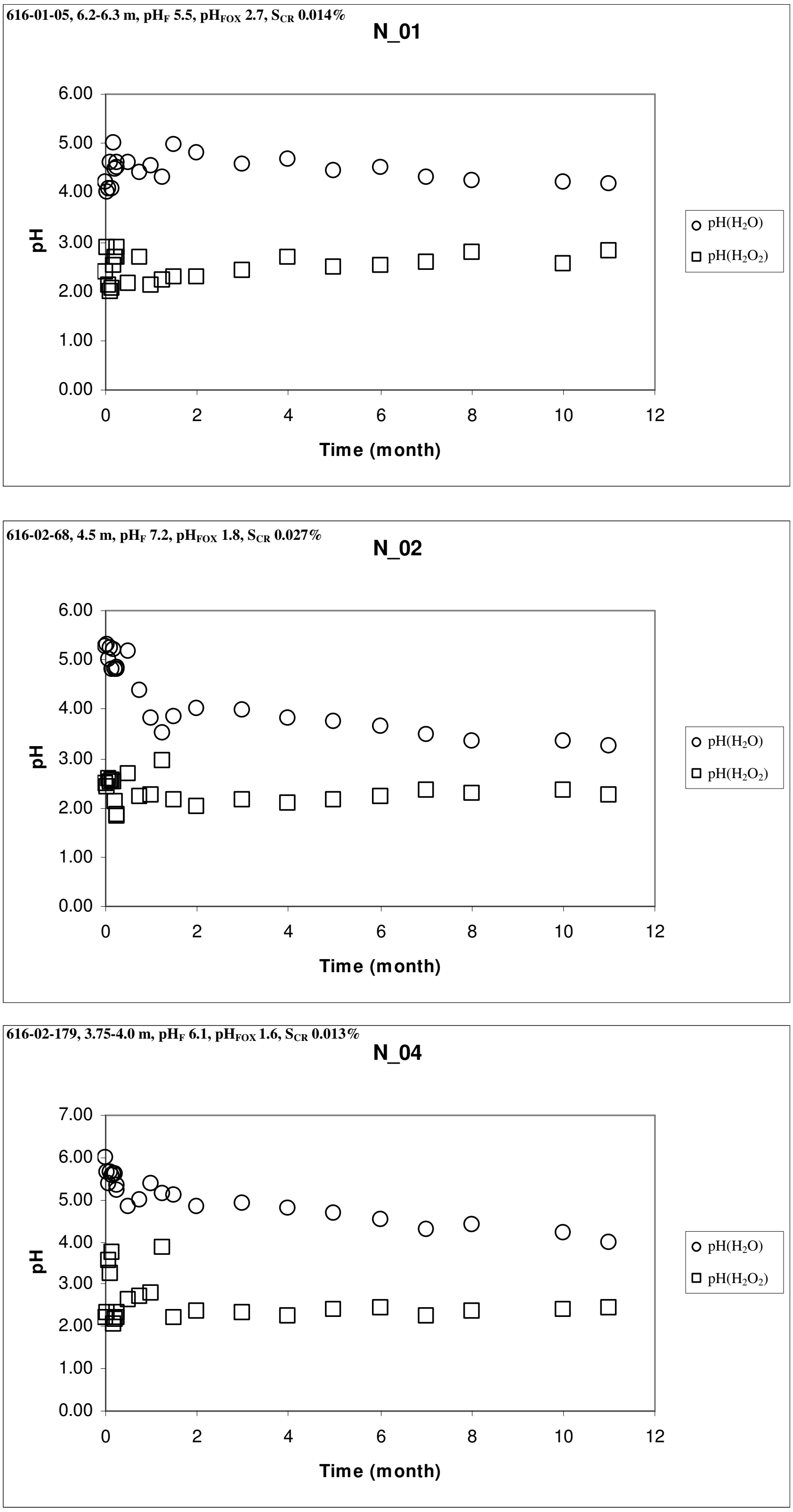



**Figure 34** Changes in pH of B horizon from site 616-02-05 (N_01), 616-02-68 (N_02) and 616-02-179 (N_04) the during 11 month incubation period (the USA/Australian standard methods requires 8 weeks incubation).

**Table 5** Summary of incubation results for some representative soil samples and several incubation procedures.

| No | Site | Horizon | Depth (m) | $pH_F$ | $pH_{FOX}$ | $S_{CR}$ (%) | Standard method $pHH_2O$ | Nearly saturated soil method $pHH_2O$ | Moist soil method $pHH_2O$ | Standard method $pHH_2O_2$ | Nearly saturated soil method $pHH_2O_2$ | Moist soil method $pHH_2O_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | (------after 12 months------) | | | | | |
| 143 | 616-02-68 | E horizon | 0.25-2.0 | 6.1 | 4.7 | <0.02 | 3.8 | 4.1 | - | 3.1 | 2.9 | - |
| 144 | 616-02-68 | coffee rock | 2.0-3.0 | 5.5 | 2.3 | 0.04 | 3.5 | 3.4 | - | 2.1 | 2.2 | - |
| 145 | 616-02-68 | B1 horizon | 3.0-4.0 | 6.5 | 1.2 | 0.03 | 3.5 | 3.2 | - | 2.4 | 2.4 | - |
| 146 | 616-02-68 | B2 horizon | 4.0-5.0 | 6.7 | 1.4 | 0.03 | 3.4 | 3.1 | - | 2.4 | 2.3 | - |
| 147 | 616-02-68 | B3 horizon | 5.0-6.0 | 7.3 | 1.4 | 0.04 | 3.4 | 3.2 | - | 2.5 | 2.5 | - |
| 148 | 616-02-68 | B4 horizon | 6.0-7.0 | 7.5 | 1.0 | 0.10 | 2.9 | 2.5 | - | 2.3 | 2.3 | - |
| 149 | 616-02-68 | B5 horizon | 7.0-8.0 | 7.3 | 1.4 | 0.13 | 3.2 | 2.4 | 2.5 | 2.2 | 2.2 | 2.1 |
| 151 | 616-02-65 | Peat2 | 0.2-1.8 | 5.7 | 3.0 | <0.02 | 5.1 | 4.4 | - | 2.9 | 2.7 | - |
| 152 | 616-02-65 | B1 horizon | 1.8-3.5 | 5.7 | 1.7 | <0.02 | 3.7 | 3.2 | - | 2.2 | 2.0 | - |
| 153 | 616-02-65 | B2 horizon | 3.5-4.8 | 5.8 | 1.8 | <0.02 | 4.8 | 3.3 | - | 2.2 | 2.1 | - |
| 154 | 616-02-65 | coffee rock1 | 4.8-5.6 | 6.0 | 1.4 | <0.02 | 4.5 | 4.7 | - | 2.8 | 2.4 | - |
| 155 | 616-02-65 | coffee rock2 | 5.6-6.5 | 6.0 | 1.4 | <0.02 | 4.8 | 4.7 | - | 3.1 | 3.0 | - |
| 156 | 616-02-65 | coffee rock3 | 6.5-7.0 | 6.0 | 1.4 | <0.02 | 4.7 | 4.0 | - | 2.4 | 2.3 | - |
| 157 | 616-02-65 | coffee rock4 | 7.0-8.0 | 6.0 | 1.4 | <0.02 | 4.3 | 4.1 | - | 2.7 | 2.4 | - |
| 158 | 616-02-122 | B/E horizon | 8.0-9.0 | 6.7 | 2.7 | <0.02 | 3.7 | 3.4 | - | 2.7 | 2.7 | - |
| 159 | 616-02-122 | 2E2 horizon | 3.25-4.0 | 6.7 | 2.7 | <0.02 | 3.6 | 3.4 | - | 2.4 | 2.6 | - |
| 160 | 616-02-122 | 3E horizon | 9.0-10.0 | 6.7 | 2.7 | <0.02 | 3.5 | 3.3 | - | 2.8 | 2.7 | - |
| N_01 | 616-01-05 | B horizon | 6.2-6.3 | 5.5 | 2.7 | 0.014 | 4.2 | - | - | 2.8 | - | - |
| N_02 | 616-02-68 | B horizon | 4.5 | 7.2 | 1.8 | 0.027 | 3.2 | - | - | 2.3 | - | - |
| N_04 | 616-02-179 | B horizon | 3.75-4.0 | 6.1 | 1.6 | 0.013 | 4.0 | - | - | 2.5 | - | - |

## 5.7 Buffering capacity

Acid buffering capacity of the A, E, B, coffee rock and C horizon materials was determined by acid batch titration against $H_2SO_4$ (0.0012, 0.0036, 0.0060, 0.0072, 0.0144 and 0.0288M for coffee rock and B horizon corresponding to acid loads of 24-576 mmol $H^+$ $kg^{-1}$ and 0.000005, 0.000010, 0.000025, 0.000050, 0.000075 and 0.00010M for other soil horizons corresponding to acid loads of 0.1-2.0 mmol $H^+$ $kg^{-1}$). The buffering curves were used to estimate the acid required to reach the pH $H_2O_2$ value and these provide an estimate of acid generated on oxidation of pyrite and sulfur (also dissolution of jarosite) (Table 6, Figures 35-36). However, some pyrite was probably oxidised during the titration resulting in an underestimation of acid production.

Total acid production, including oxidation pyrite and sulfur and digestion of organic matter, on oxidation was also determined by base (NaOH) batch titration (0.00001, 0.0012, 0.0024, 0.0048, 0.0072, 0.0120, 0.0144 and 0.0288M for coffee rock and B horizon corresponding to base loads of 0.1-288 mmol $OH^-$ $kg^{-1}$ and 0.00001, 0.00002, 0.00005, 0.00010, 0.00015, 0.00020, 0.00030M for other soil horizon corresponding to base loads of 0.1-3.0 mmol $OH^-$ $kg^{-1}$). The initial pH $H_2O$ of the soil was used in conjunction with the $OH^-$ buffering curve to calculate the amount of $OH^-$ required to neutralise the acidity released by $H_2O_2$ addition (Table 7, Figures 37-38).

The oxidation of pyrite and marcasite ($FeS_2$) and elemental sulfur produces $H^+$, oxidation of humus organic–Al complex releases Al which hydrolyses causing acidity and dissolution of jarosite releases acidity. Buffering of acidity is provided by organic matter, allophane $(Al, Fe)_2O_3(SiO_2)1.3\text{-}2(H_2O)_{2.5\text{-}3}$), kaolin, gibbsite and Fe-oxides which have high surface area with exposed hydroxyl. Primary minerals (feldspar, ilmenite etc) are minor constituents of these soils and are sand-size and are essentially insoluble so they do not provide a rapid buffering capacity.

On the basis of both acid and alkali batch titrations, it is evident that coffee rock and B horizon have a much greater acid buffering and acidity production than the other horizons.

[NB These are both imprecise measures of the acidity produced by oxidation of pyrite, marcasite and sulfur and dissolution of jarosite. Acidity is also produced *inter alia* by oxidation of organic matter and hydrolysis of aluminium from the aluminium-organic matter complex.]

The relationships between buffering capacity and some soil properties are shown in Table 8 and Figures 39-40. The buffering capacity of coffee rock and B horizons has positive relationships with iron extracted by Na-pyrophosphate and $NH_4$ oxalate (Figure 40). Finally, the summary of $S_{CR}$ (%) analyses of some pyrite B horizon materials and the evaluation of these samples by direct mineralogical methods is shown in Table 9. Evidently analytical values of 0.01% $S_{CR}$ correctly identify the presence of pyrite. A result of <0.005% $S_{CR}$ might be interpreted as the sample not containing pyrite but in this example (N09) pyrite was present. Clearly the useful LLD for $S_{CR}$ % should be 0.005% $S_{CR}$ or better.

$pH_{FOX}$ is an excellent indicator to predict acidification minerals in very sandy soils. Table 9 shows that when $pH_{FOX}$ is more than 2.5, SXRD is unable to detect pyrite. Treatment of a small samples with hydrogen peroxide offers a quicker method of prediction of potential acid sulfate soils, especially very sandy (quartz rich) soils. The criterion for the $pH_{FOX}$ of potential acid sulfate soils should be a value of pH<2.5. Brinkman and Pons (1973) also suggested a tentative limit for dangerous acid sulfate soils of pH 2.5 after peroxide treatment.

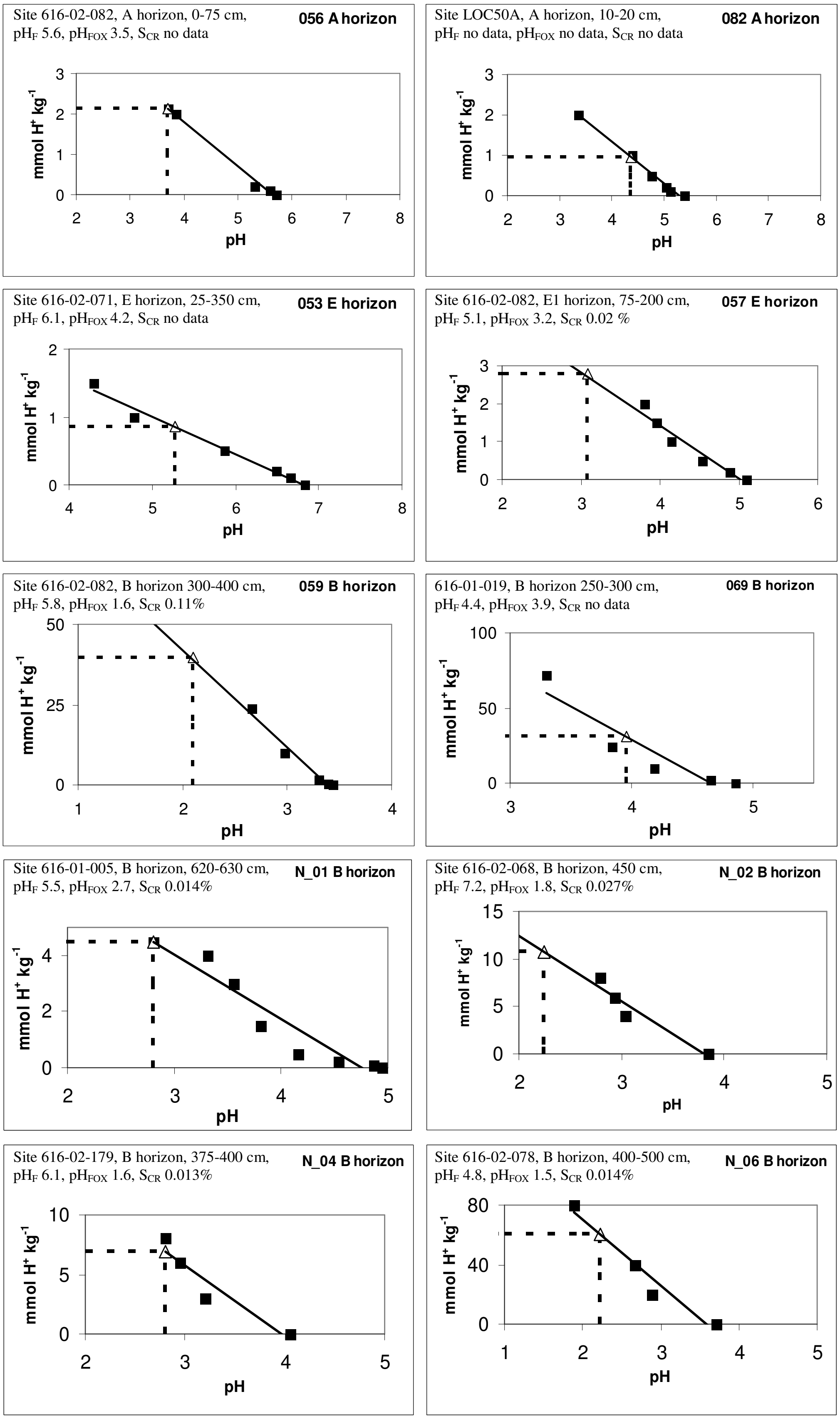



**Figure 35** Acid batch titration results for A, E and B horizons. Dashed lines correspond to the pH of $H_2O_2$ oxidised samples ($\Delta$ = predicted mmol $H^+$ $kg^{-1}$ value from linear equation).

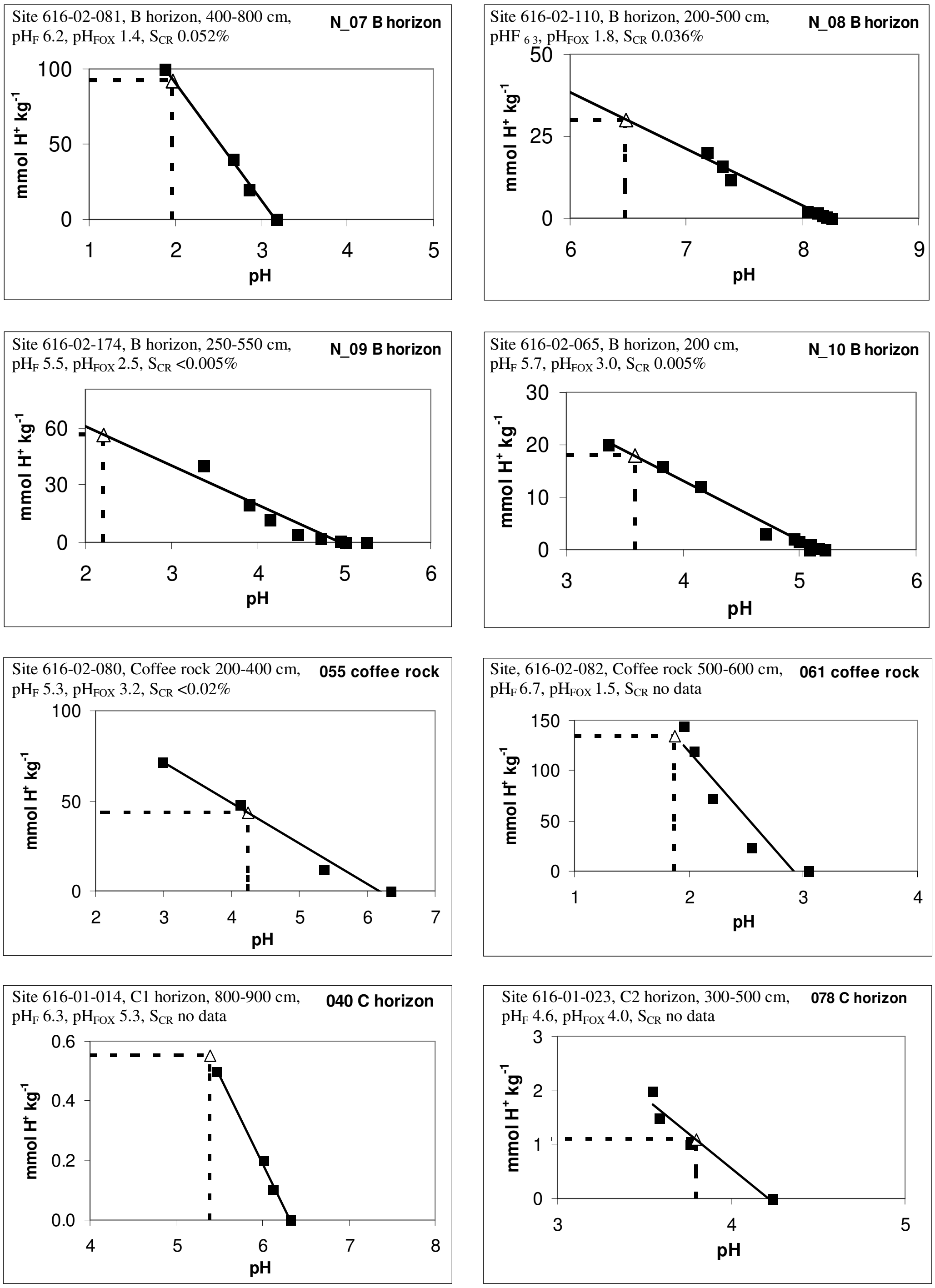



**Figure 36** Acid batch titration results for B, coffee rock and C horizon. Dashed lines correspond to the pH of $H_2O_2$ oxidised samples ($\Delta$ = predicted mmol $H^+$ $kg^{-1}$ value from linear equation).

**Table 6** Buffering capacity (buffer[a]) of representative horizons of soil samples calculated from linear equations for acid batch titration.

| No | Horizon | $R^2$ | Linear equation* | Buffering capacity (mmol $H^+$ $kg^{-1}$/ pH) | mmol $H^+$ $kg^{-1}$** |
|---|---|---|---|---|---|
| 056 | A horizon | 0.99 | y = -1.11x + 6.24 | 1.1 | 2.1 |
| 082 | A horizon | 0.99 | y = -1.04x + 5.48 | 1.0 | 1.0 |
| 053 | E horizon | 0.98 | y = -0.55x + 3.77 | 0.6 | 0.9 |
| 057 | E horizon | 0.94 | y = -1.45x + 7.24 | 1.4 | 2.8 |
| 059 | B horizon | 0.97 | y = -30.8x + 104 | 31 | 40 |
| 069 | B horizon | 0.86 | y = -44.0x + 183 | 44 | 31 |
| N_01 | B horizon | 0.91 | y = -2.30x + 10.9 | 2.3 | 4 |
| N_02 | B horizon | 0.92 | y = -6.89x + 26.2 | 6.9 | 11 |
| N_04 | B horizon | 0.90 | y = -5.94x + 23.5 | 5.9 | 7 |
| N_06 | B horizon | 0.95 | y = -44.2x + 158 | 44 | 60 |
| N_07 | B horizon | 0.98 | y = -78.5x + 248 | 79 | 92 |
| N_08 | B horizon | 0.97 | y = -17.3x + 142 | 17 | 30 |
| N_09 | B horizon | 0.88 | y = -20.5x + 102 | 21 | 56 |
| N_10 | B horizon | 0.99 | y = -11.5x + 59.0 | 12 | 18 |
| 055 | coffee rock | 0.98 | y = -22.5x + 139 | 23 | 43 |
| 061 | coffee rock | 0.89 | y = -129x + 376 | 129 | 134 |
| 040 | C horizon | 0.99 | y = -0.59x + 3.75 | 0.6 | 0.55 |
| 078 | C horizon | 0.94 | y = -2.62x + 11.0 | 2.6 | 1.1 |

* y = mmol $H^+$ $kg^{-1}$; x = pH

** interpreted from the graph as the amount of $H^+$ required to achieve the pH value obtained after $H_2O_2$ oxidation (values indicated in corresponding Figures 35-36).

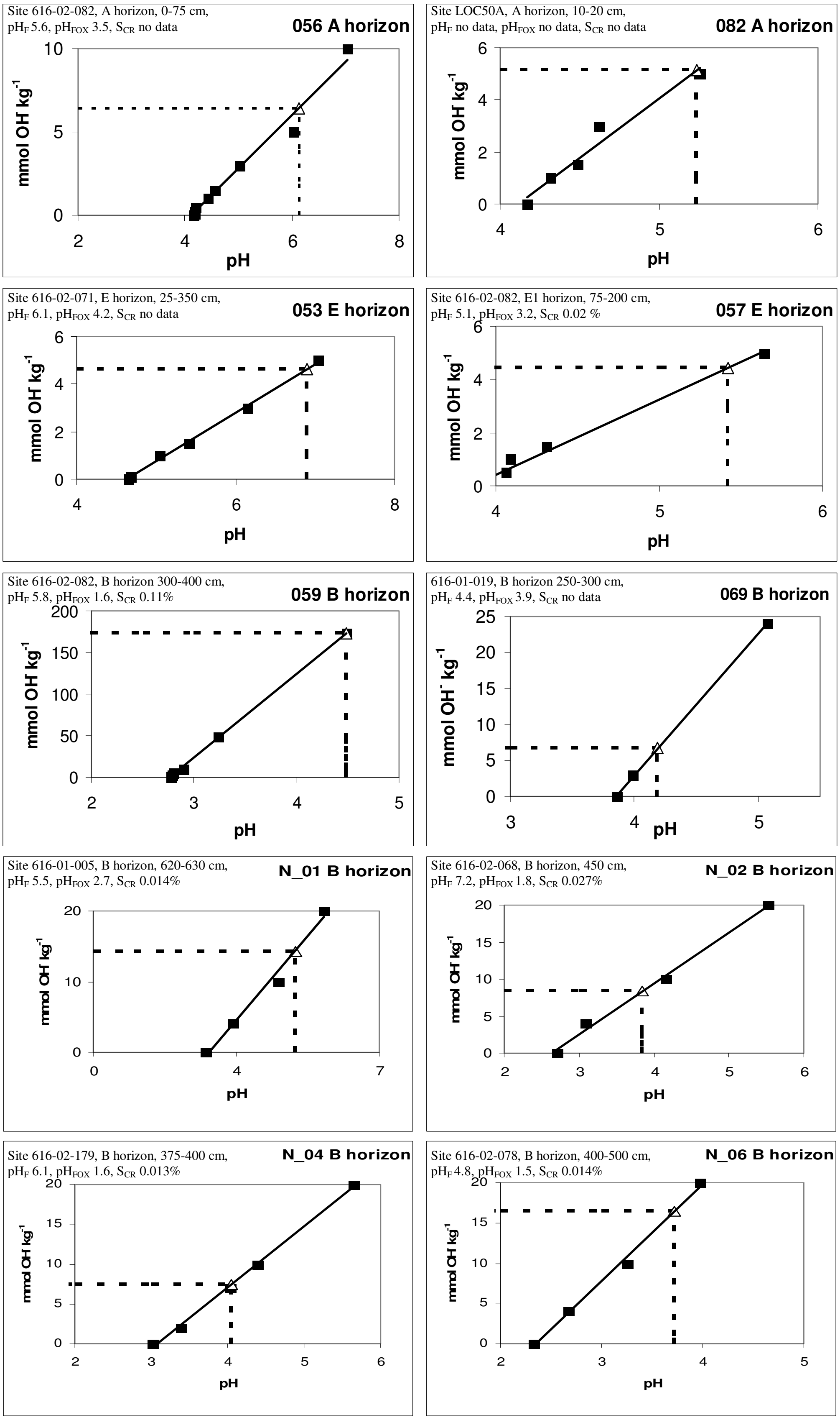



**Figure 37** Base batch titration results for $H_2O_2$ treated samples of A, E and B horizons. Dashed lines correspond to the initial pH $H_2O$ value ($\Delta$ = predicted mmol $OH^- \, kg^{-1}$ value from linear equation).

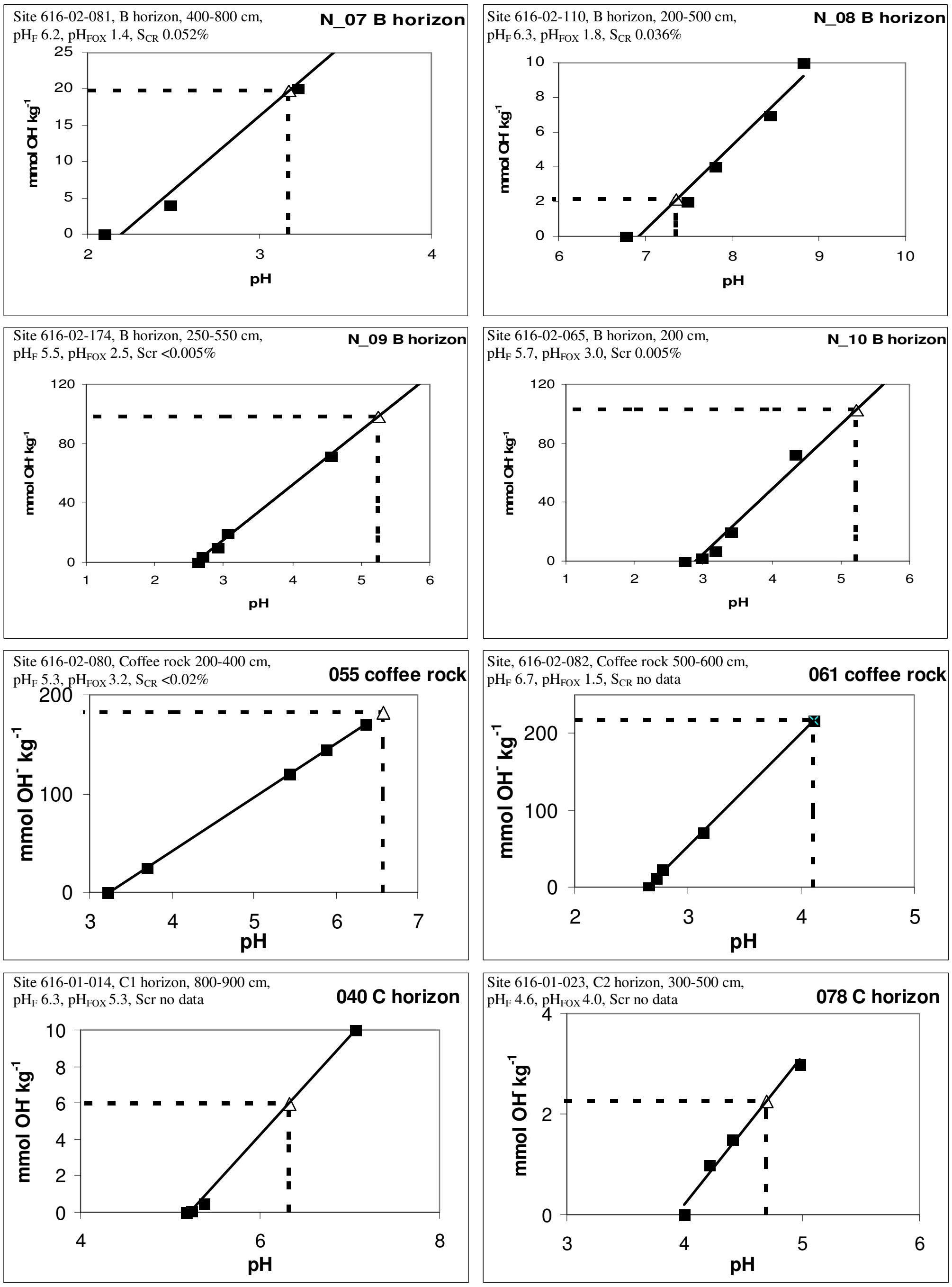



**Figure 38** Base batch titration results for $H_2O_2$ treated samples of B, coffee rock and C horizons. Dashed lines correspond to the initial pH $H_2O$ value ($\Delta$ = predicted mmol $OH^-$ $kg^{-1}$ value from linear equation).

**Table 7** Buffering capacity (buffer[b]) of representative horizons of soil samples calculated from linear equation for base batch titration.

| No | Horizon | $R^2$ | Linear equation* | Buffering capacity (mmol $OH^-$ $kg^{-1}$/ pH) | mmol $OH^-$ $kg^{-1}$** |
|---|---|---|---|---|---|
| 056 | A horizon | 0.98 | y = 3.23x - 13.4 | 3.2 | 6.4 |
| 082 | A horizon | 0.96 | y = 4.54x - 18.6 | 4.5 | 5.1 |
| 053 | E horizon | 1.00 | y = 2.05x - 9.49 | 2.1 | 4.6 |
| 057 | E horizon | 0.99 | y = 2.82x - 10.8 | 2.8 | 4.4 |
| 059 | B horizon | 0.99 | y = 101.3x – 281 | 101 | 173 |
| 069 | B horizon | 1.00 | y = 19.7x - 75.8 | 20 | 6.7 |
| N_01 | B horizon | 0.99 | y = 6.78x - 19.2 | 7 | 14 |
| N_02 | B horizon | 0.99 | y = 6.85x - 18.0 | 7 | 8 |
| N_04 | B horizon | 1.00 | y = 7.71x - 23.8 | 8 | 7 |
| N_06 | B horizon | 1.00 | y = 12.0x - 28.2 | 12 | 16 |
| N_07 | B horizon | 1.00 | y = 20.3x - 44.6 | 20 | 20 |
| N_08 | B horizon | 0.97 | y = 4.87x - 33.7 | 4.9 | 2.1 |
| N_09 | B horizon | 1.00 | y = 37.0x - 96.0 | 37 | 98 |
| N_10 | B horizon | 0.99 | y = 43.7x - 125 | 44 | 103 |
| 055 | coffee rock | 1.00 | y = 54.3x - 176 | 54 | 182 |
| 061 | coffee rock | 0.99 | y = 147x - 387 | 147 | 217 |
| 040 | C horizon | 1.00 | y = 5.42x - 28.3 | 5.4 | 6.0 |
| 078 | C horizon | 0.98 | y = 2.94x - 11.6 | 2.9 | 2.3 |

* y = mmol $OH^-$ $kg^{-1}$; x = pH

** interpreted from the graph for a sample oxidised with $H_2O_2$ as the $OH^-$ required to achieve the initial pH $H_2O$ value (values indicated in corresponding Figures 37-38).

**Table 8** Correlation matrix (r) for relationships between buffering capacity (buffer[a] and buffer[b]), mmmol $H^+$ $kg^{-1}$, mmol$OH^-$ $kg^{-1}$, Al, Fe, Si and Mn extracted by dithionite citrate bicarbonate (d); $NH_4$ oxalate (ox) and Na-pyrophosphate (p) and some soil properties for whole soil samples ($p<0.05$) (N = 18).

| | Buffer[a] | $H^+$ | Buffer[b] | $OH^-$ | pH $H_2O$ | pH $CaCl_2$ | pH $H_2O_2$ | pH NaF | C | N | CEC | $SO_4^{2-}$ | EC | Sid | Ald | Fed | Mnd | Sip | Alp | Fep | Mnp | Siox | Alox | Feox | Mnox |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Buffer[a] | | | | | | | | | | | | | | | | | | | | | | | | | |
| $H^+$ | 0.96 | | | | | | | | | | | | | | | | | | | | | | | | |
| Buffer[b] | 0.73 | 0.73 | | | | | | | | | | | | | | | | | | | | | | | |
| $OH^-$ | 0.56 | 0.63 | 0.93 | | | | | | | | | | | | | | | | | | | | | | |
| pH $H_2O$ | | | | | | | | | | | | | | | | | | | | | | | | | |
| pH $CaCl_2$ | | | | | 0.89 | | | | | | | | | | | | | | | | | | | | |
| pH $H_2O_2$ | -0.48 | -0.50 | | | 0.81 | 0.87 | | | | | | | | | | | | | | | | | | | |
| pH NaF | | | | | | | | | | | | | | | | | | | | | | | | | |
| C | | | | | | | | 0.70 | | | | | | | | | | | | | | | | | |
| N | | | | | | | | 0.52 | 0.78 | | | | | | | | | | | | | | | | |
| CEC | | | | 0.50 | 0.47 | | | | 0.80 | 0.72 | | | | | | | | | | | | | | | |
| $SO_4^{2-}$ | 0.77 | 0.71 | 0.93 | 0.75 | | | | | | | | | | | | | | | | | | | | | |
| EC | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sid | | | | | | | | 0.59 | 0.84 | 0.57 | 0.72 | | | | | | | | | | | | | | |
| Ald | | | | | | | | 0.65 | 0.75 | 0.51 | | | | 0.66 | | | | | | | | | | | |
| Fed | | | | | | | | | | | | | | 0.51 | | | | | | | | | | | |
| Mnd | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sip | | | | 0.67 | | | | | 0.50 | 0.51 | 0.83 | | | | | | | | | | | | | | |
| Alp | | | | 0.69 | | | | | 0.50 | 0.53 | 0.84 | | | | | | | 0.99 | | | | | | | |
| Fep | 0.68 | 0.77 | 0.85 | 0.82 | | | | | | | | 0.75 | | | | 0.69 | | | | | | | | | |
| Mnp | | -0.49 | | | | | | | -0.48 | | | | | | | | 0.79 | | | | | | | | |
| Siox | | | | | | | | 0.56 | 0.64 | | | | | | 0.92 | | | | | | | | | | |
| Alox | | | | | | | | 0.58 | 0.62 | | | | | | 0.93 | | | | | | | 1.00 | | | |
| Feox | 0.47 | 0.61 | 0.58 | 0.55 | | | | | | | | 0.48 | | 0.56 | | 0.83 | | | | 0.86 | | | | | |
| Mnox | | | | | | | | | 0.47 | 0.58 | | | | 0.72 | | 0.55 | | | | | | | | 0.71 | |

(a) (b) (c) (d)

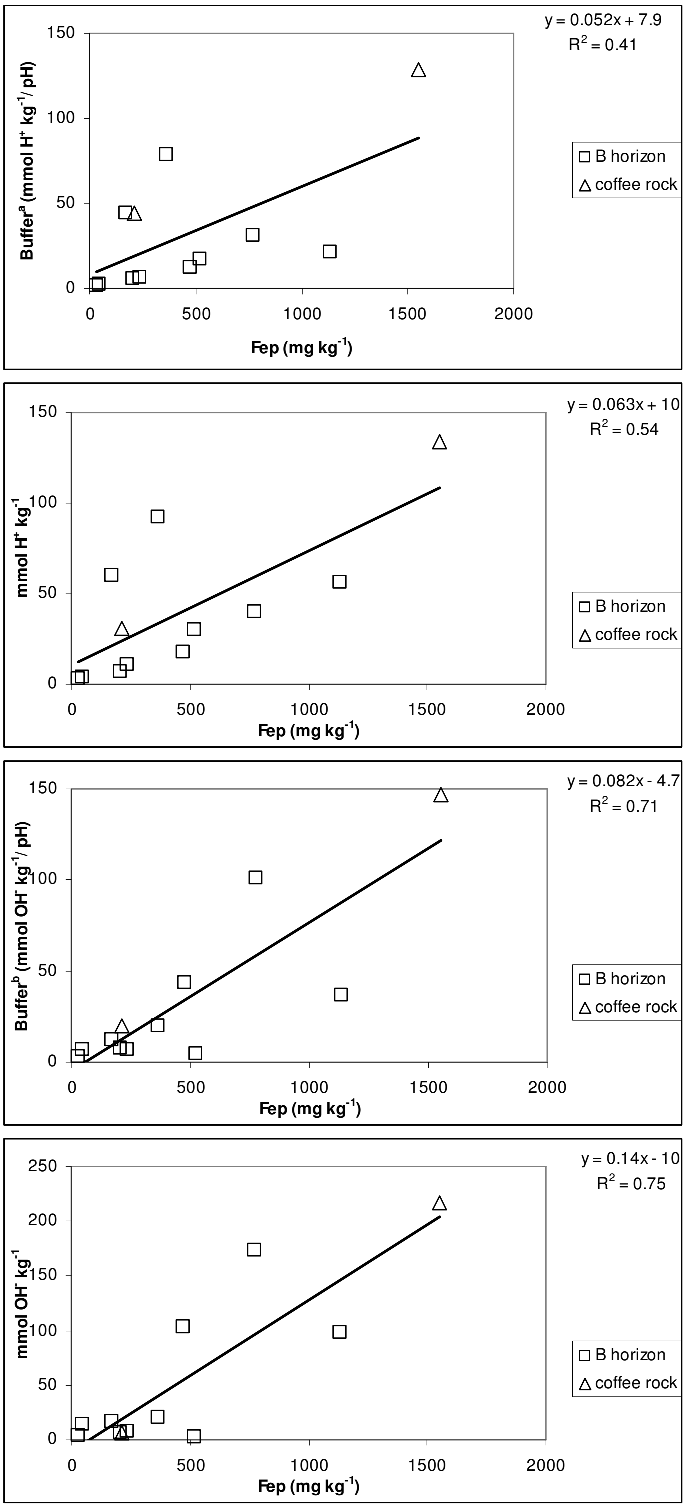



**Figure 39** Bivariate relationships between (a) buffering capacity (acid; buffer$^a$) and iron extracted by Na-pyrophosphate (Fep), (b) mmol $H^+$ $kg^{-1}$ and Fep, (c) buffering capacity (base; buffer$^b$) and Fep and (d) mmol $OH^-$ $kg^{-1}$ and Fep.

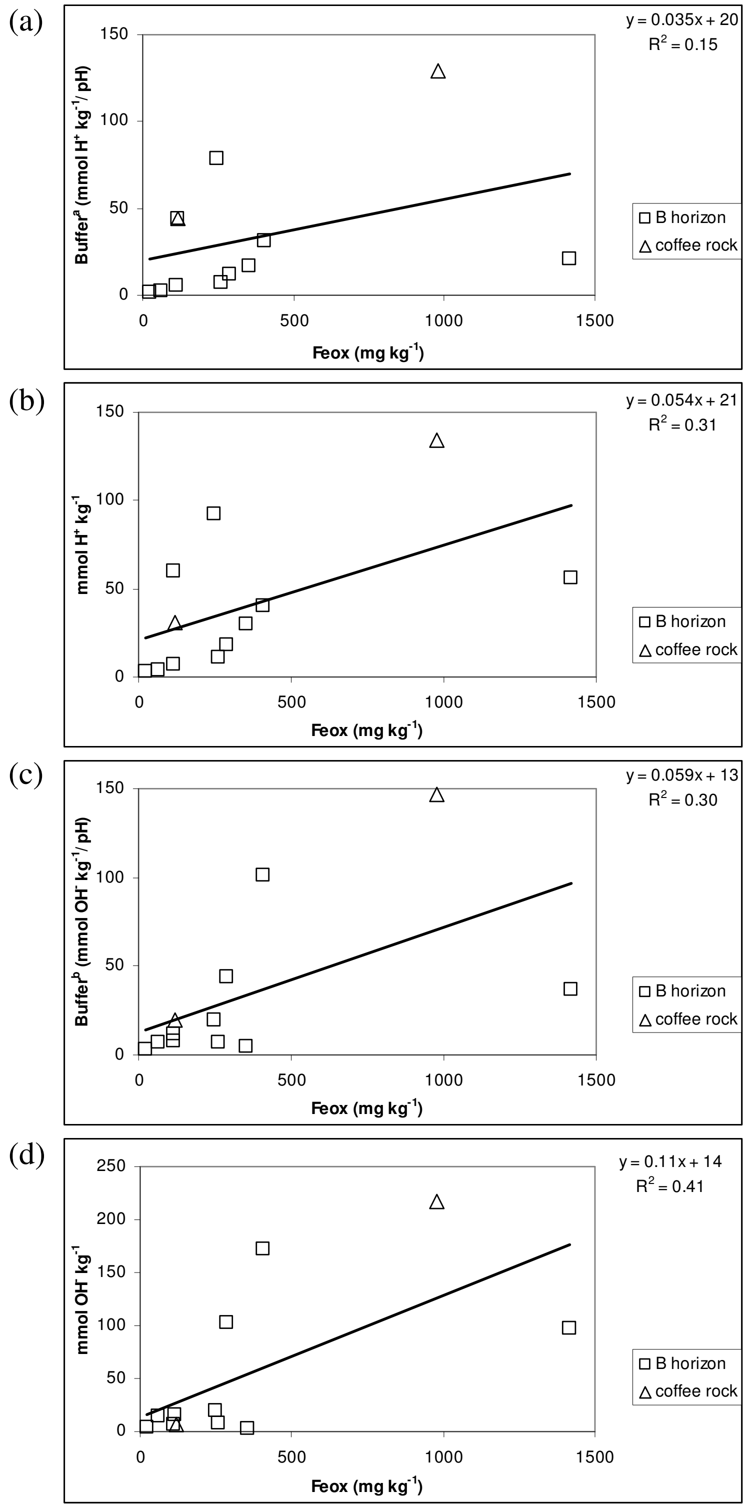



**Figure 40** Weak bivariate relationships between (a) buffering capacity (acid; buffer$^{a}$) and iron extracted by oxalic acid (Feox), (b) mmol $H^+$ $kg^{-1}$ and Feox, (c) buffering capacity (base; buffer$^{b}$) and Fep and (d) mmol $OH^-$ $kg^{-1}$ and Feox.

**Table 9** Summary of $S_{CR}$ (%) analyses of some pyrite containing podosol materials and the evaluation of these samples by direct mineralogical methods to determine if the $S_{CR}$ (%) values are a reliable indicator of the presence of pyrite.

| Sample No | Site | Horizon | Depth (cm) | $pH_F$ | $pH_{FOX}$ | $S_{CR}$(%) | SXRD | SEM | TEM |
|---|---|---|---|---|---|---|---|---|---|
| N_01 | 616-01-05 | B horizon | 620-630 | 5.5 | 2.7 | 0.014 | ✗ | ✓[d] | ✓[d] |
| N_02 | 616-02-68 | B horizon | 450 | 7.2 | 1.8 | 0.027 | ✓[e] | ✓[e] | ✓[e] |
| N_04 | 616-02-179 | B horizon | 375-400 | 6.1 | 1.6 | 0.013 | ✓[e] | ✓[e] | ✓[e] |
| N_06 | 616-02-78 | B horizon | 400-500 | 4.8 | 1.5 | 0.014 | ✓[e] | ✓[e] | ✓[e] |
| N_07 | 616-02-81 | B horizon | 400-800 | 6.2 | 1.4 | 0.052 | ✓[e] | ✓[e] | ✓[e] |
| N_08 | 616-02-110 | B horizon | 200-500 | 6.3 | 1.8 | 0.036 | ✓[e] | ✓[e] | ✓[e] |
| N_09 | 616-02-174 | B horizon | 250-550 | 5.5 | 2.5 | <0.005 | ✗ | ✓[d] | ✓[d] |
| N_10 | 616-02-65 | B horizon | 200 | 5.7 | 3.0 | 0.005 | ✗ | ✗ | ✓[d] |

✗ = no detectable pyrite; ✓ = detectable pyrite, d = difficult to detect pyrite, e = easy to detect pyrite
SXRD = synchrotron XRD, SEM = scanning electron microscopy with EDS, TEM = transmission electron microscopy with EDS.

# 6. Overview and Recommendations

Perth metropolitan area of the Swan Coastal Plain is covered by sandy aeolian sediments primarily of the Bassendean Dune System (BDS). These sandy soils developed on dune sands are classified as podosols in recognition of their highly leached near surface horizons (A and E horizons) and subsurface horizon (B horizon) enriched by compounds of organic matter, Al and Fe. Aeric podosols occur on well drained dunes where groundwater table is 2.0 metres below ground and aquic podosols are common in poorly drained low-lying areas of the BDS.

These podosols are dominated by quartz sand. Their clay content is generally <1% so that these soils are extremely sandy with a small buffering capacity provided by organic matter, allophane $(Al, Fe)_2O_3(SiO_2)1.3\text{-}2(H_2O)_{2.5\text{-}3})$, kaolin, gibbsite and Fe-oxides which have high surface area with exposed hydroxyl. Primary minerals (feldspar, ilmenite etc) are minor constituents of these soils and are sand-size and essentially insoluble so they do not provide any effective buffering capacity. Poor pH buffering capacity of these sandy soils is also demonstrated by batch titrations and cation exchange capacity measurements carried out in this study.

No carbonates or considerable amounts of clay were detected in soils developed on the highly leached Bassendean Due System. Therefore, any acid generating event, such as oxidation of sulfidic material, is expected to have a strong impact on lowering the soil pH.

The investigation has firmly established that horizons of podosols that are at or below the water table commonly and variously contain small amounts of pyrite, marcasite, elemental sulfur and jarosite. SXRD investigations of the soil fine concentrates revealed that acidifying sulfur minerals are commonly present in the permanently water-logged soil horizons. Pyrite is the main acid-generating mineral while elemental sulfur and marcasites also occur as minor constituents in some horizons with high organic matter content. Pyrite occurs in all horizons (including E, B and coffee rock, mud, peat and C horizons) that are water-logged and show low $pH_{FOX}$.

No pyrite was detected by SXRD technique in soil horizons above the water table where it probably oxidised, if present, when exposed to air in past. Abundant jarosite was found in soil fines of unsaturated zones of soil profiles (mainly A horizon). Where present, its occurrence was consistent with field observations of low soil pH (~4.0) and yellow brown mottles.

Electron microscopic investigations of the fine fractions have demonstrated the occurrence of pyrite in form of particles of various sizes and shapes in field capacity and water-logged section of the soil profiles. The two most common morphologies present are framboids of 1-10 µm diameter and sub-micron sized single crystals. Both framboids and singles appeared to have growth related pores/cavities, suggesting high surface area and thus potentially high reactivity of these pyrites. A combination of high reactivity of pyrite, extremely low pH buffering capacity and high porosity of these sandy soils makes them prone to acidification during even a short exposure (less than a week) to air during temporary excavation or dewatering.

Western Australia adopts a texture based action criteria for managing ASS based on Queensland and New South Wales model. Accordingly sandy soils with sulfur content <0.03%S require no ASS management. In the Perth metropolitan area, however, such sandy soils often record low $pH_{FOX}$ values less than 3 which indicates that these sandy soils are likely to become acidic on exposure to air. These soils with low sulfur content have been a particular focus of this investigation.

Analytical electron microscopy and synchrotron X-ray diffraction carried out in the present study have demonstrated the presence of pyrite in these low sulfur sandy soils. Table 9 shows that pyrite is readily detected by SXRD in soils with >0.01%S while soils with <0.01%S pyrite can only be detected by SEM and TEM. Table 9 shows that when $pH_{FOX}$ is more than 2.5, SXRD is unable to detect pyrite. Treatment of a small sample with hydrogen peroxide offers a quick method of prediction potential soil acidity, especially for sandy (quartz rich) soils. Brinkman and Pons (1973) also suggested a tentative limit for dangerous acid sulfate soils of pH 2.5 after peroxide treatment.

The minor amounts of acid-generation potential would not normally be of concern but the extremely small acid buffering capacity of some Bassendean Dune materials results in significant reductions in pH on oxidation. This interpretation has been substantiated by the incubation studies where soils with soils with <0.03% $S_{CR}$ resulted in soil pH to less than 3. It must be noted that sandy soils as defined in the texture based criteria may contain up to 5% clay which is far greater than the clay content of Bassendean sands. Typically, Bassendean sands contain <1% clay content so that texture based criteria developed in Ahern *et al.* (1998) may not be directly applicable.

Thus these soils are acid sulfate soils and should be managed appropriately including chemical analysis before disturbance or drainage. We have established that even when the Cr reducible S content is at or below the detection limit of 0.005% there may be minor amounts of these S compounds in the soils.

This minor amount of reduced S in the soil may still constitute a hazard in view of the very weak acid buffering capacity of some soil horizons (particularly E horizon) but the newly adopted more sensitive chemical analysis procedure is clearly much more appropriate than the procedures developed for coastal clayey acid sulfate soils.

Chemical analysis has demonstrated that apart from the acidifying potential of the S minerals in soils and the elevated As concentration in some peaty soils the concentration of heavy metals is well below hazardous levels.

A clear priority for future work is to identify the extent of sulfidic soil materials in the Bassendean Dune landscape and in particular to identify if these hazardous materials exist in wet horizons beneath other landscape elements of the Bassendean Dunes (slope, crest position) and if they occur in deep horizons.

**Recommendations**

The key recommendations for managing pyrite very sandy soil samples; quartz-rich soils are as follow:

1. Acid sulfate soils on Bassendean Dunes System should be managed appropriately including chemical analysis before disturbance or drainage. We have established that even when the $S_{CR}$ content is at or below the current action criteria (~0.03%), oxidation S compounds are present in the soils. These S compounds are responsible for observed low $pH_{FOX}$ values and low soil pH under natural oxidation if these soils are disturbed.

2. The least expensive, easy and quick method to identify acid sulfate soils is using a combination of field water and hydrogen peroxide pH ($pH_F$ and

$pH_{FOX}$) to predict the extreme soil acidity. However laboratory analysis is still required to determine the appropriate liming rate.

3. Based on this investigation, we recommend that $pH_{FOX}$, soil morphology and analytical value of 0.01% $S_{CR}$ or greater are excellent indicators of acid sulfate soil and can be used as a basis for managing potential acid sulfate soils in the Bassendean Dunes System. The action criteria need to be re-evaluated as the data indicate that more appropriate criterion is required for soils of sandy texture.

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# Appendix

**Appendix Table 1** Latitude and longitude of soil sample sites.

| Site | Latitude | Longitude |
|---|---|---|
| 616-01-003 | -31.8135 | 115.9156 |
| 616-01-005 | -31.7777 | 115.9075 |
| 616-01-011 | -31.7224 | 115.8356 |
| 616-01-014 | -31.7408 | 115.8781 |
| 616-01-018 | -31.8134 | 115.9446 |
| 616-01-019 | -31.9386 | 115.8735 |
| 616-01-023 | -31.9237 | 115.8150 |
| 616-01-024 | -31.9098 | 115.8009 |
| 616-02-009 | -31.9245 | 115.9433 |
| 616-02-028 | -32.2779 | 115.9373 |
| 616-02-031 | -32.0909 | 115.9593 |
| 616-02-032 | -32.0921 | 115.9125 |
| 616-02-058 | -32.1436 | 115.9515 |
| 616-02-065 | -32.1673 | 115.8817 |
| 616-02-068 | -32.0818 | 115.8354 |
| 616-02-071 | -32.1319 | 115.8347 |
| 616-02-078 | -32.1770 | 115.8768 |
| 616-02-080 | -32.1982 | 115.9056 |
| 616-02-081 | -32.1984 | 115.8855 |
| 616-02-082 | -32.2117 | 115.8419 |
| 616-02-085 | -32.0422 | 115.9562 |
| 616-02-087 | -32.2326 | 115.8625 |
| 616-02-094 | -32.0336 | 115.9432 |
| 616-02-099 | -32.1966 | 115.9023 |
| 616-02-100 | -32.0202 | 115.8762 |
| 616-02-101 | -31.9059 | 115.7933 |
| 616-02-105 | -31.8802 | 115.8234 |
| 616-02-106 | -31.8798 | 115.8136 |
| 616-02-110 | -31.8741 | 115.7900 |
| 616-02-112 | -31.8548 | 115.7584 |
| 616-02-113 | -31.8169 | 115.8150 |
| 616-02-122 | -31.9117 | 115.8871 |
| 616-02-127 | -31.9026 | 115.9243 |
| 616-02-131 | -31.9543 | 115.8724 |
| 616-02-136 | -31.9710 | 115.9452 |
| 616-02-145 | -31.9212 | 115.9793 |
| 616-02-155 | -32.3050 | 115.8263 |
| 616-02-158 | -32.3542 | 115.8303 |
| 616-02-174 | -31.8434 | 115.9129 |
| 616-02-179 | -31.8744 | 115.9383 |
| Ellenbrook | -31.7910 | 115.9741 |
| LOC50A | - | - |

**Appendix Table 2** Total chemical composition (XRF analyses) of oven dried whole soil samples.

| Site | Horizon | Depth (cm) | $Al_2O_3$ | $SiO_2$ | $TiO_2$ | $Fe_2O_3$ | MnO | CaO | $K_2O$ | MgO | $Na_2O$ | $P_2O_5$ | $SO_3$ | V | Cr | Ni | Cu | Zn | Rb | Sr | Ba | Zr | Co | As | La | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (-------------------%-------------------) | | | | | | | | | | | (-------------------mg $kg^{-1}$-------------------) | | | | | | | | | | | | |
| 616-01-003 | A horizon | 0-25 | 0.15 | 94 | 0.18 | 0.07 | 0.002 | 0.154 | 0.110 | 0.015 | nd | 0.009 | nd | 11 | nd | 65 | 34 | nd | 17 | 17 | 26 | 154 | nd | 8 | 15 | 12 |
| 616-01-003 | Coffee rock | 175-200 | 3.14 | 86 | 0.12 | 1.51 | 0.002 | 0.013 | 0.096 | 0.022 | 0.010 | 0.012 | 0.04 | 18 | nd | 62 | 29 | nd | 1 | 31 | 59 | 51 | 4 | 9 | 15 | 13 |
| 616-01-003 | C1 horizon | 200-300 | 0.88 | 96 | 0.15 | 0.04 | 0.003 | nd | 0.219 | nd | 0.000 | 0.005 | nd | nd | nd | 44 | 43 | 2 | 20 | 9 | 66 | 110 | 13 | 1 | 19 | 17 |
| 616-01-003 | C2 horizon | 300-400 | 0 59 | 97 | 0.16 | 0.04 | 0.001 | nd | 0.160 | 0.011 | 0.005 | 0.008 | nd | 4 | nd | 56 | 40 | 1 | 13 | 18 | nd | 88 | 11 | 4 | 17 | 20 |
| 616-01-003 | C3 horizon | 400-600 | 0.48 | 99 | 0.21 | 0.11 | 0.002 | nd | 0.148 | nd | nd | 0.006 | nd | 7 | nd | 50 | 31 | 9 | 26 | 17 | 129 | 161 | 9 | 13 | 34 | 12 |
| 616-01-005 | B horizon | 620-630 | 0.32 | 98 | 0.10 | nd | 0.010 | 0.063 | 0.035 | nd | 0.140 | nd | 0.00 | nd | nd | nd | 3 | nd | 13 | 4 | 105 | 66 | nd | nd | 14 | 13 |
| 616-01-005 | A horizon | 0-20 | 0.19 | 92 | 0.10 | 0.57 | 0.003 | 0.195 | 0.007 | 0.018 | 0.005 | 0.014 | nd | 1 | 522 | 61 | 30 | 6 | 12 | 26 | nd | 74 | 16 | 3 | 20 | 14 |
| 616-01-005 | E horizon | 20-180 | 0.07 | 99 | 0.12 | 0.44 | 0.004 | nd | 0.008 | nd | nd | 0.005 | nd | nd | 389 | 73 | 44 | nd | 15 | 15 | 49 | 63 | 10 | 4 | nd | 11 |
| 616-01-005 | Coffee rock | 180-200 | 2.03 | 93 | 0.23 | 0.41 | 0.006 | 0.008 | 0.034 | 0.033 | 0.005 | 0.015 | 0.00 | 12 | 370 | 72 | 24 | 1 | 11 | 18 | 106 | 164 | nd | 0 | 11 | 18 |
| 616-01-005 | B horizon | 200-250 | 0.60 | 97 | 0.14 | 0.45 | 0.005 | nd | 0.023 | 0.147 | 0.030 | 0.007 | 0.00 | 14 | 369 | 68 | 33 | 11 | 20 | 16 | 111 | 109 | 12 | 1 | nd | 8 |
| 616-01-005 | 2E1 horizon | 250-260 | 0.45 | 96 | 0.12 | 0.37 | 0.001 | nd | nd | 0.021 | nd | 0.005 | 0.06 | 1 | 352 | 62 | 39 | 19 | 9 | 16 | 17 | 69 | 13 | 2 | 18 | 12 |
| 616-01-005 | 2E2 horizon | 260-400 | 0.19 | 95 | 0.11 | 0.48 | 0.003 | nd | nd | nd | nd | 0.006 | 0.04 | nd | 426 | 62 | 39 | 6 | 12 | 36 | 69 | 49 | 16 | 5 | nd | 31 |
| 616-01-005 | 2E3 horizon | 400-500 | nd | 99 | 0.08 | nd | 0.000 | nd | nd | nd | nd | 0.005 | nd | 7 | nd | 49 | 50 | nd | 5 | 16 | 12 | 14 | 17 | 3 | 14 | 12 |
| 616-01-005 | 2E4 horizon | 500-830 | nd | 92 | 0.09 | 0.00 | 0.000 | nd | nd | nd | nd | 0.005 | nd | nd | nd | 62 | 38 | nd | 20 | 14 | 56 | 42 | 20 | 1 | nd | nd |
| 616-01-005 | 2Coffee rock1 | 830-900 | 0.23 | 97 | 0.13 | nd | 0.000 | nd | nd | 0.010 | 0.000 | 0.005 | 0.02 | nd | nd | 50 | 47 | 7 | 21 | 22 | 47 | 58 | 13 | 8 | 33 | 28 |
| 616-01-005 | 2Coffee rock2 | 900-1000 | 0.89 | 96 | 0.38 | 0.13 | 0.005 | nd | 0.221 | 0.001 | nd | 0.009 | 0.02 | 4 | nd | 57 | 38 | nd | 23 | 21 | 152 | 221 | 5 | 7 | 14 | 5 |
| 616-02-009 | E1 horizon | 225-250 | 0 99 | 97 | 0.21 | 0.05 | 0.014 | 0.086 | 0.438 | nd | 0.090 | nd | 0.00 | nd | 20 | nd | 20 | 10 | 31 | 3 | 151 | 80 | nd | 5 | nd | 6 |
| 616-01-011 | A horizon | 0-75 | nd | 97 | 0.12 | 0.02 | 0.001 | 0.102 | nd | 0.004 | 0.000 | 0.010 | 0.00 | nd | nd | 54 | 39 | 9 | 7 | 42 | 54 | 44 | 13 | 1 | 5 | 2 |
| 616-01-011 | E1 horizon | 75-500 | nd | 98 | 0.14 | 0.01 | 0.001 | nd | nd | 0.003 | 0.000 | 0.006 | nd | 25 | nd | 61 | 30 | 6 | 2 | 32 | 88 | 80 | 9 | 0 | 41 | nd |
| 616-01-011 | E2 horizon | 500-600 | nd | 100 | 0.21 | 0.08 | 0.003 | nd | nd | 0.014 | 0.005 | 0.006 | nd | nd | nd | 54 | 39 | nd | nd | 13 | 52 | 174 | 4 | 11 | 32 | nd |
| 616-01-011 | E3 horizon | 600-700 | 1.46 | 99 | 0.60 | 0.26 | 0.011 | nd | 0 902 | 0.013 | 0.015 | 0.012 | 0.00 | 17 | nd | 45 | 40 | 6 | 31 | 37 | 233 | 346 | 18 | 7 | 17 | 19 |
| 616-01-014 | A horizon | 0-50 | nd | 100 | 0.05 | 0.02 | nd | 0.041 | nd | 0.011 | nd | 0.008 | nd | 19 | nd | 47 | 40 | 3 | 0 | 24 | 32 | 28 | 3 | 0 | 47 | 10 |
| 616-01-014 | E1 horizon | 50-300 | nd | 97 | 0.07 | nd | 0.001 | nd | nd | nd | nd | 0.007 | nd | 21 | nd | 63 | 51 | 3 | nd | 7 | 42 | 36 | nd | nd | 57 | 20 |
| 616-01-014 | E2 horizon | 300-650 | 0 57 | 98 | 0.10 | 0.20 | 0.000 | 0.000 | 0.016 | 0.006 | 0.000 | 0.006 | nd | nd | nd | 62 | 39 | 2 | 7 | 23 | 5 | 48 | 22 | nd | 34 | 4 |
| 616-01-014 | Coffee rock | 650-800 | 0 97 | 99 | 0.11 | 0.24 | 0.001 | nd | 0.008 | nd | 0.000 | 0.007 | nd | 16 | nd | 49 | 26 | 2 | 13 | 23 | nd | 65 | 13 | 10 | 26 | 14 |
| 616-01-014 | C1 horizon | 800-900 | 0 94 | 97 | 0.11 | 0.64 | 0.004 | 0.007 | nd | 0.005 | 0.000 | 0.008 | nd | nd | 253 | 67 | 40 | 2 | 12 | 16 | 32 | 53 | 9 | 7 | 32 | 17 |
| 616-01-014 | C2 horizon | 900-1000 | 0 91 | 97 | 0.11 | 0.64 | 0.003 | 0.008 | nd | nd | nd | 0.008 | nd | 3 | 269 | 54 | 44 | nd | 12 | 21 | 67 | 38 | 3 | 6 | nd | 17 |
| 616-01-014 | C3 horizon | 1000-1200 | 0.66 | 97 | 0.16 | 0.37 | 0.002 | nd | 0.073 | 0.003 | 0.000 | 0.007 | nd | nd | 264 | 62 | 39 | 9 | nd | 27 | 93 | 101 | 19 | 10 | nd | 7 |
| 616-01-014 | C4 horizon | 1200-1300 | 2 53 | 94 | 0.44 | 0.18 | 0.006 | nd | 0.409 | 0.010 | 0.005 | 0.010 | nd | 10 | nd | 58 | 36 | 2 | 13 | 19 | 131 | 328 | 11 | 8 | nd | 2 |

**Appendix Table 2** (Cont.) total chemical composition (XRF analyses) of oven dried whole soil samples.

| Site | Horizon | Depth (cm) | $Al_2O_3$ | $SiO_2$ | $TiO_2$ | $Fe_2O_3$ | MnO | CaO | $K_2O$ | MgO | $Na_2O$ | $P_2O_5$ | $SO_3$ | V | Cr | Ni | Cu | Zn | Rb | Sr | Ba | Zr | Co | As | La | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (---------------% | | | | | | | | | | ---------------) | (---------------mg $kg^{-1}$ | | | | | | | | | | | | ---------------) |
| 616-01-018 | A horizon | 0-25 | 0.01 | 99 | 0.06 | 0.28 | 0.004 | 0.069 | nd | 0.022 | 0.010 | 0.004 | nd | 6 | 234 | 53 | 45 | nd | 6 | 16 | 84 | 35 | 15 | 2 | nd | 8 |
| 616-01-018 | E1 horizon | 25-200 | nd | 97 | 0.05 | 0.35 | 0.003 | 0.005 | nd | 0.008 | 0.005 | 0.007 | 0.02 | nd | 348 | 49 | 44 | 8 | 4 | 39 | 51 | 25 | 16 | 0 | nd | 9 |
| 616-01-018 | E2 horizon | 200-300 | 0.04 | 97 | 0.08 | 0.44 | 0.003 | 0.005 | nd | 0.011 | nd | 0.007 | 0.02 | 3 | 421 | 63 | 46 | nd | 5 | 10 | 63 | 37 | 16 | nd | 51 | 3 |
| 616-01-018 | E3 horizon | 300-400 | nd | 98 | 0.06 | 0.43 | 0.002 | nd | nd | nd | nd | 0.005 | nd | nd | 389 | 70 | 47 | 3 | 13 | 16 | 6 | 25 | 9 | 12 | 14 | 8 |
| 616-01-018 | Coffee rock | 400-450 | 1.28 | 93 | 0.13 | 0.01 | 0.001 | nd | 0.011 | nd | 0.000 | 0.010 | 0.06 | 32 | nd | 62 | 40 | 6 | 10 | 15 | 57 | 43 | 20 | 6 | 10 | 2 |
| 616-01-018 | 2E horizon | 450-600 | 0.10 | 98 | 0.11 | nd | 0.001 | nd | nd | nd | nd | 0.004 | 0.00 | 7 | nd | 66 | 22 | nd | 19 | 17 | 91 | 63 | 12 | 5 | 26 | 1 |
| 616-01-018 | 2Coffee rock1 | 600-700 | 0.14 | 97 | 0.07 | 0.50 | 0.005 | 0.002 | nd | 0.008 | 0.005 | 0.007 | nd | 20 | 415 | 61 | 48 | 11 | 14 | 18 | 5 | 55 | 7 | nd | 17 | 18 |
| 616-01-018 | 2Coffee rock2 | 700-800 | 2.65 | 93 | 0.15 | 0.44 | 0.003 | 0.000 | 0.056 | 0.004 | 0.010 | 0.010 | 0.06 | 9 | 322 | 71 | 36 | nd | 5 | 19 | 27 | 77 | 7 | nd | 26 | 7 |
| 616-01-019 | A horizon | 0-50 | 0.05 | 97 | 0.12 | nd | 0.010 | 0.059 | 0.038 | nd | 0.050 | nd | nd | nd | nd | nd | 14 | 2 | 6 | 19 | nd | 65 | nd | nd | 18 | 4 |
| 616-01-019 | E1 horizon | 50-200 | 0.03 | 95 | 0.15 | nd | 0.011 | 0.056 | 0.025 | nd | 0.030 | nd | nd | 1 | 10 | nd | 20 | 11 | 22 | 1 | 13 | 107 | nd | 10 | 25 | 4 |
| 616-01-019 | B horizon | 250-300 | 4.78 | 83 | 0.34 | 0.06 | 0.010 | 0.059 | 0.280 | nd | 0.030 | nd | 0.12 | 36 | 18 | 1 | nd | 4 | 13 | 12 | 88 | 135 | nd | 2 | 39 | 12 |
| 616-01-023 | A horizon | 0-25 | 0.11 | 100 | 0.13 | nd | 0.011 | 0.098 | 0.060 | nd | 0.040 | nd | nd | 2 | nd | nd | 18 | 5 | 7 | 13 | 57 | 66 | nd | nd | nd | 5 |
| 616-01-023 | E horizon | 25-100 | 0.14 | 100 | 0.18 | nd | 0.012 | 0.059 | 0.076 | nd | 0.120 | nd | 0.00 | nd | 4 | nd | 9 | nd | 15 | 13 | 70 | 122 | nd | 5 | nd | nd |
| 616-01-023 | B horizon | 100-200 | 1.39 | 97 | 0.19 | 0.01 | 0.013 | 0.059 | 0.143 | nd | 0.110 | nd | 0.00 | 11 | nd | nd | 19 | nd | 17 | 11 | 87 | 128 | nd | 10 | 35 | 14 |
| 616-01-023 | C3 horizon | 500-1000 | 1.04 | 98 | 0.12 | nd | 0.009 | 0.060 | 0.320 | nd | 0.120 | nd | 0.02 | 2 | 5 | 1 | 14 | nd | 39 | 6 | 112 | 77 | nd | 2 | 1 | 15 |
| 616-01-024 | A horizon | 0-25 | 0.04 | 92 | 0.09 | nd | 0.010 | 0.088 | 0.026 | nd | 0.100 | nd | 0.00 | 1 | 0 | 1 | 11 | 4 | 15 | 14 | 124 | 69 | nd | nd | 33 | nd |
| 616-01-024 | E horizon | 25-150 | 0.04 | 92 | 0.12 | nd | 0.011 | 0.058 | 0.020 | nd | 0.110 | nd | nd | nd | nd | nd | 7 | nd | 16 | 6 | 4 | 127 | nd | 2 | 11 | 6 |
| 616-01-024 | B horizon | 150-200 | 0.47 | 99 | 0.11 | nd | 0.010 | 0.058 | 0.065 | nd | 0.000 | nd | 0.01 | 8 | nd | nd | 14 | nd | 12 | 20 | 132 | 46 | nd | 3 | 12 | nd |
| 616-01-024 | 2B horizon | 400-500 | 1.82 | 91 | 0.17 | 0.00 | 0.010 | 0.074 | 0.165 | nd | nd | nd | 0.06 | 15 | 9 | nd | 19 | nd | 31 | 18 | 108 | 77 | nd | 6 | nd | 3 |
| 616-01-024 | 3E horizon | 500-800 | 0.56 | 97 | 0.09 | nd | 0.010 | 0.060 | 0.137 | nd | 0.030 | nd | nd | nd | 5 | 0 | 13 | nd | 33 | 24 | 95 | 41 | nd | 1 | nd | 2 |
| 616-02-028 | B horizon | 30-100 | 2.78 | 92 | 0.27 | 1.47 | 0.016 | 0.148 | 1.112 | nd | 0.350 | nd | 0.26 | 20 | 28 | 7 | 17 | 2 | 56 | 20 | 331 | 179 | nd | 10 | 29 | 1 |
| 616-02-028 | Mud1 | 100-200 | 9.74 | 66 | 0.97 | 6.39 | 0.064 | 0.445 | 1.093 | 0.227 | 0.840 | 0.020 | 2.42 | 91 | 56 | 32 | 28 | 15 | 44 | 37 | 187 | 351 | 27 | 14 | 31 | 22 |
| 616-02-031 | A horizon | 0-75 | nd | 96 | 0.30 | 0.02 | 0.001 | 0.105 | nd | 0.045 | 0.000 | 0.010 | 0.00 | 26 | nd | 57 | 35 | nd | 7 | 21 | 20 | 198 | 8 | 8 | 32 | 3 |
| 616-02-031 | E horizon | 75-200 | nd | 89 | 0.54 | 0.03 | 0.001 | nd | nd | nd | nd | 0.006 | nd | 4 | nd | 53 | 38 | nd | 3 | 11 | 51 | 673 | 5 | 3 | 13 | nd |
| 616-02-031 | Coffee rock1 | 200-300 | 4.81 | 86 | 0.77 | 0.44 | 0.002 | 0.003 | 0.056 | 0.079 | 0.070 | 0.019 | 0.21 | 14 | 8 | 57 | 41 | 3 | 1 | 23 | 83 | 678 | 7 | 8 | nd | 21 |
| 616-02-031 | Coffee rock2 | 200-300 | 5.14 | 85 | 0.78 | 0.37 | 0.004 | 0.001 | 0.057 | 0.074 | 0.055 | 0.020 | 0.28 | 8 | 5 | 64 | 36 | nd | 5 | 25 | 106 | 638 | 9 | 11 | 13 | 26 |
| 616-02-031 | 2E horizon | 300-400 | 0.28 | 100 | 0.30 | 0.14 | 0.004 | nd | 0.156 | 0.003 | 0.010 | 0.009 | 0.14 | nd | nd | 60 | 44 | nd | 17 | 8 | 55 | 257 | 2 | nd | 30 | 12 |
| 616-02-031 | 2Coffee rock1 | 400-500 | 3.93 | 92 | 0.27 | 0.17 | 0.004 | 0.006 | 0.467 | 0.037 | 0.020 | 0.037 | 0.19 | 8 | 3 | 77 | 28 | nd | 7 | 27 | 174 | 100 | 0 | 13 | 37 | 12 |
| 616-02-031 | 2Coffee rock2 | 500-600 | 2.26 | 93 | 0.22 | 0.11 | 0.005 | 0.008 | 0.506 | 0.035 | 0.020 | 0.029 | 0.10 | 15 | nd | 47 | 34 | nd | 20 | 43 | 191 | 99 | 10 | 10 | nd | 14 |

**Appendix Table 2** (Cont.) total chemical composition (XRF analyses) of oven dried whole soil samples.

| Site | Horizon | Depth (cm) | $Al_2O_3$ | $SiO_2$ | $TiO_2$ | $Fe_2O_3$ | MnO | CaO | $K_2O$ | MgO | $Na_2O$ | $P_2O_5$ | $SO_3$ | V | Cr | Ni | Cu | Zn | Rb | Sr | Ba | Zr | Co | As | La | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (------%------) | | | | | | | | | | | (------mg $kg^{-1}$------) | | | | | | | | | | | | |
| 616-02-032 | A horizon | 0-50 | 0.03 | 96 | 0.37 | 0.12 | 0.005 | 1.161 | nd | 0.021 | nd | 0.008 | 0.00 | 2 | nd | 61 | 45 | 11 | 16 | 45 | nd | 308 | 8 | 2 | 34 | 16 |
| 616-02-032 | E horizon | 50-200 | nd | 99 | 0.33 | 0.06 | 0.004 | nd | nd | nd | nd | 0.009 | 0.00 | nd | nd | 60 | 43 | 5 | 2 | 24 | 17 | 252 | 19 | 0 | 6 | 0 |
| 616-02-032 | Coffee rock1 | 160 | 0.39 | 91 | 1.48 | 0.21 | 0.011 | 0.001 | 0.013 | 0.035 | 0.005 | 0.013 | 0.14 | 40 | 5 | 56 | 35 | 7 | nd | 16 | 56 | 473 | nd | 2 | 19 | 11 |
| 616-02-032 | Coffee rock2 | 200-300 | 2.92 | 89 | 0.34 | 0.15 | 0.004 | nd | 0.100 | 0.018 | 0.000 | 0.010 | 0.09 | 12 | 36 | 65 | 31 | 5 | 8 | 20 | 64 | 230 | 21 | 2 | 42 | 30 |
| 616-02-032 | 2E1 horizon | 300-350 | 0.49 | 95 | 0.96 | 0.41 | 0.017 | nd | 0.300 | 0.013 | 0.005 | 0.011 | 0.05 | nd | 2 | 58 | 42 | 6 | 12 | 22 | 141 | 542 | 13 | nd | 56 | 22 |
| 616-02-032 | 2E2 horizon | 350-400 | 0.77 | 94 | 0.75 | 0.33 | 0.013 | nd | 0.442 | 0.021 | 0.005 | 0.010 | 0.08 | 7 | 11 | 50 | 41 | 1 | 21 | 26 | 130 | 448 | 19 | nd | 31 | 23 |
| 616-02-058 | B horizon | 300-500 | 0.24 | 86 | 0.29 | 0.06 | 0.014 | 0.076 | 0.049 | nd | 0.000 | nd | 0.19 | 19 | 16 | 4 | 6 | 7 | 21 | 12 | 29 | 107 | nd | 3 | 15 | 7 |
| 616-02-065 | B horizon | 200 | 3.79 | 88 | 0.30 | 0.15 | 0.013 | 0.143 | 0.173 | 0.012 | 0.120 | 0.011 | 0.07 | 19 | 19 | nd | 10 | 5 | 11 | 15 | 28 | 141 | nd | 0 | 23 | 1 |
| 616-02-065 | PETZ | 0-20 | 6.74 | 84 | 0.30 | 0.37 | 0.011 | 0.231 | 0.185 | 0.105 | 0.170 | 0.085 | 0.11 | 23 | 15 | 7 | nd | nd | 18 | 34 | 101 | 83 | nd | 8 | 26 | 17 |
| 616-02-065 | Coffee rock1 | 480-560 | 2.05 | 93 | 0.38 | 0.15 | 0.013 | 0.096 | 0.115 | 0.007 | 0.000 | nd | 0.27 | 14 | 40 | 41 | 8 | nd | 5 | 9 | 62 | 236 | nd | 4 | 27 | 1 |
| 616-02-065 | Coffee rock3 | 650-700 | 0.50 | 98 | 0.14 | nd | 0.011 | 0.068 | 0.116 | nd | 0.100 | nd | 0.06 | 1 | 6 | 8 | 4 | nd | 15 | 6 | 7 | 88 | nd | 1 | 44 | 11 |
| 616-02-068 | B horizon | 450 | 1.59 | 97 | 0.37 | 0.17 | 0.016 | 0.073 | 0.551 | nd | 0.080 | nd | 0.07 | 20 | 24 | nd | 14 | nd | 21 | 19 | 127 | 205 | nd | 2 | 20 | 8 |
| 616-02-068 | A horizon | 0-25 | 0.09 | 100 | 0.07 | nd | 0.011 | 0.073 | 0.047 | nd | 0.070 | nd | nd | nd | nd | nd | 11 | 11 | 12 | 11 | nd | 43 | nd | 1 | 22 | nd |
| 616-02-068 | E horizon | 25-200 | 0.12 | 100 | 0.14 | nd | 0.012 | 0.059 | 0.064 | nd | 0.130 | nd | nd | 15 | 9 | 6 | 7 | nd | 4 | 2 | 24 | 67 | nd | 6 | 7 | 6 |
| 616-02-068 | Coffee rock | 200-300 | 1.72 | 96 | 0.22 | 0.08 | 0.012 | 0.084 | 0.354 | nd | 0.020 | nd | 0.08 | 19 | 9 | nd | 6 | 5 | 25 | 17 | 32 | 113 | nd | 8 | 4 | 23 |
| 616-02-068 | B1 horizon | 300-400 | 1.14 | 93 | 0.27 | 0.10 | 0.015 | 0.067 | 0.420 | nd | 0.140 | nd | 0.04 | 17 | 20 | 6 | 2 | 13 | 20 | 5 | 104 | 172 | nd | 8 | 14 | 3 |
| 616-02-068 | B3 horizon | 500-600 | 1.26 | 98 | 0.38 | 0.17 | 0.017 | 0.071 | 0.571 | nd | 0.110 | nd | 0.08 | 7 | 32 | 3 | 2 | 0 | 34 | 26 | 234 | 171 | nd | 3 | 8 | 6 |
| 616-02-068 | A horizon | 0-75 | 0.12 | 97 | 0.09 | 0.00 | 0.010 | 0.070 | 0.072 | nd | 0.110 | nd | nd | 0 | nd | nd | 17 | 4 | 16 | 7 | 51 | 56 | nd | nd | nd | 14 |
| 616-02-068 | E1 horizon | 75-300 | 0.12 | 92 | 0.12 | nd | 0.010 | 0.058 | 0.064 | nd | 0.020 | nd | 0.00 | 13 | nd | 37 | 21 | 9 | 23 | nd | nd | 94 | nd | 4 | nd | 8 |
| 616-02-071 | E horizon | 25-350 | 0.06 | 100 | 0.10 | nd | 0.011 | 0.062 | 0.020 | nd | 0.060 | nd | nd | 6 | nd | 6 | 4 | nd | 14 | 11 | 49 | 78 | nd | 7 | nd | 5 |
| 616-02-071 | B horizon | 350-600 | 0.75 | 96 | 0.25 | 0.10 | 0.013 | 0.072 | 0.307 | nd | 0.050 | nd | 0.14 | 3 | 13 | 1 | nd | 7 | 14 | 9 | 142 | 98 | nd | 5 | 8 | 8 |
| 616-02-078 | B horizon | 400-500 | 0.03 | 98 | 0.20 | nd | 0.009 | 0.063 | 0.019 | nd | 0.080 | nd | 0.05 | 12 | 6 | nd | 1 | nd | 25 | nd | 44 | 85 | nd | nd | nd | 6 |
| 616-02-080 | Coffee rock | 200-400 | 2.81 | 85 | 0.31 | 0.15 | 0.010 | 0.105 | 0.206 | 0.026 | 0.130 | nd | 0.21 | 20 | 17 | 5 | 13 | nd | 17 | 10 | 80 | 115 | nd | 4 | 5 | 3 |
| 616-02-081 | B horizon | 400-800 | 0.49 | 92 | 0.22 | 0.08 | 0.012 | 0.077 | 0.292 | nd | 0.090 | nd | 0.17 | 7 | 4 | nd | nd | nd | 33 | 18 | 125 | 113 | nd | nd | 44 | 21 |
| 616-02-082 | A horizon | 0-75 | 0.80 | 94 | 0.28 | 0.04 | 0.013 | 0.061 | 0.524 | nd | 0.090 | nd | 0.00 | 11 | 5 | 20 | 16 | 5 | 29 | 13 | 84 | 193 | nd | 2 | nd | 17 |
| 616-02-082 | E1 horizon | 75-200 | 1.04 | 97 | 0.29 | 0.05 | 0.013 | 0.063 | 0.607 | nd | 0.150 | nd | nd | 8 | 24 | nd | 13 | 1 | 17 | 20 | 110 | 188 | nd | 2 | 12 | 1 |
| 616-02-082 | B horizon | 300-400 | 1.72 | 91 | 0.40 | 0.34 | 0.017 | 0.075 | 0.909 | nd | 0.080 | nd | 0.31 | 31 | 18 | nd | 14 | nd | 45 | 23 | 175 | 236 | nd | nd | 12 | 14 |
| 616-02-082 | Coffee rock | 500-600 | 2.51 | 93 | 0.40 | 0.57 | 0.016 | 0.085 | 0.959 | nd | nd | nd | 0.65 | 28 | 27 | nd | 18 | 6 | 48 | 18 | 263 | 249 | nd | 9 | 12 | 23 |
| 616-02-085 | A horizon | 0-70 | 14.47 | 60 | 0.93 | 9.04 | 0.149 | 0.785 | 0.851 | 0.372 | 0.530 | 0.419 | 0.08 | 133 | 75 | 38 | 69 | 73 | 56 | 59 | 359 | 251 | 31 | 47 | 55 | 73 |
| 616-02-085 | B1 horizon | 100-300 | 5.97 | 88 | 0.45 | 0.65 | 0.016 | 0.254 | 1.555 | 0.004 | 0.710 | nd | 0.03 | 31 | 37 | 11 | 25 | 10 | 50 | 42 | 391 | 183 | nd | 3 | nd | 8 |
| 616-02-085 | B2 horizon | 300-400 | 3.00 | 92 | 0.14 | 0.28 | 0.012 | 0.200 | 1.198 | nd | 0.480 | nd | 0.35 | 20 | 14 | 5 | 21 | 1 | 53 | 37 | 423 | 74 | nd | 7 | 14 | nd |
| 616-02-085 | Mud | 400-600 | 11.67 | 63 | 1.19 | 7.01 | 0.106 | 2.911 | 1.582 | 0.492 | 0.910 | 0.031 | 2.83 | 129 | 51 | 11 | 32 | 25 | 80 | 207 | 533 | 364 | 23 | 9 | 26 | 21 |

**Appendix Table 2** (Cont.) total chemical composition (XRF analyses) of oven dried whole soil samples.

| Site | Horizon | Depth (cm) | $Al_2O_3$ | $SiO_2$ | $TiO_2$ | $Fe_2O_3$ | MnO | CaO | $K_2O$ | MgO | $Na_2O$ | $P_2O_5$ | $SO_3$ | V | Cr | Ni | Cu | Zn | Rb | Sr | Ba | Zr | Co | As | La | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (---% | | | | | | | | | | ---) | (---mg $kg^{-1}$ | | | | | | | | | | | | ---) |
| 616-02-087 | Coffee rock2 | 300-400 | 6.52 | 78 | 0.39 | 0.11 | 0.012 | 0.129 | 0.650 | 0.015 | 0.140 | nd | 0.11 | 9 | 31 | 6 | 10 | nd | 34 | 14 | 179 | 116 | nd | 8 | 23 | 7 |
| 616-02-087 | B horizon | 500-600 | 0.81 | 97 | 0.65 | 0.27 | 0.018 | 0.060 | 0.425 | nd | 0.050 | nd | 0.07 | 54 | 19 | nd | 15 | nd | 19 | 21 | 179 | 318 | nd | 7 | 15 | 14 |
| 616-02-094 | A1 horizon | 0-100 | 9.53 | 71 | 1.43 | 7.59 | 0.026 | 0.219 | 1.469 | 0.130 | 0.780 | 0.012 | 1.39 | 141 | 53 | 6 | 38 | 12 | 40 | 29 | 361 | 487 | 18 | 20 | 10 | 37 |
| 616-02-094 | A2 horizon | 100-175 | 3.93 | 90 | 0.98 | 2.45 | 0.017 | 0.144 | 0.714 | 0.046 | 0.400 | nd | 0.64 | 79 | 49 | nd | 29 | 6 | 50 | 26 | 203 | 474 | 7 | 8 | nd | 14 |
| 616-02-094 | E horizon | 175-600 | 1.52 | 92 | 2.37 | 1.14 | 0.039 | 0.083 | 0.225 | nd | 0.180 | nd | 0.07 | 145 | 45 | 2 | 23 | 4 | 18 | 9 | 151 | 3244 | 1 | 11 | nd | 19 |
| 616-02-099 | E horizon | 25-200 | 0.28 | 98 | 0.13 | 0.03 | 0.012 | 0.090 | 0.062 | nd | 0.020 | nd | 0.01 | 6 | 19 | nd | 19 | nd | 21 | 16 | 38 | 71 | nd | 6 | nd | 9 |
| 616-02-099 | B1 horizon | 200-300 | 0.35 | 97 | 0.18 | 0.06 | 0.011 | 0.090 | 0.054 | nd | 0.160 | nd | 0.04 | nd | 16 | nd | 26 | nd | 16 | 0 | 104 | 97 | nd | 6 | 50 | 4 |
| 616-02-099 | B2 horizon | 300-400 | 0.55 | 97 | 0.31 | 0.43 | 0.016 | 0.101 | 0.094 | nd | 0.070 | nd | 0.67 | 15 | 17 | nd | 27 | 11 | 24 | 9 | 96 | 165 | nd | 9 | nd | 12 |
| 616-02-100 | A horizon | 0-80 | 1.28 | 93 | 0.32 | 1.28 | 0.016 | 1.347 | 0.240 | 0.022 | 0.150 | 0.006 | 0.04 | 33 | 35 | 43 | 30 | 41 | 21 | 53 | 54 | 113 | nd | 29 | 31 | 28 |
| 616-02-100 | PETZ | 80-110 | 1.17 | 83 | 0.23 | 0.62 | 0.013 | 0.509 | 0.208 | 0.108 | 0.230 | 0.018 | 0.09 | 24 | 41 | 24 | 14 | 3 | 15 | 41 | 101 | 95 | nd | 2 | 9 | 10 |
| 616-02-100 | PETZ | 110-200 | 1.72 | 89 | 0.73 | 0.78 | 0.023 | 0.083 | 0.349 | nd | 0.280 | 0.010 | 0.57 | 59 | 39 | 3 | 24 | nd | 27 | 19 | 92 | 384 | nd | 7 | 37 | 10 |
| 616-02-100 | E horizon | 200-600 | 0.30 | 96 | 0.05 | nd | 0.011 | 0.060 | 0.141 | nd | 0.130 | nd | 0.01 | nd | 11 | 31 | 17 | 1 | 6 | 5 | 46 | 28 | nd | 1 | 44 | 0 |
| 616-02-101 | A horizon | 0-75 | 1.22 | 95 | 0.11 | 0.68 | 0.010 | 0.201 | 0.206 | nd | 0.120 | nd | 0.00 | 19 | 21 | nd | 17 | 15 | 22 | 5 | 15 | 56 | nd | 4 | nd | 11 |
| 616-02-101 | Peat1 | 150-200 | 1.22 | 25 | 0.08 | 5.44 | 0.071 | 14.879 | 0.474 | 0.479 | 0.290 | 0.051 | 5.14 | 19 | 30 | 1 | 16 | 13 | 40 | 138 | 331 | 52 | 5 | 18 | 18 | 11 |
| 616-02-101 | E horizon | 350-600 | 1.87 | 94 | 0.11 | 0.06 | 0.012 | 0.090 | 1.199 | nd | 0.170 | nd | 0.13 | 6 | nd | nd | 11 | nd | 53 | 36 | 241 | 65 | nd | 4 | 41 | 17 |
| 616-02-105 | A horizon | 0-160 | 2.17 | 92 | 0.16 | 0.96 | 0.009 | 0.407 | 0.350 | nd | 0.160 | 0.017 | 0.09 | 46 | 18 | 9 | 14 | 3 | 21 | 19 | 89 | 80 | 0 | 17 | 17 | 20 |
| 616-02-105 | Peat | 250-360 | 0.58 | 5 | 0.03 | 12.16 | 0.011 | 1.480 | 0.047 | 0.239 | 0.090 | 0.003 | 2.88 | nd | 49 | nd | 9 | 11 | 20 | 16 | 75 | 20 | 28 | 369 | 17 | 532 |
| 616-02-105 | PETZ | 360-480 | 0.60 | 98 | 0.07 | 0.11 | 0.010 | 0.099 | 0.247 | nd | 0.170 | nd | 0.27 | 2 | nd | nd | 14 | 2 | 25 | 10 | 45 | 34 | nd | 11 | nd | 3 |
| 616-02-105 | E horizon | 480-700 | 0.76 | 99 | 0.12 | nd | 0.011 | 0.074 | 0.450 | nd | 0.150 | nd | nd | 11 | 25 | nd | 26 | nd | 27 | nd | 199 | 79 | nd | 18 | 9 | 7 |
| 616-02-106 | A horizon | 0-50 | 0.51 | 96 | 0.10 | 0.40 | 0.010 | 0.104 | 0.192 | nd | 0.040 | 0.020 | 0.13 | nd | 18 | 6 | 2 | 2 | 12 | 30 | 179 | 73 | nd | 17 | nd | 20 |
| 616-02-106 | E horizon | 50-700 | 1.18 | 97 | 0.20 | 0.16 | 0.013 | 0.095 | 0.631 | nd | 0.090 | nd | 0.16 | 10 | 22 | 10 | 5 | 11 | 29 | 23 | 202 | 71 | nd | 9 | 6 | 15 |
| 616-02-110 | B horizon | 200-500 | 4.01 | 73 | 0.16 | 1.31 | 0.012 | 9.685 | 2.304 | 0.057 | 0.290 | 0.011 | 1.95 | nd | 10 | 5 | 6 | 5 | 74 | 79 | 527 | 89 | nd | 13 | 46 | 12 |
| 616-02-112 | B horizon | 25-80 | 0.04 | 3 | 0.03 | nd | 0.026 | 49.751 | 0.045 | 3.781 | 0.650 | 0.031 | 0.47 | 15 | 47 | 15 | 25 | 5 | 2 | 1324 | 265 | 102 | nd | nd | nd | 10 |
| 616-02-112 | Mud | 125-200 | 0.03 | 8 | 0.02 | nd | 0.024 | 35.130 | 0.051 | 2.009 | 0.670 | 0.007 | 1.00 | nd | 9 | 2 | 15 | nd | 3 | 1063 | 325 | 87 | nd | 4 | 44 | 5 |
| 616-02-112 | Peat | 200-300 | 0.08 | 1 | 0.02 | 0.59 | 0.014 | 0.937 | 0.155 | 0.737 | 3.210 | 0.001 | 2.29 | nd | 12 | nd | 11 | nd | 28 | 62 | 113 | 12 | nd | 31 | nd | 45 |
| 616-02-112 | Bb horizon | 300-400 | 2.94 | 85 | 0.20 | 1.59 | 0.053 | 3.714 | 0.760 | 0.101 | 0.360 | 0.022 | 1.44 | 23 | 58 | 11 | 16 | nd | 50 | 271 | 245 | 130 | nd | 9 | 52 | 24 |
| 616-02-112 | C horizon | 400-600 | 1.70 | 59 | 0.23 | 0.35 | 0.017 | 22.811 | 0.575 | 0.168 | 0.270 | 0.012 | 0.14 | 4 | 102 | 106 | 17 | 19 | 23 | 499 | 198 | 169 | nd | 8 | 39 | 21 |
| 616-02-113 | A horizon | 0-50 | 1.10 | 93 | 0.13 | 0.14 | 0.010 | 0.226 | 0.497 | nd | 0.150 | 0.006 | 0.06 | 6 | 14 | 3 | nd | 39 | 30 | 24 | 184 | 81 | nd | 2 | 19 | 10 |
| 616-02-113 | E2 horizon | 250-300 | 1.33 | 98 | 0.21 | 0.16 | 0.015 | 0.091 | 0.719 | nd | 0.140 | nd | 0.20 | 5 | 25 | nd | 10 | 17 | 26 | 21 | 239 | 128 | nd | 4 | 11 | 5 |
| 616-02-122 | E horizon | 20-235 | 0.11 | 100 | 0.09 | nd | 0.010 | 0.078 | 0.059 | nd | 0.030 | nd | nd | 8 | 10 | 2 | 20 | 6 | 13 | 23 | nd | 64 | nd | nd | 8 | 7 |
| 616-02-122 | B horizon | 235-315 | 0.98 | 92 | 0.20 | 0.04 | 0.013 | 0.100 | 0.163 | nd | 0.040 | nd | 0.01 | nd | 6 | nd | 13 | nd | 13 | 19 | 131 | 149 | nd | 4 | 9 | 2 |
| 616-02-122 | 2E2 horizon | 375-500 | 0.99 | 97 | 0.76 | 0.42 | 0.026 | 0.063 | 0.500 | nd | 0.090 | nd | 0.02 | 29 | 26 | nd | nd | nd | 25 | 11 | 162 | 353 | nd | 7 | 36 | 10 |
| 616-02-122 | B/E horizon | 700-900 | 0.70 | 99 | 0.15 | nd | 0.010 | 0.061 | 0.113 | nd | 0.040 | nd | 0.02 | nd | 18 | 3 | 6 | 1 | 15 | 10 | 111 | 91 | nd | 4 | 45 | 5 |

**Appendix Table 2** (Cont.) total chemical composition (XRF analyses) of oven dried whole soil samples.

| Site | Horizon | Depth (cm) | $Al_2O_3$ | $SiO_2$ | $TiO_2$ | $Fe_2O_3$ | MnO | CaO | $K_2O$ | MgO | $Na_2O$ | $P_2O_5$ | $SO_3$ | V | Cr | Ni | Cu | Zn | Rb | Sr | Ba | Zr | Co | As | La | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (----%----) | | | | | | | | | | | (----mg $kg^{-1}$----) | | | | | | | | | | | | |
| 616-02-127 | Coffee rock | 100-235 | 1.57 | 94 | 0.13 | nd | 0.009 | 0.090 | 0.074 | nd | 0.110 | nd | 0.13 | nd | 14 | 2 | 13 | 17 | 10 | 16 | 13 | 77 | nd | 8 | nd | 4 |
| 616-02-127 | 2E1 horizon | 235-300 | 0.31 | 92 | 0.23 | 0.05 | 0.013 | 0.059 | 0.061 | nd | 0.060 | nd | 0.00 | 8 | nd | nd | 5 | nd | 21 | 9 | 53 | 192 | 5 | 3 | 36 | 5 |
| 616-02-131 | A horizon | 0-50 | 1.54 | 96 | 0.21 | 0.55 | 0.013 | 0.166 | 0.219 | 0.004 | 0.090 | nd | 0.00 | 8 | 25 | 11 | 19 | 13 | 23 | 9 | 141 | 74 | nd | 8 | 31 | 12 |
| 616-02-131 | E horizon | 50-325 | 0.62 | 98 | 0.18 | 0.01 | 0.010 | 0.064 | 0.275 | nd | 0.140 | nd | nd | 9 | 4 | 2 | 10 | 14 | 25 | 12 | 155 | 74 | nd | 1 | 37 | 9 |
| 616-02-131 | B horizon | 325-425 | 15.22 | 70 | 1.00 | 7.90 | 0.022 | 0.129 | 1.158 | 0.226 | 0.360 | nd | 0.00 | 111 | 96 | 11 | 27 | 9 | 53 | 24 | 348 | 431 | 18 | 14 | 14 | 18 |
| 616-02-131 | 2E horizon | 425-600 | 4.05 | 92 | 0.13 | 0.24 | 0.009 | 0.090 | 1.094 | nd | 0.420 | nd | nd | 14 | 6 | nd | 13 | 11 | 44 | 10 | 306 | 76 | nd | 12 | 29 | 1 |
| 616-02-136 | A horizon | 0-25 | 0.09 | 99 | 0.39 | 0.03 | 0.012 | 0.076 | 0.053 | nd | 0.080 | nd | 0.00 | 14 | 14 | 14 | 10 | 12 | 20 | 12 | 15 | 229 | nd | nd | 18 | 1 |
| 616-02-136 | Coffee rock | 200-260 | 2.35 | 93 | 0.76 | 0.26 | 0.016 | 0.136 | 0.212 | nd | 0.200 | nd | 0.09 | 31 | 42 | 17 | 10 | 6 | 31 | 24 | 105 | 458 | nd | 5 | 28 | 14 |
| 616-02-145 | E1 horizon | 50-300 | 0.17 | 92 | 0.30 | nd | 0.010 | 0.060 | 0.087 | 0.002 | 0.120 | nd | nd | 3 | 3 | nd | 3 | nd | 21 | 4 | 10 | 181 | nd | 2 | 6 | 5 |
| 616-02-145 | E2 horizon | 300-450 | 0.30 | 94 | 0.23 | nd | 0.011 | 0.058 | 0.081 | nd | 0.070 | nd | 0.02 | 5 | 40 | 102 | 11 | nd | 21 | 5 | 41 | 143 | 2 | 5 | nd | nd |
| 616-02-145 | B horizon | 450-475 | 11.18 | 70 | 0.44 | 10.62 | 0.013 | 0.090 | 0.276 | 0.088 | 0.120 | 0.036 | 0.07 | 392 | 98 | 17 | 4 | 18 | 33 | 10 | 112 | 189 | 23 | 33 | nd | 40 |
| 616-02-145 | 2E horizon | 475-600 | 5.86 | 87 | 0.21 | 0.27 | 0.009 | 0.068 | 0.720 | nd | 0.060 | nd | 0.10 | 2 | 15 | 4 | 3 | 4 | 42 | 18 | 175 | 89 | nd | 9 | 6 | 8 |
| 616-02-155 | E horizon | 50-150 | 0.66 | 90 | 0.19 | 0.02 | 0.011 | 2.334 | 0.404 | 0.017 | 0.050 | nd | nd | 9 | nd | 6 | 6 | 5 | 28 | 76 | 138 | 75 | nd | nd | 27 | 11 |
| 616-02-155 | 2E horizon | 200-500 | 2.63 | 94 | 0.32 | 0.30 | 0.014 | 0.100 | 0.953 | nd | 0.150 | nd | 0.19 | 12 | 11 | 7 | 1 | nd | 35 | 30 | 228 | 148 | nd | 3 | 11 | 11 |
| 616-02-155 | B horizon | 500-600 | 11.27 | 74 | 1.18 | 4.12 | 0.028 | 0.326 | 1.548 | 0.411 | 0.280 | nd | nd | 123 | 76 | 11 | 14 | 0 | 50 | 29 | 403 | 453 | 7 | 24 | 67 | 26 |
| 616-02-158 | E horizon | 25-225 | 0.07 | 100 | 0.19 | nd | 0.012 | 0.059 | 0.036 | nd | 0.180 | nd | nd | 14 | 3 | nd | 14 | 1 | 5 | nd | nd | 70 | nd | 6 | 41 | 4 |
| 616-02-158 | Coffee rock1 | 225-300 | 3.26 | 88 | 0.52 | 0.46 | 0.015 | 0.067 | 0.241 | nd | 0.040 | 0.043 | 0.14 | 28 | 16 | 6 | 7 | 3 | 10 | 14 | 117 | 236 | nd | 6 | 24 | 2 |
| 616-02-158 | Coffee rock2 | 300-400 | 2.29 | 84 | 0.81 | 0.41 | 0.022 | 0.072 | 0.454 | nd | 0.110 | nd | 0.17 | 47 | 18 | 5 | 5 | 6 | 34 | 19 | 253 | 387 | nd | 4 | 22 | 4 |
| 616-02-174 | B horizon | 250-550 | 0.52 | 93 | 0.13 | 0.13 | 0.011 | 0.107 | 0.055 | nd | 0.020 | nd | 0.05 | 17 | nd | nd | nd | 9 | 19 | 3 | 10 | 43 | nd | 0 | nd | nd |
| 616-02-179 | B horizon | 375-400 | 0.73 | 97 | 0.11 | nd | 0.010 | 0.062 | 0.101 | nd | 0.090 | nd | 0.03 | 7 | 14 | 1 | 10 | 4 | 24 | 14 | nd | 35 | nd | nd | 36 | 7 |
| Ellenbrook | E horizon | 0-150 | 0.04 | 97 | 0.22 | nd | 0.011 | 0.058 | 0.018 | nd | 0.020 | nd | nd | 8 | nd | nd | 0 | 3 | 4 | 0 | 73 | 254 | nd | 2 | 12 | 15 |
| Ellenbrook | Coffee rock | 150-200 | 4.17 | 91 | 0.21 | 0.15 | 0.011 | 0.092 | 0.070 | nd | 0.070 | 0.003 | 0.15 | 15 | 25 | nd | 15 | 7 | 7 | 20 | 178 | 194 | nd | 8 | 26 | 4 |
| Ellenbrook | 2B1 horizon | 500-550 | 0.35 | 96 | 0.09 | 0.09 | 0.010 | 0.064 | 0.192 | nd | 0.060 | nd | 0.28 | nd | 7 | nd | nd | nd | 23 | 14 | 92 | 46 | nd | 0 | 19 | 1 |

**Appendix Table 3** Element analyses by ICP-OES of aqua regia method (in mg $kg^{-1}$ unit).

| Site | Horizon | Depth (cm) | Ca | Mg | Fe | Mn | P | Zn | S | As | Cu | Pb | Ba | Be | Ce | Co | Cr | Ga | Gd | Ge | Hf | La | Mo | Nd | Sc | Sr | Th | V | Y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 616-01-03 | A horizon | 0-25 | 1170 | 71 | 559 | 12 | 10 | 0.90 | 51 | nd | 0.85 | 0.14 | 5.83 | 0.009 | 1.82 | 0.19 | 0.95 | 0.13 | 0.10 | 0.07 | 0.07 | 1.16 | 0.15 | 0.65 | 0.02 | 10.64 | 0.56 | 0.82 | 2.70 |
| 616-01-03 | coffee rock | 180-200 | 150 | 44 | 10415 | 3 | 25 | 1.08 | 230 | 2.33 | 1.77 | 2.91 | 2.45 | 0.051 | 3.48 | 0.57 | 10.81 | 4.24 | 0.44 | 0.15 | 0.10 | 2.59 | 0.30 | 1.37 | 0.31 | 2.46 | 3.89 | 13.89 | 1.14 |
| 616-01-03 | E horizon | 250-300 | 28 | 14 | 277 | 6 | 8 | 0.67 | 74 | nd | 1.08 | 0.47 | 2.09 | 0.019 | 1.46 | 0.29 | 3.00 | 0.92 | 0.09 | 0.05 | 0.04 | 0.74 | 0.04 | 0.53 | 0.07 | 0.61 | 0.80 | 1.23 | 1.35 |
| 616-01-03 | E horizon | 400 | 29 | 10 | 254 | 7 | 5 | 0.58 | 19 | nd | 0.67 | 0.29 | 2.32 | 0.012 | 1.14 | 0.20 | 2.53 | 0.61 | 0.05 | 0.05 | 0.03 | 0.61 | 0.06 | 0.45 | 0.04 | 0.50 | 0.74 | 1.17 | 1.73 |
| 616-01-03 | E horizon | 600 | 18 | 12 | 244 | 9 | 3 | 0.12 | 36 | nd | 0.16 | 1.58 | 2.50 | 0.012 | 2.55 | 0.18 | 1.57 | 0.69 | 0.14 | 0.04 | 0.03 | 1.45 | 0.01 | 0.99 | 0.06 | 0.34 | 1.10 | 1.05 | 1.63 |
| 616-01-05 | B horizon | 620-630 | 49 | 16 | 315 | 5 | 3 | 1.82 | 49 | 0.05 | 0.32 | 0.55 | 1.31 | nd | 0.91 | 0.05 | 2.29 | 1.09 | 0.07 | nd | nd | 0.63 | 0.12 | 0.41 | 0.05 | 1.07 | 0.32 | 0.86 | 0.13 |
| 616-01-05 | A horizon | 0-20 | 1266 | 108 | 464 | 7 | 26 | 4.29 | 86 | nd | 1.23 | 1.62 | 4.29 | 0.008 | 1.13 | 0.19 | 1.17 | 0.32 | 0.08 | 0.07 | 0.05 | 0.77 | 0.15 | 0.47 | 0.03 | 5.52 | 0.39 | 0.74 | 0.91 |
| 616-01-05 | E horizon | 130-150 | 22 | 8 | 128 | 4 | 5 | 1.18 | 29 | nd | 0.36 | nd | 1.18 | 0.005 | 0.98 | 0.12 | 0.52 | 0.49 | 0.05 | nd | 0.04 | 0.57 | 0.09 | 0.37 | 0.03 | 0.38 | 0.41 | 0.67 | 4.14 |
| 616-01-05 | coffee rock | 180-200 | 88 | 40 | 520 | 6 | 18 | 1.04 | 98 | nd | 0.55 | 0.57 | 2.26 | 0.028 | 1.58 | 0.25 | 6.26 | 4.01 | 0.09 | 0.08 | 0.05 | 1.12 | 0.22 | 0.63 | 0.14 | 1.64 | 0.64 | 3.37 | 1.02 |
| 616-01-05 | B horizon | 220-250 | 11 | 10 | 239 | 5 | 4 | 1.58 | 99 | nd | 0.85 | nd | 0.82 | 0.007 | 1.19 | 0.14 | 2.86 | 0.92 | 0.07 | 0.02 | 0.03 | 0.74 | 0.10 | 0.49 | 0.06 | 0.28 | 0.56 | 1.18 | 1.70 |
| 616-01-05 | E horizon | 250-260 | 10 | 10 | 130 | 3 | 3 | 2.25 | 245 | nd | 2.78 | nd | 0.94 | 0.007 | 0.89 | 0.35 | 2.86 | 1.08 | 0.04 | 0.05 | 0.03 | 0.76 | 0.07 | 0.38 | 0.07 | 0.27 | 0.41 | 1.08 | 1.30 |
| 616-01-05 | E horizon | 260-300 | 14 | 8 | 87 | 2 | 3 | 0.92 | 194 | nd | 0.96 | nd | 0.66 | 0.007 | 0.86 | 0.15 | 1.76 | 0.71 | 0.05 | 0.03 | 0.01 | 0.46 | 0.08 | 0.37 | 0.06 | 0.27 | 0.40 | 0.95 | 1.93 |
| 616-01-05 | E horizon | 440-470 | 9 | 6 | 113 | 2 | 2 | 0.07 | 30 | 1.34 | 0.40 | nd | 0.46 | 0.004 | 0.61 | 0.05 | 0.41 | 0.11 | 0.01 | 0.02 | 0.02 | 0.29 | 0.01 | 0.21 | 0.02 | 0.09 | 0.23 | 0.38 | 1.73 |
| 616-01-05 | E horizon | 710-730 | 7 | 5 | 251 | 4 | 4 | 0.55 | 50 | nd | 0.89 | 0.26 | 1.54 | 0.010 | 0.52 | 0.25 | 1.47 | 0.27 | 0.02 | 0.02 | 0.02 | 0.33 | 0.14 | 0.19 | 0.04 | 0.28 | 0.22 | 0.71 | 1.17 |
| 616-01-05 | coffee rock | 840-860 | 32 | 42 | 67 | 2 | 5 | nd | 127 | nd | 0.27 | 4.02 | 1.61 | 0.015 | 1.29 | 0.14 | 4.08 | 1.22 | 0.10 | 0.05 | 0.04 | 0.77 | 0.08 | 0.49 | 0.26 | 0.80 | 0.92 | 1.58 | 0.19 |
| 616-01-05 | coffee rock | 940-960 | 54 | 31 | 230 | 10 | 11 | 0.09 | 136 | 0.08 | 0.36 | 3.22 | 2.16 | 0.023 | 2.25 | 0.17 | 5.89 | 2.11 | 0.15 | 0.05 | 0.08 | 1.26 | 0.14 | 0.84 | 0.32 | 0.86 | 1.74 | 2.60 | 0.39 |
| 616-02-09 | E horizon | 225-250 | 45 | 23 | 366 | 11 | 7 | nd | 39 | 0.44 | 0.08 | 1.33 | 7.41 | 0.002 | 2.66 | nd | 3.00 | 0.85 | 0.12 | 0.00 | nd | 1.63 | 0.04 | 0.96 | 0.07 | 0.61 | 0.69 | 0.62 | 0.19 |
| 616-01-11 | A horizon | 0-50 | 924 | 82 | 320 | 7 | 21 | 3.19 | 100 | 0.02 | 1.32 | 1.61 | 6.75 | 0.010 | 1.45 | 0.22 | 0.83 | 0.31 | 0.08 | 0.06 | 0.01 | 0.75 | 0.11 | 0.57 | 0.04 | 5.48 | 0.49 | 0.59 | 1.14 |
| 616-01-11 | E horizon | 230-250 | 32 | 4 | 198 | 5 | 3 | 0.16 | 12 | nd | 0.56 | nd | 1.33 | 0.004 | 0.87 | 0.14 | 0.37 | 0.22 | 0.05 | 0.01 | 0.01 | 0.56 | 0.10 | 0.37 | 0.01 | 0.20 | 0.29 | 0.42 | 1.83 |
| 616-01-11 | E horizon | 520-540 | 22 | 4 | 300 | 9 | 2 | 0.15 | 11 | nd | 0.27 | nd | 1.39 | 0.007 | 1.30 | 0.26 | 0.65 | 0.22 | 0.07 | 0.03 | 0.02 | 0.66 | 0.06 | 0.51 | 0.04 | 0.22 | 0.39 | 0.82 | 2.89 |
| 616-01-11 | E horizon | 640-660 | 47 | 25 | 560 | 24 | 7 | 0.28 | 76 | nd | 0.19 | 1.64 | 8.39 | 0.016 | 5.07 | 0.34 | 1.83 | 1.13 | 0.23 | 0.03 | 0.02 | 2.70 | 0.10 | 1.94 | 0.11 | 1.31 | 1.75 | 1.69 | 0.09 |
| 616-01-14 | A horizon | 0-50 | 361 | 18 | 307 | 3 | 6 | 0.95 | 25 | nd | 1.05 | nd | 2.12 | 0.003 | 0.87 | 0.21 | 0.97 | 0.18 | 0.05 | 0.04 | 0.03 | 0.52 | 0.16 | 0.35 | 0.03 | 1.42 | 0.32 | 0.45 | 1.88 |
| 616-01-14 | E horizon | 250-270 | 43 | 5 | 161 | 3 | 2 | 0.23 | 9 | nd | 0.50 | nd | 1.39 | 0.002 | 0.70 | 0.13 | 0.34 | 0.10 | 0.03 | 0.00 | 0.05 | 0.31 | 0.08 | 0.26 | nd | 0.39 | 0.24 | 0.55 | 2.98 |
| 616-01-14 | E horizon | 600 | 41 | 12 | 1222 | 3 | 7 | 0.31 | 8 | 0.26 | 0.20 | nd | 1.30 | 0.012 | 1.54 | 0.15 | 3.87 | 1.19 | 0.07 | 0.01 | 0.01 | 0.65 | 0.16 | 0.38 | 0.07 | 0.49 | 0.80 | 2.55 | 1.28 |
| 616-01-14 | coffee rock | 700 | 48 | 22 | 1859 | 2 | 9 | 0.43 | 21 | nd | 0.30 | 0.10 | 1.26 | 0.017 | 1.60 | 0.19 | 4.64 | 1.45 | 0.08 | 0.07 | 0.02 | 0.87 | 0.16 | 0.44 | 0.08 | 0.54 | 0.86 | 3.70 | 0.92 |
| 616-01-14 | E horizon | 800 | 41 | 14 | 1536 | 4 | 7 | 0.60 | 9 | nd | 0.22 | 0.04 | 1.27 | 0.015 | 1.66 | 0.20 | 4.21 | 1.55 | 0.09 | 0.05 | 0.07 | 0.83 | 0.11 | 0.43 | 0.10 | 0.51 | 0.88 | 3.18 | 1.70 |
| 616-01-14 | E horizon | 900 | 107 | 15 | 1853 | 2 | 10 | 0.56 | 12 | nd | 0.15 | 0.02 | 1.57 | 0.020 | 1.71 | 0.16 | 3.28 | 1.50 | 0.10 | 0.07 | 0.00 | 0.95 | 0.17 | 0.47 | 0.07 | 0.69 | 0.83 | 3.72 | 1.74 |
| 616-01-14 | C horizon | 1000 | 30 | 10 | 408 | 7 | 7 | 4.95 | 4 | nd | 0.31 | 1.13 | 2.97 | 0.010 | 1.57 | 0.24 | 2.85 | 1.02 | 0.07 | 0.05 | 0.08 | 0.96 | 0.08 | 0.54 | 0.05 | 0.56 | 1.20 | 1.52 | 1.75 |
| 616-01-14 | C horizon | 1250-1270 | 24 | 14 | 364 | 10 | 6 | 0.34 | 16 | nd | 0.24 | 5.11 | 8.19 | 0.017 | 3.17 | 0.38 | 7.18 | 2.28 | 0.10 | 0.12 | 0.08 | 2.06 | 0.31 | 1.00 | 0.17 | 1.08 | 3.01 | 1.77 | nd |
| 616-01-18 | A horizon | 0-25 | 363 | 11 | 143 | 2 | 4 | 1.01 | 17 | nd | 0.40 | nd | 2.36 | 0.003 | 1.00 | 0.24 | 0.66 | 0.17 | 0.05 | 0.03 | 0.00 | 0.59 | 0.01 | 0.35 | 0.00 | 1.36 | 0.39 | 0.56 | 2.81 |
| 616-01-18 | E horizon | 180-200 | 75 | 4 | 50 | 1 | 4 | 2.57 | 128 | nd | 0.49 | nd | 0.70 | 0.003 | 0.89 | 0.07 | 0.70 | 0.56 | 0.04 | 0.02 | 0.05 | 0.51 | 0.19 | 0.33 | nd | 0.26 | 0.45 | 0.84 | 2.22 |
| 616-01-18 | E horizon | 280-300 | 44 | 3 | 48 | 1 | 3 | 0.68 | 98 | nd | 0.35 | 0.34 | 0.70 | 0.000 | 0.83 | 0.09 | 0.51 | 0.32 | 0.05 | 0.01 | nd | 0.59 | nd | 0.31 | 0.01 | 0.20 | 0.33 | 0.47 | 1.86 |
| 616-01-18 | E horizon | 380-400 | 23 | 3 | 43 | 1 | 3 | 0.74 | 37 | 0.16 | 0.41 | 0.02 | 0.65 | 0.000 | 0.79 | 0.07 | 0.32 | 0.21 | 0.04 | 0.02 | 0.03 | 0.38 | 0.11 | 0.31 | nd | 0.19 | 0.23 | 0.97 | 2.53 |
| 616-01-18 | coffee rock | 420-440 | 21 | 13 | 233 | 2 | 15 | 1.16 | 297 | 0.21 | 2.15 | 1.36 | 1.06 | 0.028 | 2.51 | 0.25 | 5.57 | 2.28 | 0.18 | 0.07 | 0.04 | 1.38 | 0.12 | 0.99 | 0.37 | 0.38 | 1.13 | 2.77 | 0.73 |
| 616-01-18 | E horizon | 520-540 | 16 | 9 | 158 | 4 | 5 | 0.24 | 79 | 0.25 | 0.34 | 0.02 | 1.02 | 0.008 | 1.12 | 0.20 | 1.00 | 0.66 | 0.05 | 0.06 | 0.03 | 0.58 | 0.23 | 0.43 | 0.07 | 0.25 | 0.41 | 0.98 | 1.56 |
| 616-01-18 | coffee rock | 600-625 | 59 | 7 | 576 | 7 | 6 | 2.96 | 62 | nd | 3.03 | 0.10 | 0.85 | 0.005 | 1.36 | 1.13 | 3.01 | 0.49 | 0.08 | 0.02 | 0.02 | 0.90 | 0.29 | 0.54 | 0.06 | 0.41 | 0.60 | 0.66 | 1.88 |
| 616-01-18 | coffee rock | 700-725 | 41 | 25 | 727 | 4 | 21 | 2.22 | 323 | nd | 2.38 | 1.66 | 1.77 | 0.042 | 3.19 | 0.58 | 6.66 | 3.40 | 0.29 | 0.11 | 0.16 | 2.02 | 0.31 | 1.41 | 0.40 | 0.59 | 2.95 | 6.55 | 1.14 |
| 616-01-19 | A horizon | 25-50 | 43 | 34 | 106 | 3 | 8 | 1.07 | 19 | 0.00 | 0.14 | 0.44 | 3.00 | 0.002 | 1.68 | 0.02 | 0.42 | 0.06 | 0.08 | 0.07 | 0.03 | 0.86 | 0.19 | 0.62 | 0.05 | 0.92 | 0.47 | 0.98 | 2.51 |
| 616-01-19 | E horizon | 125-150 | 15 | 5 | 162 | 6 | 5 | 0.67 | 9 | nd | 0.17 | 0.46 | 2.03 | 0.002 | 1.82 | 0.04 | 0.40 | 0.27 | 0.08 | 0.03 | 0.03 | 1.07 | 0.25 | 0.68 | 0.03 | 0.27 | 0.51 | 1.61 | 4.96 |
| 616-01-19 | E horizon | 225-250 | 25 | 8 | 1635 | 12 | 6 | 0.94 | 15 | nd | 1.64 | 0.35 | 1.75 | 0.001 | 2.26 | 0.15 | 9.16 | 0.13 | 0.11 | 0.02 | 0.00 | 1.32 | 2.09 | 0.84 | 0.03 | 0.32 | 0.78 | 1.47 | 2.67 |
| 616-01-19 | B horizon | 275-300 | 31 | 57 | 605 | 6 | 37 | 0.54 | 737 | 0.51 | 0.76 | 6.63 | 10.42 | 0.069 | 8.45 | 0.23 | 10.82 | 5.53 | 0.57 | 0.12 | 0.19 | 4.93 | 0.42 | 3.28 | 0.92 | 1.61 | 4.14 | 2.64 | 1.77 |

**Appendix Table 3** (Cont.) Element analyses by ICP-OES of aqua regia method (in mg $kg^{-1}$ unit).

| Site | Horizon | Depth (cm) | Ca | Mg | Fe | Mn | P | Zn | S | As | Cu | Pb | Ba | Be | Ce | Co | Cr | Ga | Gd | Ge | Hf | La | Mo | Nd | Sc | Sr | Th | V | Y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 616-01-23 | A horizon | 0-25 | 406 | 25 | 188 | 5 | 5 | 0.46 | 15 | 0.04 | 0.14 | 0.66 | 2.90 | 0.004 | 1.38 | 0.09 | 0.29 | 0.14 | 0.08 | 0.03 | 0.01 | 0.97 | 0.03 | 0.50 | 0.05 | 3.17 | 0.46 | 1.00 | 2.93 |
| 616-01-23 | E horizon | 25-50 | 16 | 5 | 187 | 7 | 4 | 0.14 | 5 | nd | 0.12 | 0.68 | 2.53 | 0.001 | 1.56 | 0.04 | 0.27 | 0.24 | 0.07 | 0.03 | 0.03 | 0.95 | 0.02 | 0.60 | 0.05 | 0.25 | 0.48 | 1.16 | 4.79 |
| 616-01-23 | B horizon | 150-175 | 14 | 30 | 437 | 8 | 6 | 0.32 | 28 | 0.15 | 0.18 | 0.99 | 2.97 | 0.024 | 1.81 | 0.20 | 4.68 | 2.37 | 0.11 | 0.03 | 0.03 | 1.15 | 0.58 | 0.66 | 0.19 | 0.93 | 0.86 | 2.29 | 1.54 |
| 616-01-23 | E horizon | 250-275 | 37 | 33 | 451 | 9 | 8 | 0.03 | 41 | 0.01 | 0.18 | 5.47 | 3.44 | 0.023 | 1.90 | 0.21 | 7.36 | 2.25 | 0.12 | 0.04 | 0.04 | 1.15 | 0.10 | 0.70 | 0.22 | 0.67 | 1.13 | 2.00 | 1.72 |
| 616-01-23 | E horizon | 550 | 16 | 10 | 223 | 5 | 3 | nd | 44 | 0.04 | 0.18 | 0.91 | 2.32 | 0.005 | 1.26 | 0.12 | 2.66 | 0.49 | 0.06 | 0.04 | 0.03 | 0.61 | 0.02 | 0.47 | 0.07 | 0.30 | 0.61 | 0.94 | 2.25 |
| 616-01-23 | E horizon | 825 | 23 | 20 | 300 | 6 | 4 | nd | 48 | nd | 0.27 | 2.33 | 6.60 | 0.009 | 1.67 | 0.13 | 4.52 | 0.52 | 0.08 | 0.03 | 0.04 | 1.13 | 0.07 | 0.60 | 0.13 | 0.59 | 0.82 | 1.30 | 2.01 |
| 616-01-24 | A horizon | 0-25 | 337 | 57 | 116 | 3 | 8 | 4.61 | 42 | 0.09 | 0.11 | 0.27 | 2.71 | 0.003 | 0.96 | 0.07 | 0.23 | 0.13 | 0.06 | 0.05 | 0.01 | 0.68 | 0.10 | 0.37 | 0.06 | 2.13 | 0.43 | 0.31 | 2.21 |
| 616-01-24 | E horizon | 100-125 | 25 | 9 | 153 | 6 | 4 | 0.58 | 9 | nd | 0.13 | 0.30 | 1.01 | 0.002 | 0.70 | 0.03 | 0.31 | 0.20 | 0.03 | 0.04 | 0.03 | 0.24 | 0.28 | 0.26 | 0.04 | 0.25 | 0.18 | 1.10 | 4.01 |
| 616-01-24 | B horizon | 150-175 | 21 | 12 | 198 | 3 | 4 | nd | 79 | nd | 0.18 | 0.62 | 1.28 | 0.009 | 1.20 | 0.07 | 2.53 | 1.12 | 0.08 | 0.03 | 0.00 | 0.77 | 0.29 | 0.48 | 0.09 | 0.40 | 0.47 | 1.27 | 2.16 |
| 616-01-24 | E horizon | 350-375 | 20 | 4 | 156 | 6 | 4 | 0.56 | 7 | 0.03 | 0.12 | 1.11 | 1.44 | 0.001 | 1.58 | 0.06 | 0.54 | 0.10 | 0.07 | 0.02 | 0.02 | 0.95 | 0.08 | 0.62 | 0.06 | 0.20 | 0.47 | 0.91 | 4.85 |
| 616-01-24 | B horizon | 450-475 | 164 | 65 | 434 | 6 | 20 | 0.63 | 264 | 0.39 | 0.40 | 3.63 | 7.10 | 0.077 | 8.02 | 0.21 | 10.38 | 3.05 | 0.56 | 0.08 | 0.12 | 4.26 | 0.08 | 3.48 | 0.87 | 1.48 | 2.17 | 5.52 | 2.89 |
| 616-01-24 | E horizon | 550-575 | 22 | 14 | 173 | 4 | 3 | 0.73 | 16 | 0.12 | 0.17 | 1.02 | 3.61 | 0.012 | 1.11 | 0.09 | 3.27 | 0.21 | 0.06 | 0.02 | 0.02 | 0.72 | 0.05 | 0.47 | 0.08 | 0.33 | 0.48 | 0.82 | 2.22 |
| 616-02-28 | B horizon | 25-50 | 132 | 271 | 13994 | 33 | 21 | nd | 452 | 0.29 | 1.31 | 2.40 | 11.61 | 0.041 | 3.76 | 1.36 | 9.13 | 4.71 | nd | nd | nd | 1.92 | 0.84 | 1.30 | 0.85 | 1.97 | 3.47 | 12.72 | 0.47 |
| 616-02-28 | B horizon | 125-150 | 1819 | 1510 | 32526 | 368 | 79 | 8.91 | 28940 | 6.91 | 9.95 | 12.08 | 16.91 | 0.597 | 37.12 | 36.99 | 26.34 | 14.87 | 0.58 | nd | 0.05 | 15.35 | 7.64 | 12.59 | 5.81 | 16.51 | 10.97 | 50.65 | 9.73 |
| 616-02-31 | A horizon | 0-20 | 878 | 140 | 315 | 5 | 14 | 0.45 | 108 | nd | 0.32 | 0.95 | 4.70 | 0.007 | 1.25 | 0.12 | 0.36 | 0.22 | 0.06 | 0.04 | 0.05 | 0.74 | 0.11 | 0.47 | 0.05 | 7.32 | 0.38 | 0.48 | 1.45 |
| 616-02-31 | E horizon | 150-170 | 10 | 3 | 142 | 4 | 1 | 0.01 | 5 | nd | 0.06 | nd | 0.66 | 0.006 | 1.27 | 0.11 | 0.38 | 0.19 | 0.05 | 0.04 | 0.05 | 0.69 | 0.09 | 0.49 | 0.05 | 0.14 | 0.43 | 0.62 | 0.85 |
| 616-02-31 | coffee rock | 200-300 | 83 | 366 | 2693 | 11 | 40 | nd | 1052 | 1.15 | 0.49 | 9.60 | 8.46 | 0.182 | 9.83 | 0.80 | 17.69 | 7.87 | 0.72 | 0.20 | 0.26 | 5.28 | 0.63 | 3.96 | 0.65 | 5.24 | 4.40 | 10.45 | 1.90 |
| 616-02-31 | coffee rock | 200-300 | 57 | 279 | 1949 | 7 | 32 | nd | 1064 | 0.75 | 0.07 | 7.89 | 6.86 | 0.141 | 7.61 | 0.60 | 14.98 | 7.03 | 0.53 | 0.20 | 0.19 | 4.10 | 0.34 | 3.02 | 0.50 | 4.09 | 3.63 | 9.08 | 1.22 |
| 616-02-31 | E horizon | 380-400 | 12 | 20 | 734 | 9 | 2 | nd | 446 | 0.27 | 0.11 | 1.30 | 6.75 | 0.010 | 1.74 | 0.31 | 1.02 | 0.69 | 0.06 | 0.00 | 0.07 | 1.00 | 0.05 | 0.62 | 0.03 | 0.84 | 0.78 | 1.11 | 1.51 |
| 616-02-31 | coffee rock | 430-450 | 99 | 225 | 1044 | 7 | 95 | nd | 644 | nd | 0.15 | 6.87 | 16.45 | 0.065 | 7.04 | 0.48 | 10.82 | 3.55 | 0.32 | 0.12 | 0.10 | 4.91 | 0.15 | 2.42 | 0.27 | 5.54 | 2.51 | 4.53 | 2.33 |
| 616-02-31 | coffee rock | 530-550 | 106 | 213 | 651 | 10 | 85 | 0.10 | 390 | nd | 0.15 | 2.83 | 12.30 | 0.053 | 5.52 | 0.36 | 8.67 | 2.07 | 0.30 | 0.08 | 0.09 | 3.15 | 0.10 | 2.02 | 0.29 | 3.44 | 2.28 | 3.42 | 1.88 |
| 616-02-32 | A horizon | 0-20 | 8155 | 137 | 315 | 12 | 14 | 0.27 | 128 | nd | 0.61 | nd | 1.89 | 0.009 | 0.90 | 0.24 | 7.61 | 0.27 | 0.06 | 0.06 | 0.03 | 1.09 | 0.11 | 0.37 | 0.01 | 28.75 | 0.52 | 0.72 | 1.58 |
| 616-02-32 | E horizon | 150-160 | 44 | 19 | 275 | 11 | 2 | 0.77 | 83 | 0.07 | 0.51 | 0.09 | 0.67 | 0.006 | 2.14 | 0.26 | 12.32 | 0.35 | 0.09 | 0.02 | 0.02 | 1.31 | 0.20 | 0.90 | 0.04 | 0.33 | 0.59 | 0.86 | 2.45 |
| 616-02-32 | coffee rock | 160 | 64 | 134 | 467 | 24 | 10 | 0.81 | 805 | 0.16 | 0.18 | 5.77 | 3.63 | 0.023 | 10.35 | 0.44 | 4.95 | 3.76 | 0.45 | 0.06 | 0.10 | 6.59 | 0.18 | 3.84 | 0.26 | 3.57 | 3.53 | 3.84 | 0.41 |
| 616-02-32 | coffee rock | 220-240 | 47 | 35 | 602 | 12 | 17 | 0.02 | 706 | nd | 0.91 | 13.55 | 3.71 | 0.031 | 6.57 | 0.40 | 58.37 | 4.13 | 0.39 | 0.15 | 0.14 | 4.07 | 0.53 | 2.39 | 0.44 | 1.23 | 3.84 | 5.25 | 1.70 |
| 616-02-32 | E horizon | 320-340 | 54 | 80 | 757 | 36 | 9 | 0.81 | 252 | nd | 0.29 | 8.20 | 5.17 | 0.025 | 12.73 | 0.57 | 5.91 | 1.59 | 0.46 | 0.05 | 0.04 | 7.10 | 0.29 | 4.70 | 0.19 | 2.20 | 4.46 | 3.82 | 0.37 |
| 616-02-32 | E horizon | 380-400 | 27 | 97 | 777 | 38 | 8 | 0.46 | 340 | nd | 0.25 | 6.37 | 4.95 | 0.031 | 11.01 | 0.55 | 6.29 | 1.19 | 0.43 | 0.08 | 0.04 | 6.25 | 0.12 | 3.90 | 0.19 | 1.87 | 4.14 | 3.18 | 0.62 |
| 616-02-58 | B horizon | 400-500 | 242 | 423 | 540 | 12 | 7 | nd | 2352 | 0.08 | 0.96 | 5.69 | 7.03 | 0.023 | 3.39 | 0.29 | 26.45 | 0.74 | 0.20 | 0.18 | 0.11 | 2.31 | 0.34 | 1.21 | 0.23 | 4.22 | 0.77 | 3.48 | 0.55 |
| 616-02-65 | B horizon | 200 | 755 | 615 | 1135 | 13 | 67 | 4.34 | 321 | 0.67 | 1.04 | 5.14 | 26.86 | 0.116 | 6.98 | 0.95 | 13.28 | 5.09 | 0.38 | nd | 0.00 | 3.99 | 0.34 | 2.74 | 0.64 | 9.94 | 1.08 | 5.15 | 1.67 |
| 616-02-65 | B horizon | 0-20 | 1335 | 1133 | 2441 | 15 | 258 | 1.84 | 444 | 2.29 | 3.17 | 7.83 | 47.43 | 0.408 | 22.65 | 2.61 | 25.88 | 7.82 | 1.58 | nd | 0.06 | 12.15 | 0.35 | 9.50 | 2.14 | 23.08 | 3.20 | 13.70 | 6.55 |
| 616-02-65 | coffee rock | 480-560 | 365 | 547 | 824 | 7 | 35 | 1.57 | 1076 | 0.42 | 0.17 | 6.08 | 9.63 | 0.037 | 2.87 | 0.41 | 9.21 | 3.17 | 0.17 | 0.01 | 0.06 | 1.67 | 0.18 | 1.15 | 0.63 | 5.00 | 2.06 | 4.61 | 0.64 |
| 616-02-65 | coffee rock | 650-700 | 87 | 115 | 304 | 5 | 4 | 1.91 | 221 | 0.01 | 0.25 | 1.76 | 2.32 | 0.005 | 1.47 | 0.04 | 2.58 | 0.93 | 0.10 | nd | 0.02 | 0.90 | 0.12 | 0.59 | 0.16 | 1.19 | 0.67 | 1.25 | 0.19 |
| 616-02-68 | A horizon | 50 | 101 | 19 | 216 | 4 | 7 | 0.23 | 12 | nd | 0.20 | nd | 3.67 | 0.003 | 2.17 | 0.09 | 0.32 | 0.17 | 0.10 | 0.01 | 0.02 | 1.21 | 0.14 | 0.81 | 0.01 | 1.43 | 0.63 | 1.67 | 0.05 |
| 616-02-68 | E horizon | 140-150 | 9 | 5 | 118 | 4 | 4 | 0.24 | 1 | nd | 0.21 | nd | 1.42 | 0.002 | 2.00 | 0.12 | 0.23 | 0.10 | 0.09 | 0.03 | 0.01 | 1.05 | 0.15 | 0.77 | nd | 0.25 | 0.58 | 1.50 | nd |
| 616-02-68 | E horizon | 340-350 | 39 | 51 | 663 | 16 | 8 | 0.14 | 188 | nd | 0.21 | 1.94 | 3.63 | 0.018 | 5.15 | 0.26 | 4.93 | 0.79 | 0.24 | 0.06 | 0.01 | 2.76 | 0.22 | 1.91 | 0.05 | 0.49 | 1.88 | 1.93 | nd |
| 616-02-68 | E horizon | 540-550 | 49 | 9 | 681 | 13 | 5 | 0.11 | 360 | nd | 0.07 | 0.26 | 2.73 | 0.015 | 4.41 | 0.29 | 2.54 | 0.56 | 0.22 | 0.04 | 0.03 | 2.29 | 0.08 | 1.66 | 0.07 | 0.43 | 1.69 | 2.43 | nd |
| 616-02-68 | A horizon | 0-25 | 147 | 21 | 118 | 2 | 6 | 2.30 | 14 | nd | 0.14 | 0.71 | 7.49 | 0.000 | 1.56 | 0.01 | 0.56 | 0.25 | 0.10 | nd | 0.01 | 0.89 | 0.03 | 0.58 | 0.02 | 1.85 | 0.43 | 0.01 | 0.15 |
| 616-02-68 | E horizon | 25-200 | 21 | 6 | 190 | 4 | 2 | 2.50 | 3 | 0.13 | 0.07 | 0.22 | 1.90 | nd | 1.77 | nd | 0.89 | 0.10 | 0.11 | nd | nd | 1.00 | 0.11 | 0.71 | 0.02 | 0.16 | 0.43 | 0.24 | 0.14 |
| 616-02-68 | coffee rock | 200-300 | 224 | 162 | 615 | 11 | 14 | 2.07 | 285 | 0.20 | 0.30 | 4.21 | 4.53 | 0.012 | 3.89 | 0.13 | 11.73 | 2.53 | 0.19 | nd | 0.01 | 2.29 | 0.59 | 1.39 | 0.10 | 1.15 | 0.92 | 1.64 | 0.25 |
| 616-02-68 | B horizon | 300-400 | 47 | 61 | 610 | 14 | 5 | 2.26 | 182 | nd | 0.10 | 1.78 | 5.00 | nd | 3.28 | 0.01 | 4.77 | 0.79 | 0.13 | nd | 0.02 | 1.92 | 0.06 | 1.29 | 0.08 | 0.44 | 1.29 | 0.93 | 0.24 |
| 616-02-68 | B horizon | 450 | 64 | 58 | 669 | 19 | 4 | 2.04 | 188 | nd | 0.18 | 1.92 | 6.46 | nd | 2.75 | 0.03 | 7.96 | 1.00 | 0.12 | nd | 0.01 | 1.62 | 0.11 | 1.07 | 0.09 | 0.86 | 1.04 | 1.02 | 0.27 |
| 616-02-68 | B horizon | 500-600 | 82 | 18 | 743 | 19 | 4 | 1.95 | 243 | nd | 0.13 | 1.60 | 5.06 | nd | 4.91 | nd | 5.08 | 0.79 | 0.22 | nd | nd | 2.79 | 0.03 | 1.90 | 0.13 | 0.55 | 1.75 | 1.25 | 0.46 |
| 616-02-71 | E horizon | 350-370 | 18 | 11 | 145 | 3 | 3 | 0.17 | 21 | nd | 0.09 | nd | 0.82 | 0.002 | 1.09 | 0.06 | 0.32 | 0.11 | 0.07 | 0.01 | 0.02 | 0.62 | 0.14 | 0.42 | nd | 0.23 | 0.32 | 1.30 | nd |
| 616-02-71 | B horizon | 550-570 | 87 | 83 | 624 | 10 | 5 | 0.31 | 498 | nd | 0.31 | 1.33 | 3.69 | 0.024 | 4.19 | 0.30 | 2.81 | 0.82 | 0.22 | 0.03 | 0.04 | 2.38 | 0.13 | 1.47 | 0.22 | 1.28 | 1.36 | 1.94 | 0.11 |

**Appendix Table 3** (Cont.) Element analyses by ICP-OES of aqua regia method (in mg $kg^{-1}$ unit).

| Site | Horizon | Depth (cm) | Ca | Mg | Fe | Mn | P | Zn | S | As | Cu | Pb | Ba | Be | Ce | Co | Cr | Ga | Gd | Ge | Hf | La | Mo | Nd | Sc | Sr | Th | V | Y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 616-02-78 | B horizon | 450 | 50 | 14 | 385 | 4 | 5 | 1.55 | 189 | nd | 0.17 | 0.51 | 2.16 | nd | 0.39 | 0.06 | 4.06 | 0.20 | nd | 0.01 | 0.01 | 0.23 | 0.11 | 0.15 | 0.03 | 0.44 | 0.10 | 0.33 | 0.10 |
| 616-02-80 | coffee rock | 350-400 | 342 | 603 | 720 | 6 | 12 | 0.04 | 885 | nd | 0.18 | 4.63 | 8.92 | 0.057 | 3.03 | 0.90 | 5.68 | 5.00 | 0.18 | 0.08 | 0.08 | 1.97 | 0.26 | 1.11 | 0.28 | 5.54 | 1.26 | 4.50 | 0.02 |
| 616-02-81 | B horizon | 500 | 144 | 32 | 1003 | 15 | 3 | 2.06 | 548 | nd | 0.10 | 1.21 | 4.73 | nd | 2.18 | 0.11 | 1.92 | 0.41 | 0.09 | nd | 0.01 | 1.29 | 0.10 | 0.90 | 0.09 | 0.90 | 0.61 | 1.72 | 0.40 |
| 616-02-82 | A horizon | 25-75 | nd | 4 | 221 | 8 | 7 | 0.36 | 10 | nd | 0.30 | nd | 2.94 | 0.008 | 3.75 | 0.15 | 0.66 | 0.40 | 0.14 | 0.03 | 0.04 | 2.05 | 0.04 | 1.39 | 0.01 | 0.29 | 1.19 | 1.11 | nd |
| 616-02-82 | E horizon | 125-175 | nd | 6 | 272 | 12 | 5 | 0.13 | 18 | 0.05 | 0.24 | 1.04 | 3.66 | 0.010 | 4.21 | 0.18 | 1.63 | 0.37 | 0.16 | 0.01 | nd | 2.27 | 0.03 | 1.54 | 0.04 | 0.42 | 1.12 | 1.69 | nd |
| 616-02-82 | E horizon | 225-275 | 17 | 15 | 2147 | 15 | 8 | 1.87 | 1586 | nd | 0.36 | 0.58 | 5.72 | 0.031 | 4.02 | 0.35 | 4.17 | 0.65 | 0.22 | 0.07 | 0.02 | 2.45 | 0.21 | 1.47 | 0.09 | 0.63 | 1.73 | 2.86 | nd |
| 616-02-82 | E horizon | 325-375 | 46 | 27 | 1433 | 14 | 8 | 0.17 | 958 | 1.08 | 0.18 | 1.67 | 5.05 | 0.029 | 7.29 | 0.36 | 4.20 | 0.73 | 0.35 | 0.05 | 0.04 | 4.07 | 0.14 | 2.68 | 0.12 | 0.88 | 2.62 | 2.71 | 0.06 |
| 616-02-82 | E horizon | 425-475 | 67 | 33 | 2332 | 32 | 11 | 0.68 | 1385 | 2.40 | 0.11 | 2.29 | 6.98 | 0.040 | 7.56 | 0.56 | 7.22 | 1.08 | 0.41 | 0.10 | 0.02 | 4.17 | 0.16 | 2.82 | 0.22 | 1.34 | 3.85 | 4.11 | nd |
| 616-02-82 | coffee rock | 525-575 | 128 | 39 | 3500 | 21 | 17 | 0.57 | 2482 | 6.36 | 0.24 | 4.11 | 5.26 | 0.080 | 5.60 | 0.90 | 14.33 | 1.71 | 0.40 | 0.10 | 0.11 | 3.65 | 0.12 | 2.15 | 0.44 | 1.50 | 2.86 | 4.74 | 1.19 |
| 616-02-85 | A horizon | 0-25 | 4157 | 1879 | 43557 | 961 | 1094 | 43.22 | 241 | 19.70 | 53.51 | 90.24 | 194.28 | 2.553 | 120.71 | 35.41 | 46.41 | 19.99 | 4.99 | nd | nd | 54.34 | 5.39 | 37.19 | 10.11 | 26.25 | 15.46 | 92.19 | 38.03 |
| 616-02-85 | B horizon | 125-150 | 433 | 270 | 2923 | 30 | 13 | nd | 73 | 0.28 | 2.74 | 4.94 | 20.26 | 0.108 | 12.73 | 1.55 | 13.70 | 5.80 | 0.52 | nd | 0.02 | 7.02 | 1.14 | 4.50 | 2.99 | 4.23 | 7.36 | 9.83 | 1.57 |
| 616-02-85 | E horizon | 350-400 | 237 | 120 | 2279 | 39 | 14 | nd | 984 | 0.21 | 0.61 | 1.41 | 8.10 | 0.136 | 6.39 | 3.05 | 4.37 | 0.90 | 0.30 | nd | 0.02 | 3.16 | 0.96 | 2.20 | 0.40 | 2.49 | 1.41 | 3.62 | 1.79 |
| 616-02-85 | B horizon | 450-475 | 19702 | 2840 | 35378 | 694 | 109 | 5.47 | 30601 | 5.50 | 14.13 | 16.17 | 46.55 | 1.310 | 64.68 | 19.21 | 34.90 | 17.15 | 2.03 | nd | 0.08 | 28.95 | 6.61 | 20.87 | 6.88 | 178.73 | 13.75 | 75.63 | 19.64 |
| 616-02-87 | coffee rock | 200-300 | 221 | 128 | 2128 | 16 | 53 | nd | 579 | 1.64 | 2.77 | 3.45 | 5.28 | 0.113 | 13.81 | 0.40 | 35.13 | 5.28 | 1.63 | 0.25 | 0.34 | 6.76 | 2.69 | 6.25 | 2.47 | 2.17 | 7.53 | 8.62 | 4.44 |
| 616-02-87 | coffee rock | 300-400 | 536 | 348 | 538 | 8 | 37 | nd | 964 | 1.14 | 0.18 | 2.28 | 10.07 | 0.200 | 11.99 | 0.41 | 23.81 | 8.69 | 1.18 | 0.28 | 0.27 | 6.17 | 0.58 | 5.48 | 1.85 | 5.90 | 6.72 | 9.12 | 3.16 |
| 616-02-87 | B horizon | 500-600 | 19 | 21 | 339 | 3 | 5 | nd | 171 | 0.07 | 0.24 | 0.65 | 2.93 | 0.009 | 1.89 | 0.16 | 3.30 | 0.29 | 0.10 | 0.05 | 0.01 | 1.15 | 0.25 | 0.70 | 0.09 | 0.39 | 0.69 | 1.77 | 0.17 |
| 616-02-94 | B horizon | 50-75 | 345 | 546 | 37195 | 71 | 50 | nd | 4256 | 3.19 | 11.20 | 35.70 | 77.34 | 0.293 | 33.28 | 3.53 | 30.48 | 17.33 | nd | nd | nd | 11.36 | 8.48 | 10.37 | 6.87 | 13.20 | 13.56 | 63.30 | 5.47 |
| 616-02-94 | B horizon | 150-175 | 225 | 582 | 14223 | 37 | 13 | nd | 1782 | nd | 2.08 | 27.67 | 22.30 | 0.193 | 14.90 | 3.06 | 16.65 | 7.26 | nd | nd | 0.02 | 6.49 | 1.12 | 4.86 | 2.21 | 8.11 | 6.92 | 19.27 | 2.39 |
| 616-02-94 | E horizon | 400-425 | 127 | 409 | 3250 | 38 | 7 | nd | 194 | nd | 1.40 | 12.74 | 8.19 | 0.282 | 26.12 | 4.96 | 17.17 | 5.32 | 1.35 | nd | 0.05 | 9.54 | 0.41 | 8.37 | 1.90 | 1.94 | 9.70 | 11.72 | 3.68 |
| 616-02-99 | E horizon | 25-50 | 260 | 61 | 530 | 8 | 35 | nd | 49 | 0.21 | 0.34 | 1.74 | 1.84 | 0.005 | 1.00 | 0.18 | 1.83 | 0.56 | 0.05 | nd | nd | 0.51 | 0.27 | 0.37 | 0.04 | 1.60 | 0.24 | 1.02 | 0.14 |
| 616-02-99 | B horizon | 250-275 | 325 | 32 | 481 | 8 | 6 | nd | 165 | 0.20 | 0.51 | 0.97 | 4.61 | 0.005 | 1.17 | 0.19 | 2.02 | 0.49 | 0.04 | nd | nd | 0.69 | 3.70 | 0.42 | 0.16 | 1.31 | 0.72 | 1.85 | 0.14 |
| 616-02-99 | E horizon | 350-375 | 382 | 103 | 3417 | 23 | 7 | nd | 2424 | 3.99 | 1.12 | 1.73 | 3.73 | 0.021 | 3.06 | 0.88 | 2.91 | 1.29 | 0.01 | nd | 0.00 | 1.51 | 6.43 | 1.19 | 0.33 | 1.70 | 1.02 | 3.18 | 0.49 |
| 616-02-100 | E horizon | 25-50 | 10380 | 407 | 7677 | 26 | 55 | 26.98 | 133 | 0.37 | 6.90 | 99.20 | 11.11 | 0.023 | 7.16 | 0.75 | 8.90 | 4.07 | nd | nd | nd | 3.79 | 0.40 | 2.35 | 0.42 | 42.18 | 1.84 | 22.18 | 1.08 |
| 616-02-100 | Peat soil | 80-100 | 2968 | 1212 | 2699 | 16 | 66 | nd | 1102 | 1.68 | 1.39 | 5.50 | 27.76 | 0.194 | 28.47 | 0.56 | 9.69 | 1.49 | 1.67 | nd | 0.02 | 14.15 | 1.93 | 8.97 | 2.27 | 19.90 | 2.59 | 14.62 | 6.82 |
| 616-02-100 | B horizon | 175-200 | 167 | 135 | 3674 | 39 | 67 | nd | 1610 | 1.33 | 0.37 | 5.98 | 8.81 | 0.032 | 19.62 | 0.60 | 10.12 | 2.73 | 0.90 | nd | 0.02 | 10.20 | 5.87 | 7.34 | 0.77 | 1.87 | 6.20 | 10.39 | 3.38 |
| 616-02-100 | E horizon | 425-450 | 19 | 16 | 92 | 1 | 4 | nd | 36 | 0.07 | 0.05 | 0.51 | 1.89 | 0.005 | 1.22 | 0.12 | 1.97 | 0.37 | 0.10 | nd | 0.01 | 0.87 | 0.09 | 0.49 | 0.06 | 0.41 | 0.51 | 0.14 | 1.17 |
| 616-02-101 | A hotizon | 50-75 | 1662 | 205 | 2906 | 13 | 34 | 2.84 | 61 | 0.94 | 1.82 | 6.09 | 10.63 | 0.033 | 3.93 | 0.47 | 6.40 | 1.65 | 0.03 | nd | 0.01 | 1.73 | 0.17 | 1.16 | 0.36 | 4.26 | 1.23 | 5.96 | 0.55 |
| 616-02-101 | B horizon | 170-190 | 78369 | 3054 | 25928 | 335 | 157 | 2.41 | 14208 | 7.31 | 1.39 | 2.06 | 83.02 | 0.126 | 6.11 | 1.75 | 15.90 | 6.84 | nd | nd | nd | 2.61 | 0.95 | 1.82 | 0.51 | 96.49 | 1.84 | 24.46 | 1.83 |
| 616-02-101 | E horizon | 440-450 | 114 | 31 | 937 | 8 | 4 | nd | 424 | 0.49 | 0.05 | 0.48 | 6.17 | 0.004 | 3.37 | 0.09 | 2.02 | 0.50 | 0.12 | nd | 0.00 | 1.78 | 0.04 | 1.20 | 0.05 | 0.62 | 0.95 | 1.63 | 0.30 |
| 616-02-105 | A2 horizon | 75-100 | 2947 | 229 | 5605 | 11 | 86 | nd | 293 | 16.48 | 2.20 | 3.10 | 17.71 | 0.537 | 6.75 | 5.49 | 20.51 | 3.15 | 0.47 | nd | 0.01 | 2.67 | 0.29 | 2.31 | 0.50 | 9.20 | 1.37 | 33.64 | 7.37 |
| 616-02-105 | Peat soil | 300-325 | 10479 | 1216 | 54503 | 50 | 72 | 0.03 | 57117 | 417.92 | 1.34 | 1.33 | 25.90 | 4.050 | 8.23 | 1.90 | 36.50 | 8.68 | nd | nd | nd | 4.30 | 2.17 | 5.41 | 0.38 | 13.66 | 1.09 | 4.16 | 30.20 |
| 616-02-105 | B horizon | 425-450 | 478 | 51 | 1585 | 4 | 5 | nd | 1053 | 8.01 | 0.19 | 1.02 | 10.64 | 1.024 | 4.62 | 5.28 | 11.91 | 0.51 | 0.71 | nd | 0.01 | 2.57 | 0.07 | 2.41 | 0.24 | 1.66 | 0.90 | 1.17 | 10.85 |
| 616-02-105 | E horizon | 575-600 | 47 | 9 | 207 | 6 | 4 | nd | 11 | 0.27 | 0.05 | 0.85 | 5.10 | 0.060 | 2.54 | 0.17 | 1.71 | 0.02 | 0.14 | nd | 0.01 | 1.38 | 0.01 | 0.90 | 0.04 | 0.30 | 0.65 | 1.08 | 1.54 |
| 616-02-106 | A2 horizon | 25-50 | 391 | 129 | 4377 | 7 | 132 | nd | 693 | 20.39 | 1.12 | 4.46 | 28.26 | 0.010 | 2.40 | 0.09 | 4.72 | 0.77 | nd | nd | 0.00 | 1.26 | 0.19 | 0.88 | 0.17 | 5.59 | 0.72 | 2.52 | 0.49 |
| 616-02-106 | E horizon | 425-450 | 37 | 15 | 968 | 12 | 4 | nd | 488 | 5.08 | 0.04 | 1.32 | 2.90 | nd | 4.30 | 0.41 | 3.61 | 0.36 | 0.13 | nd | 0.01 | 2.55 | 0.02 | 1.57 | 0.09 | 0.39 | 1.41 | 0.57 | 0.38 |
| 616-02-110 | B horizon | 420 | 51235 | 657 | 6985 | 13 | 58 | nd | 5941 | 6.40 | 0.34 | 1.92 | 11.16 | 0.070 | 48.28 | 1.17 | 17.69 | 1.83 | 2.05 | nd | nd | 13.71 | 0.27 | 15.66 | 0.86 | 24.07 | 2.88 | 2.91 | 15.57 |
| 616-02-112 | B horizon | 25-50 | 249900 | 11338 | 203 | 76 | 111 | nd | 1276 | 1.93 | 0.43 | nd | 291.63 | 0.030 | 0.49 | 0.25 | 0.70 | nd | 0.05 | nd | nd | 0.52 | 0.34 | nd | nd | 1548.52 | 0.01 | nd | 0.13 |
| 616-02-112 | B horizon | 125-150 | 241411 | 9636 | 234 | 116 | 91 | nd | 1364 | 1.36 | 0.44 | nd | 447.80 | 0.032 | 0.54 | 0.39 | 0.95 | nd | 0.02 | nd | nd | 0.51 | 0.45 | 0.03 | nd | 1633.83 | 0.04 | nd | 0.14 |
| 616-02-112 | Peat soil | 250-275 | 7622 | 4950 | 4198 | 58 | 67 | nd | 12948 | 34.89 | 1.45 | nd | 20.38 | 0.011 | 0.41 | 0.29 | 1.21 | nd | nd | nd | 0.03 | 0.28 | 1.58 | 0.05 | 0.05 | 56.69 | 0.10 | 0.41 | 0.17 |
| 616-02-112 | B horizon | 350-375 | 29271 | 1104 | 9625 | 353 | 102 | nd | 4812 | 5.71 | 1.32 | 3.21 | 48.71 | 0.185 | 14.17 | 1.28 | 29.63 | 7.91 | 0.51 | nd | 0.00 | 7.08 | 0.64 | 4.88 | 1.11 | 292.06 | 2.50 | 13.63 | 4.66 |
| 616-02-112 | C horizon | 575-600 | 141627 | 1462 | 1452 | 19 | 72 | nd | 469 | 3.49 | 0.62 | 0.62 | 32.89 | 0.078 | 10.77 | 0.68 | 29.13 | 0.73 | 1.69 | nd | 0.05 | 9.96 | 0.28 | 6.87 | 0.59 | 490.46 | 1.63 | 4.36 | 11.07 |
| 616-02-113 | A horizon | 0-50 | 1256 | 176 | 970 | 8 | 50 | 21.96 | 214 | 0.47 | 1.38 | 13.32 | 12.28 | 0.034 | 2.60 | 0.22 | 3.66 | 0.52 | 0.09 | nd | 0.01 | 1.10 | 0.11 | 0.70 | 0.11 | 4.72 | 0.38 | 2.32 | 0.60 |
| 616-02-113 | E horizon | 250-275 | 72 | 39 | 1175 | 24 | 3 | nd | 523 | 0.92 | 0.08 | 0.77 | 5.03 | nd | 2.96 | nd | 3.86 | 0.10 | 0.05 | nd | nd | 1.73 | 0.09 | 1.09 | 0.11 | 0.67 | 0.82 | 1.75 | 0.27 |

**Appendix Table 3** (Cont.) Element analyses by ICP-OES of aqua regia method (in mg $kg^{-1}$ unit).

| Site | Horizon | Depth (cm) | Ca | Mg | Fe | Mn | P | Zn | S | As | Cu | Pb | Ba | Be | Ce | Co | Cr | Ga | Gd | Ge | Hf | La | Mo | Nd | Sc | Sr | Th | V | Y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 616-02-122 | E horizon | 50-75 | 111 | 22 | 206 | 7 | 7 | nd | 18 | 0.01 | 0.57 | 0.68 | 4.15 | nd | 1.51 | nd | 0.44 | 0.15 | 0.04 | 0.00 | nd | 0.89 | 0.12 | 0.58 | 0.04 | 0.73 | 0.38 | 0.61 | 0.13 |
| 616-02-122 | B horizon | 275-300 | 354 | 72 | 298 | 8 | 8 | nd | 68 | nd | 0.20 | 1.20 | 3.51 | 0.001 | 1.67 | 0.02 | 6.55 | 0.97 | 0.08 | nd | 0.01 | 1.04 | 0.37 | 0.64 | 0.15 | 2.08 | 0.75 | 0.83 | 0.17 |
| 616-02-122 | B horizon | 800-900 | 37 | 17 | 260 | 5 | 3 | 1.71 | 109 | 0.03 | 0.18 | 1.92 | 4.00 | 0.003 | 1.15 | 0.04 | 7.58 | 1.02 | 0.06 | nd | 0.00 | 0.67 | 0.17 | 0.42 | 0.10 | 0.47 | 0.51 | 2.18 | 0.13 |
| 616-02-122 | E horizon | 325-400 | 38 | 16 | 740 | 27 | 1 | 2.35 | 118 | nd | 0.06 | 2.66 | 3.96 | nd | 2.31 | nd | 3.55 | 0.60 | 0.10 | nd | 0.01 | 1.43 | 0.08 | 0.94 | 0.20 | 0.42 | 1.54 | 2.46 | 0.24 |
| 616-02-127 | coffee rock | 125 | 271 | 94 | 296 | 4 | 25 | nd | 796 | 0.49 | 0.35 | 1.70 | 10.39 | 0.112 | 7.91 | 0.22 | 9.28 | 1.21 | 0.66 | nd | 0.00 | 4.38 | 0.13 | 3.39 | 0.90 | 1.99 | 2.33 | 2.50 | 1.25 |
| 616-02-127 | E horizon | 275 | 15 | 11 | 396 | 15 | 14 | nd | 39 | nd | 0.04 | 0.71 | 3.69 | nd | 0.90 | nd | 2.14 | 0.85 | 0.08 | nd | 0.01 | 0.59 | 0.11 | 0.42 | 0.08 | 0.50 | 0.46 | 1.00 | 0.10 |
| 616-02-131 | E horizon | 50 | 565 | 253 | 5652 | 24 | 59 | 10.78 | 38 | 0.72 | 5.81 | 23.77 | 11.52 | 0.056 | 4.61 | 0.67 | 9.09 | 3.60 | nd | nd | nd | 2.46 | 0.59 | 1.60 | 0.56 | 3.31 | 1.72 | 14.26 | 0.57 |
| 616-02-131 | E horizon | 250 | 35 | 15 | 208 | 5 | 2 | nd | 11 | 0.05 | 0.15 | 0.49 | 2.30 | nd | 1.04 | nd | 1.09 | 0.45 | 0.08 | nd | nd | 0.66 | 0.02 | 0.43 | 0.04 | 0.39 | 0.34 | 0.38 | 0.11 |
| 616-02-131 | B horizon | 375 | 325 | 888 | 36170 | 60 | 13 | nd | 32 | 2.65 | 5.72 | 8.32 | 13.20 | 0.151 | 20.56 | 2.55 | 51.71 | 19.39 | nd | nd | 0.04 | 11.79 | 0.84 | 7.30 | 7.38 | 3.11 | 14.10 | 39.01 | 1.75 |
| 616-02-131 | E horizon | 450 | 72 | 181 | 1349 | 7 | 4 | nd | 22 | 0.13 | 1.32 | 1.85 | 6.23 | 0.027 | 4.57 | 0.36 | 11.76 | 2.22 | 0.19 | nd | 0.02 | 2.81 | 0.09 | 1.56 | 1.08 | 0.74 | 2.67 | 2.75 | 0.45 |
| 616-02-136 | E horizon | 50 | 240 | 67 | 192 | 6 | 7 | 2.87 | 37 | nd | 0.15 | 1.39 | 4.41 | nd | 3.76 | nd | 0.63 | 0.31 | 0.13 | nd | nd | 2.12 | 0.10 | 1.38 | 0.05 | 1.30 | 0.97 | 0.55 | 0.18 |
| 616-02-136 | coffee rock | 250 | 777 | 255 | 668 | 12 | 25 | 1.58 | 364 | 0.49 | 0.71 | 14.75 | 14.98 | 0.096 | 16.53 | 0.32 | 27.70 | 4.09 | 0.74 | 0.00 | 0.03 | 9.81 | 0.27 | 5.54 | 0.53 | 6.45 | 4.81 | 4.15 | 1.05 |
| 616-02-145 | E horizon | 50 | 16 | 6 | 201 | 2 | 1 | 1.05 | 3 | 0.14 | 0.02 | 0.44 | 1.47 | nd | 0.67 | 0.05 | 0.78 | 0.33 | nd | nd | nd | 0.40 | 0.13 | 0.27 | 0.02 | 0.16 | 0.20 | 0.23 | 0.06 |
| 616-02-145 | E horizon | 350 | 19 | 25 | 332 | 3 | 2 | 1.37 | 106 | 0.20 | 0.07 | 2.42 | 3.09 | 0.019 | 3.32 | 0.03 | 1.51 | 0.67 | 0.12 | nd | nd | 2.29 | 0.09 | 1.21 | 0.08 | 0.33 | 0.91 | 0.70 | 0.38 |
| 616-02-145 | B horizon | 450 | 249 | 435 | 51808 | 36 | 126 | nd | 185 | 17.78 | 0.38 | 46.18 | 32.13 | 2.813 | 16.46 | 7.37 | 63.13 | 23.20 | nd | nd | nd | 7.64 | 3.01 | 6.24 | 6.09 | 2.63 | 17.36 | 456.05 | 4.80 |
| 616-02-145 | B horizon | 550 | 82 | 192 | 1623 | 4 | 13 | 1.05 | 308 | 2.76 | 0.19 | 7.85 | 14.25 | 0.259 | 7.78 | 2.25 | 16.62 | 4.36 | 0.28 | nd | 0.06 | 5.76 | 0.27 | 2.24 | 1.08 | 4.33 | 4.55 | 9.13 | 1.04 |
| 616-02-155 | E horizon | 50 | 17689 | 716 | 490 | 11 | 6 | 1.09 | 102 | 0.12 | 0.05 | 0.53 | 5.59 | 0.003 | 2.05 | 0.13 | 2.37 | 0.40 | 0.17 | nd | 0.01 | 1.26 | 0.07 | 0.87 | 0.13 | 70.49 | 0.59 | 0.97 | 0.69 |
| 616-02-155 | E horizon | 325 | 297 | 251 | 1727 | 16 | 4 | 2.94 | 579 | 1.39 | 0.16 | 4.37 | 6.07 | 0.066 | 4.83 | 0.63 | 9.64 | 1.81 | 0.15 | nd | 0.02 | 2.52 | 1.10 | 1.66 | 0.81 | 1.76 | 2.99 | 7.88 | 0.56 |
| 616-02-155 | B horizon | 550 | 1984 | 2408 | 18457 | 48 | 11 | 2.20 | 17 | 5.90 | 1.85 | 8.36 | 16.23 | 0.180 | 18.20 | 10.77 | 43.33 | 10.77 | nd | nd | 0.03 | 11.84 | 1.25 | 6.13 | 9.04 | 9.75 | 19.77 | 42.23 | 3.63 |
| 616-02-158 | E horizon | 75 | 13 | 4 | 73 | 2 | 1 | 1.72 | 3 | 0.08 | 0.02 | 0.30 | 0.70 | nd | 0.27 | 0.01 | 0.22 | 0.11 | 0.04 | nd | 0.01 | 0.18 | 0.10 | 0.11 | 0.01 | 0.11 | 0.07 | 0.14 | 0.04 |
| 616-02-158 | coffee rock | 250 | 75 | 73 | 2272 | 12 | 172 | 1.16 | 635 | 2.32 | 0.33 | 6.07 | 5.92 | 0.092 | 4.21 | 0.22 | 8.43 | 4.24 | 0.23 | 0.00 | 0.02 | 2.35 | 1.64 | 1.69 | 0.40 | 1.39 | 1.43 | 14.97 | 0.67 |
| 616-02-158 | coffee rock | 400 | 125 | 208 | 1042 | 24 | 41 | 2.84 | 738 | 0.14 | 0.24 | 7.88 | 11.73 | 0.001 | 2.86 | 0.30 | 7.76 | 2.80 | 0.13 | 0.01 | 0.02 | 1.82 | 1.50 | 1.09 | 0.24 | 2.50 | 1.24 | 3.36 | 0.29 |
| 616-02-174 | B horizon | 400 | 380 | 68 | 1304 | 13 | 42 | 3.21 | 191 | 0.31 | 1.55 | 0.93 | 2.27 | 0.007 | 1.11 | 1.23 | 11.41 | 1.53 | 0.02 | nd | 0.00 | 0.71 | 1.08 | 0.44 | 0.09 | 1.75 | 0.49 | 0.95 | 0.20 |
| 616-02-179 | B horizon | 375-400 | 37 | 23 | 315 | 3 | 4 | 1.70 | 121 | 0.26 | 0.09 | 0.44 | 3.13 | 0.008 | 1.18 | 0.05 | 3.31 | 0.99 | 0.06 | 0.01 | 0.01 | 0.75 | 0.11 | 0.50 | 0.09 | 0.57 | 0.38 | 1.54 | 0.17 |
| Ellenbrook | E horizon | 0-150 | 16 | 5 | 80 | 2 | 1 | 1.45 | 5 | nd | 0.02 | 0.32 | 1.34 | nd | 0.42 | nd | 0.30 | 0.24 | 0.02 | 0.00 | nd | 0.24 | 0.04 | 0.16 | 0.02 | 0.12 | 0.19 | 0.08 | 0.12 |
| Ellenbrook | coffee rock | 150-200 | 295 | 57 | 1222 | 2 | 42 | 0.54 | 447 | 1.68 | nd | 5.84 | 11.26 | 0.111 | 7.60 | 0.50 | 16.54 | 4.81 | 0.67 | 0.01 | 0.09 | 4.09 | 0.18 | 3.18 | 1.37 | 1.43 | 3.66 | 7.99 | 1.88 |
| Ellenbrook | B horizon | 500-550 | 117 | 32 | 1498 | 2 | 3 | 1.49 | 1164 | 0.15 | 0.07 | 1.79 | 5.40 | 0.009 | 1.46 | 0.34 | 1.21 | 0.35 | nd | nd | nd | 0.95 | 0.05 | 0.53 | 0.09 | 0.86 | 0.36 | 0.57 | 0.27 |
| LOC50A | A horizon | 10-20 | 22 | 26 | 1802 | 6 | 11 | 1.54 | 16 | 0.08 | 0.17 | 0.89 | 2.08 | 0.015 | 1.72 | 0.14 | 2.63 | 1.30 | 0.09 | 0.04 | 0.03 | 0.89 | 0.22 | 0.58 | 0.09 | 0.65 | 0.56 | 3.39 | 1.62 |
| LOC50A | A horizon | 0-100 | 31 | 21 | 919 | 5 | 7 | 0.18 | 9 | 0.01 | 0.13 | 0.46 | 1.98 | 0.006 | 1.43 | 0.09 | 1.45 | 0.83 | 0.07 | 0.03 | 0.00 | 0.89 | 0.21 | 0.52 | 0.08 | 0.64 | 0.42 | 2.38 | 2.35 |
| LOC50A | E horizon | 300-400 | 15 | 24 | 598 | 15 | 9 | 0.53 | 56 | nd | 0.18 | 1.59 | 2.23 | 0.011 | 2.77 | 0.20 | 7.65 | 3.78 | 0.14 | 0.06 | nd | 1.73 | 0.07 | 0.99 | 0.13 | 0.71 | 0.95 | 2.45 | 1.21 |
| LOC50A | coffee rock | 400-500 | 12 | 19 | 336 | 11 | 5 | nd | 217 | nd | 1.20 | 1.14 | 1.25 | 0.007 | 1.87 | 0.08 | 7.31 | 1.67 | 0.08 | 0.06 | 0.02 | 1.24 | 0.12 | 0.69 | 0.10 | 0.43 | 0.81 | 3.91 | 0.88 |

**Appendix Table 4** Element analyses by ICP-OES of fusion acid digestion method (in mg $kg^{-1}$ unit).

| Site | Horizon | Depth (cm) | Si | Al | Na | K | Ti | Zr | Ni |
|---|---|---|---|---|---|---|---|---|---|
| 616-01-003 | A horizon | 0-25 | 574151 | 1393 | nd | 1199 | 1162 | 126 | 9 |
| 616-01-003 | coffee rock | 175-200 | 525701 | 16618 | nd | 1039 | 706 | 72 | 6 |
| 616-01-003 | C2 horizon | 300-400 | 580656 | 3590 | nd | 1666 | 831 | 95 | 18 |
| 616-01-005 | A horizon | 0-20 | 589662 | 949 | 290 | 271 | 392 | 39 | 9 |
| 616-01-005 | E horizon | 20-180 | 620853 | 743 | 270 | 244 | 437 | 86 | 8 |
| 616-01-005 | coffee rock | 180-200 | 567058 | 9667 | 310 | 474 | 1178 | 92 | 7 |
| 616-01-005 | B horizon | 200-250 | 609737 | 2879 | 311 | 385 | 589 | 69 | 8 |
| 616-01-005 | 2E1 horizon | 250-260 | 586392 | 2757 | 272 | 235 | 615 | 63 | 11 |
| 616-01-005 | 2E2 horizon | 260-400 | 581294 | 1604 | 180 | 157 | 487 | 67 | 7 |
| 616-01-005 | B horizon | 620-630 | 562310 | 1554 | 233 | 269 | 482 | 78 | 41 |
| 616-01-005 | 2coffee rock1 | 830-900 | 612839 | 1702 | 234 | 188 | 616 | 34 | 10 |
| 616-02-009 | E1 horizon | 225-250 | 574749 | 5257 | 875 | 3685 | 915 | 69 | 39 |
| 616-01-011 | A horizon | 0-75 | 598427 | 717 | 334 | 294 | 656 | 64 | 7 |
| 616-01-011 | E1 horizon | 75-500 | 614726 | 171 | 222 | 118 | 949 | 104 | 7 |
| 616-01-014 | A horizon | 0-50 | 604248 | 474 | 312 | 223 | 285 | 34 | 10 |
| 616-01-014 | E1 horizon | 50-300 | 612585 | 290 | 216 | 181 | 343 | 58 | 8 |
| 616-01-014 | coffee rock | 650-800 | 593181 | 5195 | nd | 314 | 716 | 62 | 5 |
| 616-01-014 | C3 horizon | 1000-1200 | 581823 | 3542 | nd | 926 | 871 | 71 | 4 |
| 616-01-014 | C4 horizon | 1200-1300 | 589859 | 11603 | 300 | 2927 | 1730 | 154 | 13 |
| 616-01-018 | A horizon | 0-25 | 587482 | 614 | nd | 342 | 179 | 15 | 6 |
| 616-01-018 | E3 horizon | 300-400 | 529774 | 298 | nd | 28 | 212 | 17 | 6 |
| 616-01-018 | coffee rock | 400-450 | 580955 | 6636 | 161 | 383 | 648 | 50 | 7 |
| 616-01-018 | 2E horizon | 450-600 | 604485 | 1176 | 252 | 200 | 525 | 52 | 8 |
| 616-01-018 | 2coffee rock1 | 600-700 | 590684 | 1201 | nd | 203 | 248 | 24 | 5 |
| 616-01-019 | A horizon | 0-50 | 552451 | 276 | nd | 181 | 561 | 58 | 8 |
| 616-01-019 | E1 horizon | 50-200 | 622488 | 191 | nd | 106 | 833 | 60 | 11 |
| 616-01-019 | B horizon | 250-300 | 514023 | 24396 | nd | 2227 | 2019 | 137 | 13 |
| 616-01-023 | A horizon | 0-25 | 625790 | 580 | nd | 378 | 640 | 65 | 10 |
| 616-01-023 | E horizon | 25-100 | 585393 | 600 | nd | 419 | 802 | 107 | 6 |
| 616-01-023 | B horizon | 100-200 | 607163 | 7367 | nd | 1081 | 1177 | 207 | 11 |
| 616-01-023 | C3 horizon | 500-1000 | 564159 | 5193 | nd | 2457 | 772 | 51 | 9 |
| 616-01-024 | A horizon | 0-25 | 609782 | 325 | nd | nd | 403 | 42 | 8 |
| 616-01-024 | E horizon | 25-150 | 596073 | 243 | nd | 32 | 769 | 139 | 10 |
| 616-01-024 | B horizon | 150-200 | 553318 | 2276 | nd | 360 | 599 | 45 | 16 |
| 616-01-024 | 2B horizon | 400-500 | 587107 | 9803 | nd | 1333 | 914 | 83 | 11 |
| 616-01-024 | 3E horizon | 500-800 | 609088 | 3084 | nd | 1041 | 558 | 33 | 9 |
| 616-02-028 | B horizon | 30-100 | 586730 | 15698 | 7731 | 10697 | 1757 | 161 | 26 |
| 616-02-028 | Mud1 | 100-200 | 410234 | 55930 | 12943 | 10806 | 6439 | 432 | 29 |
| 616-02-031 | A horizon | 0-75 | 549139 | 444 | 113 | 134 | 1500 | 142 | 5 |
| 616-02-031 | E horizon | 75-200 | 595116 | 325 | 210 | 110 | 2481 | 439 | 5 |
| 616-02-031 | coffee rock1 | 200-300 | 522554 | 24079 | 1120 | 797 | 4709 | 539 | 13 |
| 616-02-031 | 2E horizon | 300-400 | 594130 | 1555 | 131 | 1165 | 1409 | 118 | 6 |
| 616-02-031 | 2coffee rock1 | 400-500 | 567072 | 21767 | 635 | 4364 | 1684 | 84 | 12 |
| 616-02-032 | A horizon | 0-50 | 585966 | 957 | 255 | 308 | 2238 | 267 | 10 |
| 616-02-032 | E horizon | 50-200 | 607288 | 271 | nd | 61 | 2008 | 203 | 15 |
| 616-02-032 | coffee rock1 | 160 | 560815 | 2946 | nd | 425 | 8773 | 473 | 6 |
| 616-02-032 | 2E2 horizon | 350-400 | 580096 | 4443 | 108 | 3882 | 5129 | 571 | 6 |
| 616-02-058 | B horizon | 300-500 | 559439 | 1480 | nd | 304 | 1777 | 120 | 9 |
| 616-02-065 | Peat1 | 0-20 | 492354 | 33645 | 1332 | 1394 | 1791 | 98 | 45 |
| 616-02-065 | coffee rock1 | 480-560 | 533329 | 10181 | 389 | 932 | 2563 | 370 | 45 |
| 616-02-065 | coffee rock3 | 650-700 | 572934 | 2471 | 137 | 866 | 889 | 109 | 40 |
| 616-02-065 | B horizon | 200 | 557836 | 6677 | 537 | 3973 | 1499 | 279 | 49 |
| 616-02-068 | B horizon | 450 | 561620 | 3836 | 258 | 758 | 461 | 91 | 47 |
| 616-02-068 | A horizon | 0-75 | 592681 | 743 | nd | 486 | 588 | 84 | 6 |
| 616-02-068 | E1 horizon | 75-300 | 604555 | 593 | nd | 498 | 803 | 77 | 12 |
| 616-02-068 | A horizon | 0-25 | 587653 | 476 | 39 | 281 | 245 | 30 | 79 |
| 616-02-068 | E horizon | 25-200 | 592108 | 497 | 230 | 504 | 794 | 122 | 44 |
| 616-02-068 | coffee rock | 200-300 | 567239 | 8489 | 393 | 2985 | 1594 | 311 | 42 |
| 616-02-068 | B1 horizon | 300-400 | 583146 | 6149 | 378 | 3598 | 1524 | 142 | 36 |
| 616-02-068 | B3 horizon | 500-600 | 564463 | 6365 | 394 | 4904 | 2471 | 467 | 42 |
| 616-02-071 | E horizon | 25-350 | 610669 | 162 | nd | 69 | 532 | 79 | 7 |
| 616-02-071 | B horizon | 350-600 | 573637 | 3610 | nd | 2558 | 1497 | 140 | 7 |
| 616-02-078 | B horizon | 400-500 | 568948 | 3204 | 280 | 2818 | 1372 | 218 | 41 |
| 616-02-080 | coffee rock | 200-400 | 555971 | 15617 | 70 | 1812 | 2172 | 141 | 13 |

**Appendix Table 4** (Cont.) Element analyses by ICP-OES of fusion acid digestion method (in mg $kg^{-1}$ unit)..

| Site | Horizon | Depth (cm) | Si | Al | Na | K | Ti | Zr | Ni |
|---|---|---|---|---|---|---|---|---|---|
| 616-02-081 | B horizon | 400-800 | 454142 | 21062 | 2949 | 20288 | 754 | 108 | 29 |
| 616-02-082 | A horizon | 0-75 | 588106 | 4205 | 118 | 4622 | 1950 | 197 | 8 |
| 616-02-082 | E1 horizon | 75-200 | 581750 | 5371 | 72 | 5127 | 1898 | 250 | 8 |
| 616-02-082 | B horizon | 300-400 | 585625 | 9206 | 202 | 8049 | 2774 | 219 | 3 |
| 616-02-082 | coffee rock | 500-600 | 575373 | 12918 | 283 | 8566 | 2434 | 329 | 8 |
| 616-02-085 | A horizon | 0-70 | 372001 | 80116 | 9982 | 8753 | 6362 | 279 | nd |
| 616-02-085 | B1 horizon | 100-300 | 559100 | 32431 | 11413 | 15326 | 2961 | 188 | 39 |
| 616-02-085 | B2 horizon | 300-400 | 598857 | 16502 | 9357 | 11731 | 715 | 60 | 49 |
| 616-02-085 | Mud | 400-600 | 391766 | 64337 | 13070 | 15305 | 7694 | 412 | 12 |
| 616-02-087 | coffee rock2 | 300-400 | 488632 | 33192 | 130 | 5466 | 2368 | 131 | 9 |
| 616-02-087 | B horizon | 500-600 | 598393 | 4453 | nd | 3602 | 3964 | 389 | 7 |
| 616-02-094 | A1 horizon | 0-100 | 429471 | 50787 | 7652 | 13286 | 7929 | 623 | 7 |
| 616-02-094 | A2 horizon | 100-175 | 532807 | 21176 | 4457 | 6632 | 6210 | 800 | 29 |
| 616-02-094 | E horizon | 175-600 | 570227 | 6488 | 1757 | 2033 | 11621 | 4600 | 46 |
| 616-02-099 | E horizon | 25-200 | 586418 | 1432 | 867 | 540 | 424 | 31 | 38 |
| 616-02-099 | B1 horizon | 200-300 | 599191 | 2284 | 707 | 478 | 1147 | 135 | 50 |
| 616-02-099 | B2 horizon | 300-400 | 587888 | 3257 | 907 | 871 | 1580 | 271 | 48 |
| 616-02-100 | A horizon | 0-80 | 564245 | 6042 | 1533 | 1937 | 2013 | 151 | 41 |
| 616-02-100 | Peat | 80-110 | 443875 | 5547 | 1488 | 1678 | 1058 | 177 | 36 |
| 616-02-100 | Peat/ E horizon | 110-200 | 535717 | 10239 | 1031 | 3663 | 5180 | 869 | 38 |
| 616-02-100 | E horizon | 200-600 | 602621 | 1421 | 879 | 978 | 126 | 23 | 59 |
| 616-02-101 | A horizon | 0-75 | 453164 | 5055 | 754 | 1226 | 369 | 44 | 34 |
| 616-02-101 | Peat1 | 150-200 | 158163 | 6363 | 2141 | 3861 | 283 | 36 | nd |
| 616-02-101 | E horizon | 350-600 | 542576 | 9548 | 1398 | 10510 | 524 | 50 | 42 |
| 616-02-105 | A horizon | 0-160 | 526831 | 9789 | 1254 | 2766 | 722 | 72 | 39 |
| 616-02-105 | Peat | 250-360 | 36140 | 2478 | 1002 | 339 | 68 | 8 | nd |
| 616-02-105 | Peat/ E horizon | 360-480 | 563278 | 2656 | 802 | 1896 | 327 | 38 | 46 |
| 616-02-105 | E horizon | 480-700 | 573359 | 3962 | 1155 | 3866 | 706 | 58 | 44 |
| 616-02-106 | A horizon | 0-50 | 574812 | 2547 | 1317 | 1668 | 414 | 132 | 36 |
| 616-02-106 | E horizon | 50-700 | 591803 | 6159 | 1464 | 5312 | 961 | 117 | 41 |
| 616-02-110 | B horizon | 200-500 | 551345 | 2322 | 30 | 268 | 506 | 46 | 51 |
| 616-02-112 | B horizon | 0-80 | 21030 | 433 | 6868 | 322 | 13 | 2 | 2 |
| 616-02-112 | Mud | 125-200 | 56771 | 303 | 8137 | 471 | 5 | 2 | 13 |
| 616-02-112 | Peat | 200-300 | 6914 | 363 | 22932 | 842 | 17 | 2 | nd |
| 616-02-112 | B horizon | 300-400 | 589392 | 14759 | 2430 | 7221 | 1091 | 105 | 42 |
| 616-02-112 | C horizon | 400-600 | 342593 | 8304 | 1666 | 4873 | 1098 | 104 | 26 |
| 616-02-113 | A horizon | 0-50 | 559730 | 5065 | 846 | 4019 | 778 | 116 | 39 |
| 616-02-113 | E1 horizon | 50-250 | 578347 | 5874 | 869 | 5719 | 1363 | 110 | 50 |
| 616-02-122 | E horizon | 20-235 | 580536 | 549 | 97 | 336 | 562 | 82 | 47 |
| 616-02-122 | B horizon | 235-315 | 555068 | 4768 | 169 | 1221 | 1100 | 121 | 40 |
| 616-02-122 | 2E2 horizon | 375-500 | 580031 | 4319 | 330 | 3610 | 5239 | 690 | 35 |
| 616-02-122 | B/E horizon | 700-900 | 572739 | 2794 | 54 | 445 | 510 | 42 | 42 |
| 616-02-127 | coffee rock | 100-235 | 537675 | 7535 | 595 | 569 | 627 | 80 | 43 |
| 616-02-127 | 2E1 horizon | 235-300 | 572083 | 1630 | 192 | 492 | 1485 | 451 | 42 |
| 616-02-131 | A horizon | 0-50 | 557731 | 7600 | 496 | 1928 | 1187 | 79 | 42 |
| 616-02-131 | E horizon | 50-325 | 576149 | 2942 | 531 | 2206 | 930 | 184 | 44 |
| 616-02-131 | B horizon | 325-425 | 396098 | 74968 | 3559 | 10200 | 6192 | 582 | nd |
| 616-02-131 | 2E horizon | 425-600 | 512696 | 19930 | 2408 | 9428 | 612 | 91 | 34 |
| 616-02-136 | A horizon | 0-25 | 578463 | 515 | 118 | 381 | 2485 | 358 | 45 |
| 616-02-136 | coffee rock | 200-260 | 541960 | 11209 | 417 | 1739 | 5149 | 768 | 46 |
| 616-02-145 | E1 horizon | 50-300 | 578018 | 668 | 114 | 341 | 975 | 143 | 52 |
| 616-02-145 | E2 horizon | 300-450 | 597136 | 1736 | 144 | 611 | 1288 | 207 | 41 |
| 616-02-145 | B horizon | 450-475 | 428666 | 54443 | 695 | 2164 | 2507 | 204 | nd |
| 616-02-145 | 2E horizon | 475-600 | 547193 | 25455 | 406 | 4717 | 1060 | 95 | 46 |
| 616-02-155 | E horizon | 50-150 | 580116 | 2608 | 367 | 2555 | 676 | 39 | 41 |
| 616-02-155 | 2E horizon | 200-500 | 560552 | 12952 | 877 | 8236 | 1887 | 93 | 44 |
| 616-02-155 | B horizon | 500-600 | 427061 | 60220 | 2313 | 14845 | 8681 | 855 | 22 |
| 616-02-158 | E horizon | 25-225 | 606162 | 306 | 314 | 204 | 1349 | 37 | 44 |
| 616-02-158 | coffee rock1 | 225-300 | 518566 | 13644 | 398 | 1814 | 2897 | 317 | 39 |
| 616-02-158 | coffee rock2 | 300-400 | 521450 | 12752 | 407 | 4163 | 6140 | 513 | 33 |
| 616-02-174 | B horizon | 250-550 | 540075 | 18346 | 529 | 1180 | 1685 | 129 | 47 |
| 616-02-179 | B horizon | 375-400 | 575878 | 381 | 184 | 99 | 2365 | 399 | 51 |
| Ellenbrook | E horizon | 0-150 | 589071 | 201 | 70 | 69 | 1445 | 316 | 40 |
| Ellenbrook | coffee rock | 150-200 | 532665 | 22078 | 119 | 532 | 1182 | 354 | 38 |
| Ellenbrook | 2B1 horizon | 500-550 | 572214 | 1720 | 136 | 1456 | 407 | 41 | 38 |

**Appendix Table 5** Aluminium, Fe, Si and Mn extracted by dithionite citrate bicarbonate (d); oxalic acid (ox) and Na-pyrophosphate (p) for whole wet soil samples* (in mg $kg^{-1}$ unit).

| Site | Horizon | Depth (cm) | $Al_d$ | $Al_{ox}$ | $Al_p$ | $Fe_d$ | $Fe_{ox}$ | $Fe_p$ | $Si_d$ | $Si_{ox}$ | $Si_p$ | $Mn_d$ | $Mn_{ox}$ | $Mn_p$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 616-01-003 | A horizon | 0-25 | 40 | 36 | 60 | 237 | 188 | 51 | 61 | 6 | 97 | nd | 1.5 | 1.1 |
| 616-01-003 | Coffee rock | 175-200 | 7285 | 10094 | 4895 | 7874 | 5196 | 3643 | 1400 | 3224 | 486 | nd | 0.16 | nd |
| 616-01-003 | C1 horizon | 200-300 | 267 | 482 | 1059 | 63 | 50 | 55 | 55 | 88 | 495 | nd | 0.40 | nd |
| 616-01-003 | C2 horizon | 300-400 | 86 | 196 | 476 | 79 | 43 | 39 | 38 | 62 | 325 | nd | 0.16 | nd |
| 616-01-003 | C3 horizon | 400-600 | 8 | 43 | 345 | 25 | 11 | 20 | 12 | 19 | 288 | nd | 0.02 | nd |
| 616-01-005 | B horizon | 620-630 | 168 | 147 | 214 | 82 | 62 | 44 | 22 | 18 | 44 | 2.6 | 0.68 | 0.46 |
| 616-01-005 | A horizon | 0-20 | 154 | 166 | 237 | 307 | 251 | 72 | 32 | 11 | 111 | 2.6 | 2.3 | 2.5 |
| 616-01-005 | E horizon | 20-180 | 53 | 30 | 190 | 35 | 14 | 20 | 24 | 3 | 154 | nd | 0.10 | 0.03 |
| 616-01-005 | Coffee rock | 180-200 | 3650 | 3189 | 6796 | 239 | 142 | 349 | 319 | 294 | 2261 | nd | 0.03 | 0.13 |
| 616-01-005 | B horizon | 200-250 | 721 | 505 | 1732 | 184 | 143 | 96 | 52 | 19 | 598 | nd | 1.3 | 0.56 |
| 616-01-005 | 2E1 horizon | 250-260 | 980 | 862 | 1968 | 41 | 42 | 63 | 65 | 5 | 432 | nd | 0.33 | 0.09 |
| 616-01-005 | 2E2 horizon | 260-400 | 889 | 855 | 1434 | 31 | 36 | 44 | 72 | 6 | 323 | nd | 0.27 | nd |
| 616-01-005 | 2E3 horizon | 400-500 | 14 | 8 | 17 | 71 | 39 | 33 | 23 | 2 | 36 | nd | 0.34 | 0.25 |
| 616-01-005 | 2E4 horizon | 500-830 | 92 | 90 | 311 | 230 | 196 | 153 | 47 | 6 | 227 | nd | 1.9 | 1.55 |
| 616-01-005 | 2Coffee rock1 | 830-900 | 1161 | 1056 | 864 | 50 | 9 | 27 | 184 | 129 | 89 | nd | nd | 0.01 |
| 616-01-005 | 2Coffee rock2 | 900-1000 | 1235 | 1828 | 1163 | 58 | 9 | 17 | 198 | 551 | 99 | nd | 0.06 | 0.04 |
| 616-02-009 | E1 horizon | 225-250 | 78 | 51 | 92 | 40 | 30 | 72 | 58 | 10 | 93 | 0.78 | 0.30 | nd |
| 616-01-011 | A horizon | 0-75 | 99 | 68 | 105 | 193 | 93 | 89 | 52 | 4 | 140 | 2.25 | 1.7 | 3.4 |
| 616-01-011 | E1 horizon | 75-500 | nd | 2 | 2 | 96 | 49 | 32 | 27 | 3 | 102 | nd | 0.43 | 0.34 |
| 616-01-011 | E2 horizon | 500-600 | nd | 4 | 2 | 114 | 130 | 47 | 30 | 7 | 127 | nd | 1.2 | 0.47 |
| 616-01-011 | E3 horizon | 600-700 | 16 | 29 | 174 | 80 | 52 | 66 | 12 | 3 | 217 | nd | 0.07 | nd |
| 616-01-014 | A horizon | 0-50 | 33 | 31 | 44 | 228 | 110 | 66 | 29 | 7 | 70 | nd | 0.77 | 0.46 |
| 616-01-014 | E1 horizon | 50-300 | 15 | 11 | 25 | 94 | 45 | 37 | 17 | 4 | 72 | nd | 0.29 | nd |
| 616-01-014 | E2 horizon | 300-650 | 245 | 303 | 711 | 874 | 84 | 296 | 43 | 90 | 285 | nd | 0.14 | nd |
| 616-01-014 | Coffee rock | 650-800 | 317 | 441 | 883 | 1104 | 97 | 411 | 59 | 132 | 321 | nd | 0.09 | nd |
| 616-01-014 | C1 horizon | 800-900 | 247 | 441 | 900 | 870 | 104 | 393 | 44 | 131 | 329 | nd | 0.10 | nd |
| 616-01-014 | C2 horizon | 900-1000 | 445 | 965 | 858 | 1121 | 221 | 421 | 54 | 296 | 250 | nd | 0.21 | nd |
| 616-01-014 | C3 horizon | 1000-1200 | 23 | 87 | 479 | 196 | 50 | 66 | 30 | 41 | 440 | nd | 0.19 | nd |
| 616-01-014 | C4 horizon | 1200-1300 | 36 | 162 | 1670 | 59 | 40 | 35 | 23 | 44 | 1787 | nd | 0.17 | nd |
| 616-01-018 | A horizon | 0-25 | 24 | 47 | 35 | 136 | 77 | 30 | 23 | 13 | 87 | nd | 1.2 | 0.36 |
| 616-01-018 | E1 horizon | 25-200 | 590 | 345 | 444 | 117 | 47 | 32 | 95 | 2 | 109 | nd | 0.33 | 0.04 |
| 616-01-018 | E2 horizon | 200-300 | 455 | 428 | 407 | 71 | 18 | 12 | 53 | 3 | 71 | nd | 0.15 | nd |
| 616-01-018 | E3 horizon | 300-400 | 157 | 138 | 206 | 40 | 8 | 9 | 41 | 2 | 57 | nd | 0.07 | nd |
| 616-01-018 | Coffee rock | 400-450 | 3768 | 3948 | 2830 | 128 | 32 | 72 | 716 | 639 | 138 | nd | 0.03 | nd |
| 616-01-018 | 2E horizon | 450-600 | 497 | 324 | 645 | 80 | 20 | 43 | 135 | 49 | 293 | nd | 0.07 | nd |
| 616-01-018 | 2Coffee rock1 | 600-700 | 639 | 949 | 591 | 596 | 658 | 336 | 189 | 240 | 129 | 2.43 | 5.4 | 3.7 |
| 616-01-018 | 2Coffee rock2 | 700-800 | 1008 | 5525 | 1387 | 148 | 128 | 83 | 161 | 2298 | 102 | nd | 0.46 | 0.14 |
| 616-01-019 | A horizon | 0-50 | 12 | 15 | 19 | 22 | 14 | 6 | 19 | 4 | 114 | nd | 0.05 | nd |
| 616-01-019 | E1 horizon | 50-200 | 3 | 5 | 7 | 9 | 3 | 1 | 8 | 19 | 51 | nd | 0.03 | nd |
| 616-01-019 | E2 horizon | 200-250 | 13 | 17 | 258 | 1407 | 1326 | 237 | 45 | 38 | 166 | 4.38 | 5.6 | 0.22 |
| 616-01-019 | B horizon | 250-300 | 2853 | 13406 | 17 | 102 | 118 | 213 | 138 | 5476 | 156 | nd | 0.25 | 2.4 |
| 616-01-023 | A horizon | 0-25 | 10 | 16 | 34 | 58 | 47 | 5 | 16 | 20 | 41 | nd | 0.06 | nd |
| 616-01-023 | E horizon | 25-100 | 6 | 13 | 23 | 30 | 17 | 30 | 4 | 28 | 143 | nd | 0.02 | nd |
| 616-01-023 | B horizon | 100-200 | 127 | 624 | 16 | 20 | 17 | 11 | 12 | 150 | 66 | nd | 0.02 | nd |
| 616-01-023 | C1 horizon | 200-300 | 177 | 670 | 3164 | 50 | 38 | 130 | 25 | 251 | 2688 | nd | 0.08 | nd |
| 616-01-023 | C2 horizon | 300-500 | 23 | 69 | 1496 | 17 | 15 | 63 | 14 | 28 | 1214 | nd | 0.01 | nd |
| 616-01-023 | C3 horizon | 500-1000 | 22 | 80 | 187 | 50 | 31 | 16 | 12 | 43 | 186 | nd | 0.04 | nd |

* drying soils before analysis may affect the relative amounts extracted by the 3 extractions

**Appendix Table 5** (Cont.) Aluminium, Fe, Si and Mn extracted by dithionite citrate bicarbonate (d); oxalic acid (ox) and Na-pyrophosphate (p) for whole wet soil samples* (in mg $kg^{-1}$ unit).

| Site | Horizon | Depth (cm) | $Al_d$ | $Al_{ox}$ | $Al_p$ | $Fe_d$ | $Fe_{ox}$ | $Fe_p$ | $Si_d$ | $Si_{ox}$ | $Si_p$ | $Mn_d$ | $Mn_{ox}$ | $Mn_p$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 616-01-024 | A horizon | 0-25 | 35 | 33 | 2799 | 71 | 36 | 59 | 11 | 8 | 164 | nd | 0.08 | 0.07 |
| 616-01-024 | E horizon | 25-150 | 4 | 5 | 44 | 14 | 4 | 31 | 5 | 26 | 108 | nd | 0.03 | nd |
| 616-01-024 | B horizon | 150-200 | 288 | 445 | 5 | 48 | 39 | 4 | 15 | 166 | 68 | nd | 0.19 | nd |
| 616-01-024 | 2E horizon | 200-400 | 22 | 45 | 1151 | 20 | 8 | 65 | 8 | 37 | 759 | nd | 0.04 | nd |
| 616-01-024 | 2B horizon | 400-500 | 1219 | 4985 | 783 | 102 | 93 | 61 | 81 | 2164 | 867 | nd | nd | nd |
| 616-01-024 | 3E horizon | 500-800 | 9 | 50 | 1303 | 8 | 7 | 75 | 8 | 23 | 216 | nd | 0.05 | nd |
| 616-02-028 | B horizon | 30-100 | 53 | 50 | 557 | 3414 | 1864 | 1395 | 68 | 32 | 911 | 6 5 | 6.3 | 2.0 |
| 616-02-028 | Mud1 | 100-200 | 719 | 1154 | 3394 | 4268 | 5441 | 8985 | 261 | 154 | 4127 | 79 | 57 | 151 |
| 616-02-031 | A horizon | 0-75 | 62 | 64 | 68 | 249 | 141 | 61 | 43 | 3 | 71 | 1.49 | 1.7 | 1.7 |
| 616-02-031 | E horizon | 75-200 | nd | 3 | 1 | 56 | 44 | 6 | 16 | 1 | 56 | nd | 0.35 | nd |
| 616-02-031 | Coffee rock1 | 200-300 | 2400 | 8786 | 2668 | 1155 | 799 | 650 | 329 | 4166 | 350 | 0.79 | 2.7 | 2.9 |
| 616-02-031 | Coffee rock2 | 200-300 | 2694 | 6351 | 2142 | 604 | 457 | 303 | 440 | 2886 | 226 | nd | 0.93 | 0.65 |
| 616-02-031 | 2E horizon | 300-400 | 34 | 31 | 101 | 121 | 47 | 289 | 18 | 13 | 72 | nd | 0.04 | nd |
| 616-02-031 | 2Coffee rock1 | 400-500 | 339 | 2572 | 927 | 206 | 307 | 274 | 72 | 1509 | 469 | nd | 0.16 | nd |
| 616-02-031 | 2Coffee rock2 | 500-600 | 466 | 2465 | 1056 | 96 | 176 | 136 | 89 | 1475 | 546 | nd | 0.20 | nd |
| 616-02-032 | A horizon | 0-50 | 28 | 54 | 45 | 66 | 44 | 28 | 20 | 15 | 31 | 0.19 | 2.3 | 0.57 |
| 616-02-032 | E horizon | 50-200 | 2 | 4 | 8 | 15 | 7 | 14 | 21 | 2 | 37 | nd | 0.08 | nd |
| 616-02-032 | Coffee rock1 | 160 | 677 | 652 | 806 | 52 | 18 | 45 | 69 | 3 | 152 | nd | 0.07 | 0.25 |
| 616-02-032 | Coffee rock2 | 200-300 | 3519 | 3603 | 5585 | 107 | 125 | 158 | 648 | 621 | 2519 | nd | 0.30 | 0.35 |
| 616-02-032 | 2E1 horizon | 300-350 | 143 | 166 | 178 | 19 | 19 | 15 | 43 | 14 | 57 | nd | 0.15 | nd |
| 616-02-032 | 2E2 horizon | 350-400 | 370 | 296 | 471 | 33 | 20 | 29 | 38 | 3 | 142 | nd | 0.12 | nd |
| 616-02-058 | B horizon | 300-500 | 632 | 627 | 782 | 83 | 67 | 76 | 23 | nd | 87 | nd | 0.31 | 0.08 |
| 616-02-065 | B horizon | 200 | 709 | 2099 | 5558 | 291 | 287 | 475 | 135 | 928 | 5185 | 9.3 | 8.3 | 11 |
| 616-02-065 | PETZ | 0-20 | 1308 | 8265 | 3617 | 871 | 1631 | 800 | 354 | 4658 | 2404 | 5 9 | 9.5 | 3.7 |
| 616-02-065 | Coffee rock1 | 480-560 | 1333 | 2317 | 3226 | 183 | 262 | 225 | 408 | 933 | 1808 | 0 54 | 0.55 | 0.3 |
| 616-02-065 | Coffee rock3 | 650-700 | 926 | 1104 | 1857 | 303 | 415 | 919 | 256 | 309 | 654 | 1.8 | 1.9 | 1.7 |
| 616-02-068 | B horizon | 450 | 19 | 34 | 258 | 221 | 260 | 237 | 11 | 11 | 166 | 0.20 | 0.47 | 0.22 |
| 616-02-068 | A horizon | 0-75 | 10 | 13 | 20 | 128 | 68 | 29 | 24 | 6 | 79 | 1.3 | 0.93 | 0.66 |
| 616-02-068 | E1 horizon | 75-300 | 1 | 3 | 4 | 77 | 37 | 10 | 4 | 9 | 52 | 0.20 | 0.31 | nd |
| 616-02-068 | E2 horizon | 300-375 | 36 | 140 | 341 | 127 | 120 | 140 | 15 | 93 | 266 | nd | 0.09 | nd |
| 616-02-068 | E3 horizon | 375-600 | 4 | 48 | 110 | 148 | 133 | 209 | 16 | 37 | 118 | nd | 0.11 | nd |
| 616-02-068 | A horizon | 0-25 | 20 | 21 | 39 | 74 | 50 | 33 | 22 | 2 | 115 | 1 5 | 1.2 | 0.80 |
| 616-02-068 | E horizon | 25-200 | 4 | 6 | 7 | 36 | 39 | 16 | 7 | 4 | 42 | 0.39 | 0.58 | 0.03 |
| 616-02-068 | Coffee rock | 200-300 | 493 | 215 | 1250 | 236 | 191 | 303 | 244 | 17 | 885 | 0.45 | 0.30 | 0.03 |
| 616-02-068 | B1 horizon | 300-400 | 40 | 49 | 398 | 173 | 189 | 236 | 19 | 14 | 275 | 0.27 | 0.29 | 0.11 |
| 616-02-068 | B3 horizon | 500-600 | 52 | 37 | 358 | 285 | 295 | 381 | 36 | 17 | 279 | 0.30 | 0.48 | 0.09 |
| 616-02-071 | E horizon | 25-350 | 5 | 12 | 6 | 67 | 44 | 6 | 6 | 17 | 17 | nd | 0.44 | nd |
| 616-02-071 | B horizon | 350-600 | 266 | 317 | 941 | 166 | 160 | 239 | 64 | 61 | 901 | nd | 0.17 | nd |
| 616-02-078 | B horizon | 400-500 | 28 | 27 | 31 | 121 | 117 | 171 | 1 | 1 | 14 | 0.08 | 0.17 | 0.24 |
| 616-02-080 | Coffee rock | 200-400 | 1180 | 2881 | 9651 | 91 | 109 | 569 | 168 | 1496 | 9739 | 0.16 | 0.39 | 0.59 |
| 616-02-081 | B horizon | 400-800 | 51 | 40 | 135 | 304 | 247 | 365 | 11 | 4 | 114 | 0.18 | 0.29 | 0.15 |
| 616-02-082 | A horizon | 0-75 | 30 | 48 | 82 | 107 | 80 | 36 | 13 | 32 | 75 | 0.01 | 0.51 | 0.03 |
| 616-02-082 | E1 horizon | 75-200 | 31 | 53 | 385 | 28 | 21 | 32 | 13 | 19 | 360 | nd | 0.07 | nd |
| 616-02-082 | E2 horizon | 200-300 | 63 | 141 | 374 | 843 | 820 | 760 | 31 | 102 | 337 | nd | 0.07 | nd |
| 616-02-082 | B horizon | 300-400 | 24 | 61 | 555 | 467 | 406 | 775 | 16 | 38 | 500 | nd | 0.06 | nd |
| 616-02-082 | 2E horizon | 400-500 | 24 | 90 | 996 | 497 | 379 | 1033 | 24 | 71 | 881 | nd | 0.19 | nd |
| 616-02-082 | Coffee rock | 500-600 | 51 | 186 | 3606 | 1152 | 978 | 1553 | 35 | 116 | 3195 | nd | 0.23 | 0.18 |

* drying soils before analysis may affect the relative amounts extracted by the 3 extractions

**Appendix Table 5** (Cont.) Aluminium, Fe, Si and Mn extracted by dithionite citrate bicarbonate (d); oxalic acid (ox) and Na-pyrophosphate (p) for whole wet soil samples* (in mg $kg^{-1}$ unit).

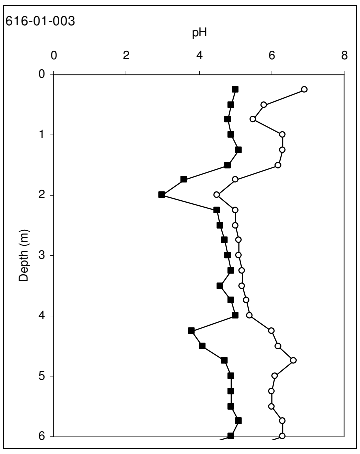
| Site | Horizon | Depth (cm) | $Al_d$ | $Al_{ox}$ | $Al_p$ | $Fe_d$ | $Fe_{ox}$ | $Fe_p$ | $Si_d$ | $Si_{ox}$ | $Si_p$ | $Mn_d$ | $Mn_{ox}$ | $Mn_p$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 616-02-085 | A horizon | 0-70 | 1786 | 4208 | 1139 | 11031 | 11546 | 1954 | 283 | 1066 | 552 | 551 | 555 | 108 |
| 616-02-085 | B1 horizon | 100-300 | 245 | 95 | 2933 | 482 | 457 | 1069 | 356 | 56 | 4721 | 4.0 | 1 5 | 2 5 |
| 616-02-085 | B2 horizon | 300-400 | 219 | 314 | 341 | 1328 | 1761 | 1271 | 128 | 57 | 359 | 22 | 29 | 25 |
| 616-02-085 | Mud | 400-600 | 64 | 618 | 487 | 3437 | 6039 | 1491 | 158 | 374 | 869 | 126 | 113 | 126 |
| 616-02-087 | Coffee rock1 | 200-300 | 3048 | 15421 | 2879 | 535 | 1356 | 376 | 136 | 697 | 130 | 3.4 | 7.6 | 5.7 |
| 616-02-087 | Coffee rock2 | 300-400 | 4444 | 15265 | 5067 | 75 | 70 | 59 | 352 | 4870 | 162 | nd | 0.22 | nd |
| 616-02-087 | B horizon | 500-600 | 26 | 90 | 431 | 133 | 112 | 264 | 17 | 91 | 528 | nd | 0.10 | nd |
| 616-02-094 | A1 horizon | 0-100 | 341 | 310 | 4648 | 7619 | 2400 | 2445 | 310 | 116 | 7227 | 2.0 | 1.37 | 2.4 |
| 616-02-094 | A2 horizon | 100-175 | 346 | 144 | 2036 | 5717 | 597 | 1603 | 320 | 41 | 3639 | 1.8 | 0.65 | 1.4 |
| 616-02-094 | E horizon | 175-600 | 242 | 79 | 1091 | 286 | 173 | 600 | 270 | 16 | 1604 | 0.75 | 0.46 | 0.32 |
| 616-02-099 | E horizon | 25-200 | 119 | 219 | 172 | 435 | 133 | 148 | 25 | 64 | 174 | 7.8 | 9 96 | 6.7 |
| 616-02-099 | B1 horizon | 200-300 | 128 | 99 | 130 | 273 | 254 | 316 | 98 | 28 | 106 | 3.4 | 3.07 | 4.7 |
| 616-02-099 | B2 horizon | 300-400 | 207 | 187 | 471 | 1486 | 1697 | 1586 | 112 | 36 | 491 | 11 | 13 | 10 |
| 616-02-100 | A horizon | 0-80 | 69 | 190 | 116 | 530 | 355 | 218 | 23 | 77 | 118 | 3.7 | 4.1 | 2.3 |
| 616-02-100 | Peat | 80-110 | 424 | 637 | 649 | 1468 | 2121 | 2471 | 74 | 74 | 365 | 1 9 | 2.9 | 2.3 |
| 616-02-100 | PETZ | 110-200 | 678 | 1073 | 826 | 1300 | 1312 | 929 | 192 | 370 | 343 | 3.2 | 3.7 | 3.0 |
| 616-02-100 | E horizon | 200-600 | nd | 11 | 30 | 42 | 46 | 64 | 3 | 3 | 53 | 0.62 | 0.30 | nd |
| 616-02-101 | A horizon | 0-75 | 160 | 116 | 110 | 1000 | 526 | 322 | 89 | 56 | 137 | 5.2 | 6.4 | 2.2 |
| 616-02-101 | Peat | 150-200 | 17 | 130 | 84 | 971 | 2576 | 860 | 158 | 251 | 547 | 34 | 53 | 42 |
| 616-02-101 | E horizon | 350-600 | 5 | 19 | 38 | 473 | 728 | 661 | 27 | 18 | 102 | 2.5 | 2.4 | 1.7 |
| 616-02-105 | A horizon | 0-160 | 540 | 655 | 315 | 4219 | 4509 | 846 | 305 | 392 | 182 | 4.6 | 7 5 | 2.1 |
| 616-02-105 | Peat | 250-360 | 303 | 475 | 538 | 14657 | 23449 | 23486 | 21 | 35 | 69 | 6.8 | 22 | 22 |
| 616-02-105 | PETZ | 360-480 | 72 | 97 | 142 | 1200 | 1748 | 1485 | 40 | 29 | 138 | 0.81 | 1.4 | 0.64 |
| 616-02-105 | E horizon | 480-700 | nd | 11 | 7 | 33 | 56 | 25 | 2 | 5 | 34 | 0.49 | 0.27 | nd |
| 616-02-106 | A horizon | 0-50 | 95 | 69 | 453 | 3945 | 3959 | 2314 | 168 | 23 | 928 | 0.84 | 2.5 | 1.0 |
| 616-02-106 | E horizon | 50-700 | 102 | 175 | 220 | 494 | 917 | 750 | 34 | 28 | 165 | 0.60 | 0.75 | 0.11 |
| 616-02-110 | B horizon | 200-500 | 154 | 68 | 101 | 699 | 355 | 522 | 161 | 19 | 115 | 0.63 | 0.67 | 0.74 |
| 616-02-112 | B horizon | 25-80 | nd | 4 | nd | 10 | 3 | 38 | 185 | 166 | 118 | 2.9 | 2.1 | 2.1 |
| 616-02-112 | Mud | 125-200 | nd | 3 | 5 | 29 | 2 | 54 | 27 | 26 | 111 | 5.0 | 1.1 | 4.8 |
| 616-02-112 | Peat | 200-300 | nd | 22 | 8 | 281 | 569 | 137 | 3 | 8 | 27 | 6.3 | 9.1 | 11 |
| 616-02-112 | Bb horizon | 300-400 | 90 | 669 | 2882 | 1145 | 2365 | 2015 | 42 | 72 | 3524 | 106 | 133 | 97 |
| 616-02-112 | C horizon | 400-600 | 39 | 168 | 6 | 273 | 166 | 51 | 12 | 82 | 82 | 1.6 | 1.31 | 4.6 |
| 616-02-113 | A horizon | 0-50 | 144 | 180 | 258 | 557 | 485 | 427 | 28 | 27 | 192 | 2.6 | 2.7 | 2.3 |
| 616-02-113 | E2 horizon | 250-300 | 10 | 28 | 135 | 643 | 914 | 749 | 16 | 17 | 178 | 0.75 | 0.90 | 0.31 |
| 616-02-122 | E horizon | 20-235 | 32 | 48 | 73 | 52 | 50 | 54 | 12 | 4 | 108 | 0.66 | 0.44 | nd |
| 616-02-122 | B horizon | 235-315 | 782 | 891 | 1240 | 32 | 25 | 48 | 140 | 85 | 392 | 0.62 | 0.36 | 0.26 |
| 616-02-122 | 2E2 horizon | 375-500 | 21 | 25 | 104 | 139 | 151 | 152 | 9 | 8 | 99 | 0.13 | 0.26 | nd |
| 616-02-122 | B/E horizon | 700-900 | 168 | 236 | 257 | 77 | 98 | 103 | 29 | 31 | 58 | 0.19 | 0.24 | 0.13 |
| 616-02-127 | Coffee rock | 100-235 | 2469 | 5907 | 2654 | 73 | 84 | 62 | 347 | 1997 | 238 | 0.80 | 0.25 | nd |
| 616-02-127 | 2E1 horizon | 235-300 | 83 | 164 | 128 | 46 | 41 | 49 | 32 | 47 | 66 | 0.52 | 0.30 | nd |
| 616-02-131 | A horizon | 0-50 | 408 | 487 | 193 | 1936 | 314 | 342 | 41 | 108 | 56 | 4.3 | 5.0 | 0.79 |
| 616-02-131 | E horizon | 50-325 | 47 | 33 | 88 | 63 | 4 | 45 | 25 | 5 | 69 | 0.28 | 0.24 | nd |
| 616-02-131 | B horizon | 325-425 | 415 | 432 | 232 | 9917 | 1597 | 243 | 175 | 247 | 288 | 0.89 | 1.4 | 0.50 |
| 616-02-131 | 2E horizon | 425-600 | 253 | 108 | 91 | 220 | 118 | 49 | 265 | 25 | 115 | 0.61 | 0.36 | nd |
| 616-02-136 | A horizon | 0-25 | 12 | 17 | 24 | 21 | 13 | 17 | 9 | 5 | 42 | 0.34 | 0.27 | nd |
| 616-02-136 | Coffee rock | 200-260 | 2505 | 5930 | 2342 | 81 | 83 | 76 | 301 | 2053 | 247 | 0.48 | 0.26 | 0.02 |

* drying soils before analysis may affect the relative amounts extracted by the 3 extractions

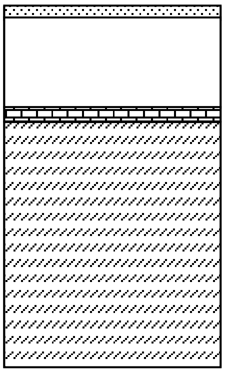
**Appendix Table 5** (Cont.) Aluminium, Fe, Si and Mn extracted by dithionite citrate bicarbonate (d); oxalic acid (ox) and Na-pyrophosphate (p) for whole wet soil samples* (in mg $kg^{-1}$ unit).

| Site | Horizon | Depth (cm) | $Al_d$ | $Al_{ox}$ | $Al_p$ | $Fe_d$ | $Fe_{ox}$ | $Fe_p$ | $Si_d$ | $Si_{ox}$ | $Si_p$ | $Mn_d$ | $Mn_{ox}$ | $Mn_p$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 616-02-145 | E1 horizon | 50-300 | 3 | 17 | 50 | 59 | 39 | 24 | 4 | 6 | 85 | 0.14 | 0.17 | 0.08 |
| 616-02-145 | E2 horizon | 300-450 | 26 | 41 | 177 | 145 | 133 | 152 | 12 | 18 | 225 | 0.60 | 0.34 | 5.1 |
| 616-02-145 | B horizon | 450-475 | 937 | 425 | 1121 | 7611 | 366 | 3524 | 62 | 101 | 523 | 0.53 | 0.29 | 2.4 |
| 616-02-145 | 2E horizon | 475-600 | 46 | 167 | 236 | 413 | 370 | 345 | 18 | 51 | 142 | 0.31 | 0.56 | 0.51 |
| 616-02-155 | E horizon | 50-150 | 27 | 31 | 19 | 148 | 66 | 17 | 63 | 31 | 97 | 3.9 | 4.0 | 1.3 |
| 616-02-155 | 2E horizon | 200-500 | 90 | 178 | 1174 | 474 | 641 | 792 | 66 | 61 | 1351 | 0.34 | 0.59 | 0.63 |
| 616-02-155 | B horizon | 500-600 | 239 | 313 | 7351 | 9224 | 496 | 3196 | 327 | 471 | 12491 | 3.2 | 0.81 | 3.6 |
| 616-02-158 | E horizon | 25-225 | nd | 14 | 5 | 8 | 4 | 3 | nd | 4 | 31 | nd | 0.03 | nd |
| 616-02-158 | Coffee rock1 | 225-300 | 5384 | 10814 | 5148 | 1112 | 1045 | 666 | 452 | 3183 | 154 | 0.55 | 0.79 | 0.37 |
| 616-02-158 | Coffee rock2 | 300-400 | 2973 | 1911 | 2574 | 386 | 345 | 386 | 875 | 194 | 579 | 0.60 | 0.62 | 0.73 |
| 616-02-174 | B horizon | 250-550 | 1223 | 826 | 1098 | 1711 | 1417 | 1133 | 267 | 72 | 227 | 18 | 14 | 13 |
| 616-02-179 | B horizon | 375-400 | 190 | 173 | 327 | 128 | 113 | 208 | 47 | 16 | 76 | nd | 0.10 | nd |
| Ellenbrook | E horizon | 0-150 | nd | 2 | nd | 5 | 2 | 5 | 1 | 3 | 15 | nd | 0.03 | nd |
| Ellenbrook | Coffee rock | 150-200 | 1378 | 11366 | 1736 | 832 | 910 | 645 | 162 | 6947 | 244 | 0.02 | 0.04 | nd |
| Ellenbrook | 2B1 horizon | 500-550 | 106 | 115 | 190 | 1205 | 1366 | 1425 | 17 | 13 | 99 | 0.08 | 0.83 | 0.55 |
| LOC50A | A horizon | 10-20 | 612 | 1069 | 292 | 1074 | 178 | 12 | 58 | 225 | 311 | nd | 0.09 | nd |
| LOC50A | A horizon | 0-100 | 137 | 165 | 2117 | 551 | 104 | 664 | 11 | 39 | 974 | nd | 0.08 | nd |
| LOC50A | E horizon | 300-400 | 352 | 785 | 710 | 6 | 13 | 266 | 11 | 100 | 556 | nd | 0.03 | nd |
| LOC50A | Coffee rock | 400-500 | 1562 | 429 | 4930 | 60 | 8 | 136 | 53 | 21 | 1702 | nd | 0.02 | nd |

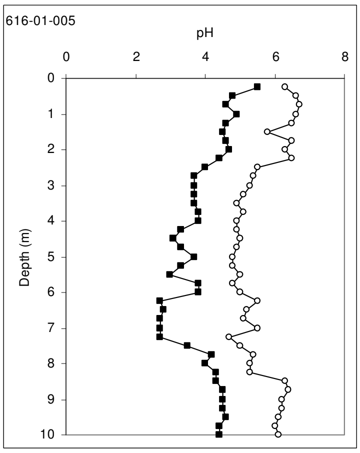
* drying soils before analysis may affect the relative amounts extracted by the 3 extractions.



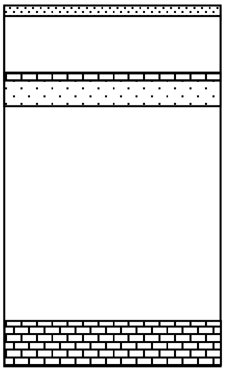

*Australian classification* *Podosol*
*USDA classification* *Spodosol*



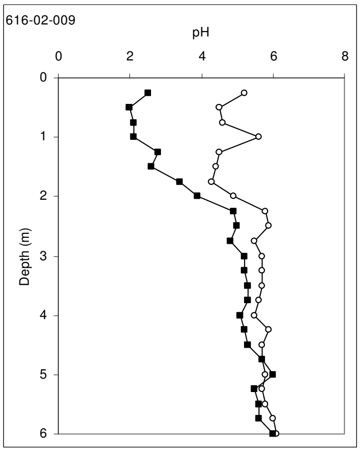
A horizon (0-25 cm) 7.5YR3/1 brownish black
E horizon (25-175 cm) 10YR8/1 white
Coffee rock (175-200 cm) 5YR2/3 very dark reddish brown
C horizon (200-600 cm) 10YR5/6 yellowish brown (200-300 cm)
10YR7/2 dull yellow orange (300-400 cm)
7.5Y7/1 light gray (400-600 cm)
▼ 490 cm



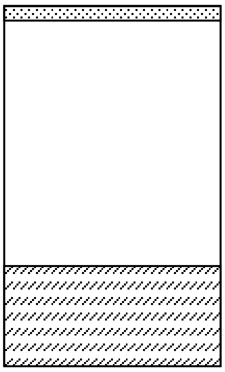

*Australian classification* *Paleopodosol*
*USDA classification* *Paleospodosol*



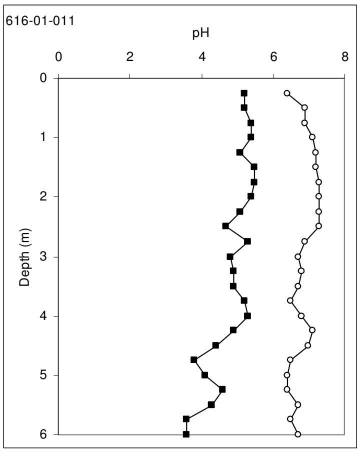
A horizon (0-20 cm) 7.5YR3/1 brownish black
E horizon (20-180 cm) 7.5YR6/1 brownish gray
Coffee rock (180-200 cm) 7.5YR2/3 very dark brown
B/E horizon (220-250 cm) 5YR3/3 dark reddish brown
2E horizon (250-830 cm) 5YR1.7/1 black (250-260 cm)
10R1.7/1 reddish black (260-400 cm)
7.5YR5/3 dull brown (400-500 cm)
7.5YR2/2 brownish black (500-830 cm)
▼ 640 cm
2Coffee rock (830-1000 cm) 2.5YR2/2 very dark reddish brown (830-900 cm)
7.5YR2/2 brownish black (900-1000 cm)



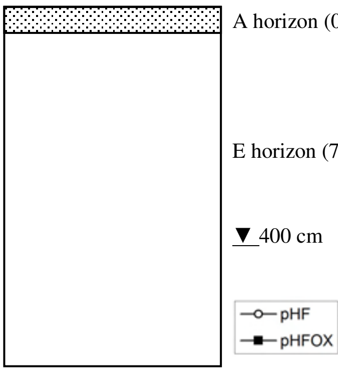

*Australian classification* *Tenosol*
*USDA classification* *Entisol*



A horizon (0-30 cm) 10YR3/1 very dark gray
E horizon (30-450 cm) 7.5YR5/2 brown
▼ 250 cm
C horizon (450-600 cm) 10YR5/4 yellowish brown

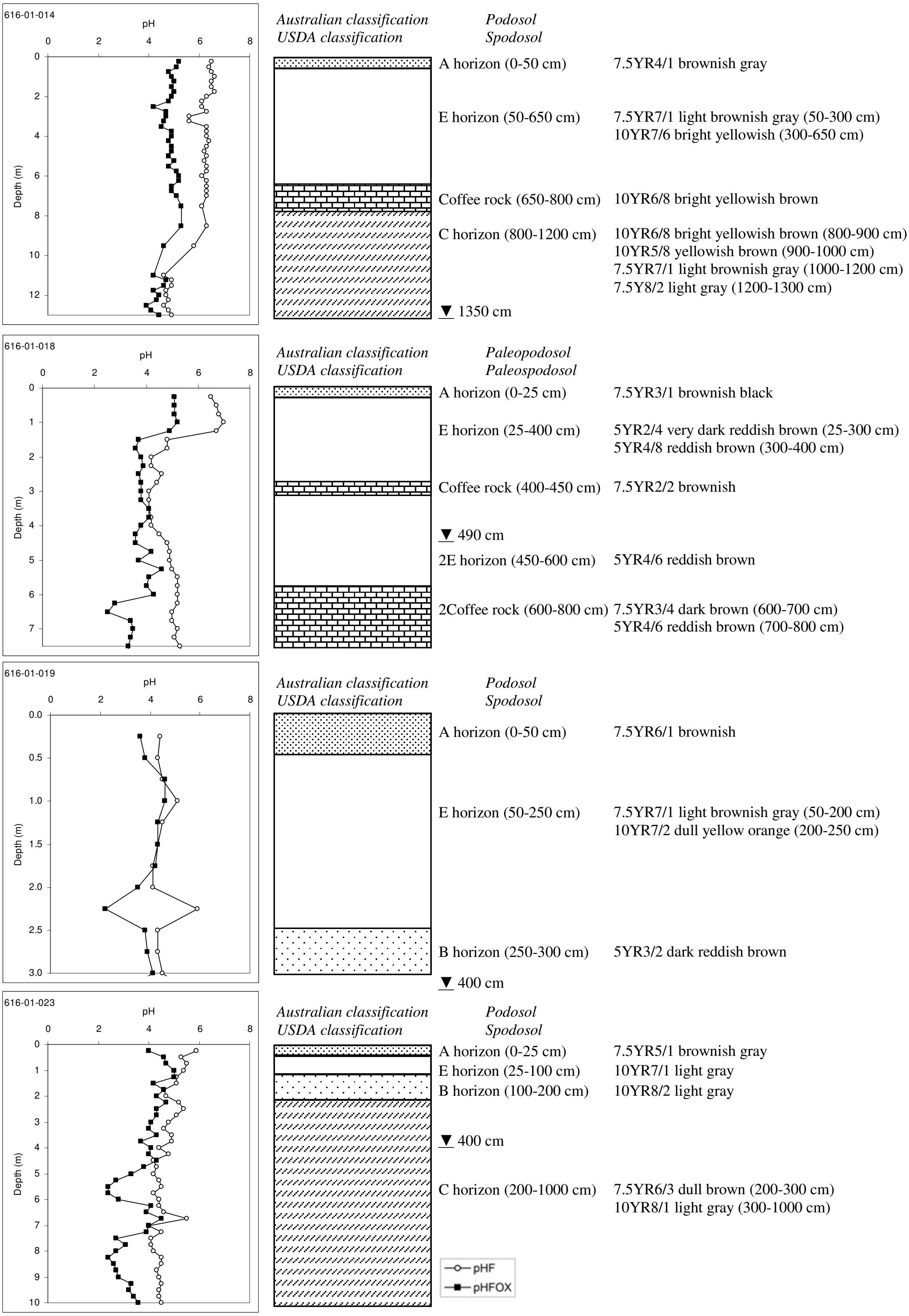



*Australian classification* *Tenosol*
*USDA classification* *Entisol*

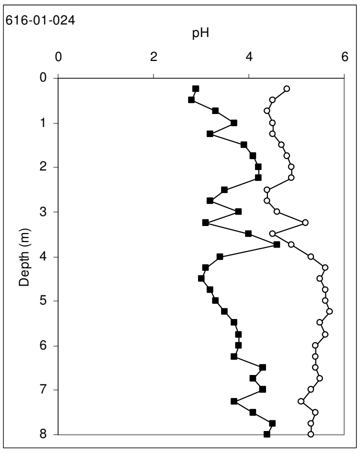



A horizon (0-75 cm) 7.5YR4/1 brownish gray
E horizon (75-600 cm) 7.5YR5/1 brownish gray
▼ 400 cm

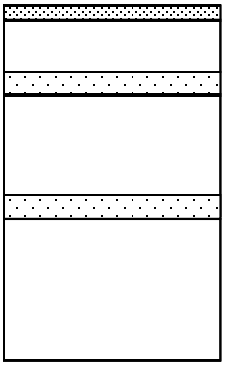
**Appendix Figure 1** Field $pHH_2O$, $pHH_2O_2$, soil colour with depth, an illustration of soil profiles and soil classification (▼ = groundwater level).



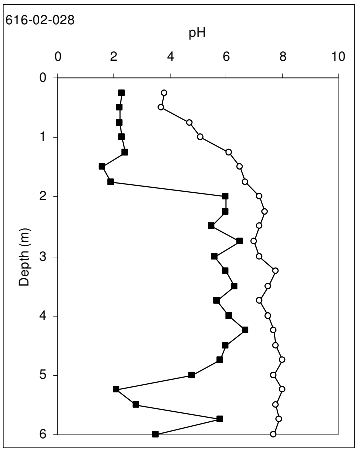

**Appendix Figure 1** (Cont.) Field $pHH_2O$, $pHH_2O_2$, soil colour with depth, an illustration of soil profiles and soil classification (▼ = groundwater level).



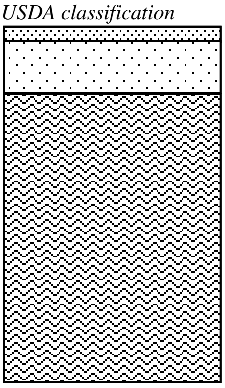

*Australian classification* *Podosol*
*USDA classification* *Spodosol*



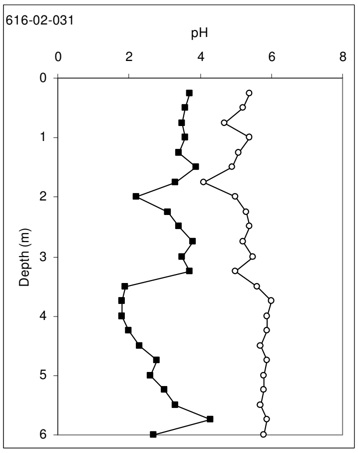
A horizon (0-25 cm) 7.5YR2/1 black
E horizon (25-150cm) 5YR6/1 brownish gray
B horizon (150-200 cm) 2.5YR3/2 dark reddish brown
2E horizon (200-400 cm) 10YR8/1 light gray
▼ 400 cm
2B horizon (400-500 cm) 5YR3/2 dark reddish brown
3E horizon (500-800 cm) 10YR8/1 light gray



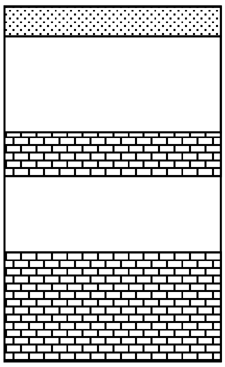

*Australian classification* *Podosol*
*USDA classification* *Spodosol*



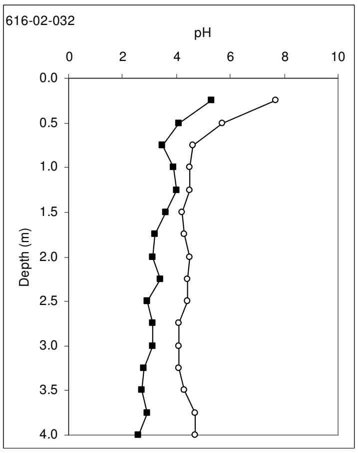
A horizon (0-30 cm) 10YR4/6 dark yellowish brown
B horizon (30-100 cm) 5YR5/6 yellowish red
▼ 150 cm
Mud (100-600 cm) 5YR2.5/1 black



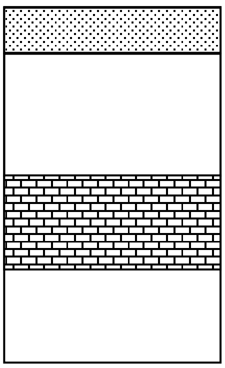

*Australian classification* *Paleopodosol*
*USDA classification* *Paleospodosol*



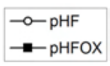
A horizon (0-75 cm) 7.5YR3/1 brownish black
▼ 75 cm
E horizon (75-200cm) 7.5YR7/1 light brownish gray
Coffee rock (200-300 cm) 10YR2/1 black; 5YR2/1 brownish black
2E horizon (300-400 cm) 7.5YR6/1 brownish gray
2Coffee rock (400-600 cm) 2.5YR2/2 very dark reddish brown



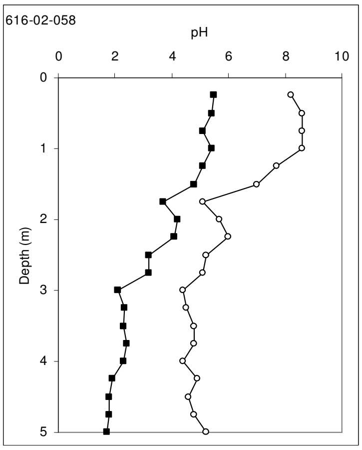

*Australian classification* *Podosol*
*USDA classification* *Spodosol*



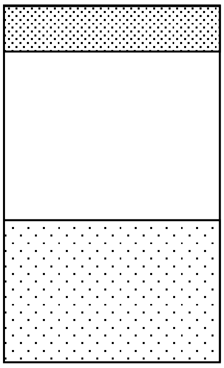
A horizon (0-50 cm) 5YR7/1 light brownish gray
▼ 20cm
E horizon (50-200 cm) 7.5YR8/1 light gray
Coffee rock (200-300 cm) 5YR2/3 very dark reddish brown (160 cm)
5YR2.5/1 black (200-300 cm)
2E horizon (300-400 cm) 7.5YR2/1 black



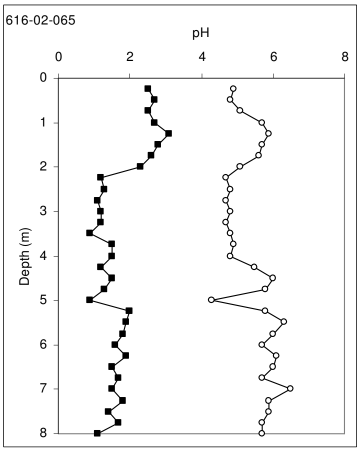

**Appendix Figure 1** (Cont.) Field $pHH_2O$, $pHH_2O_2$, soil colour with depth, an illustration of soil profiles and soil classification (▼ = groundwater level).



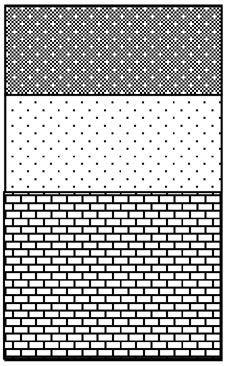

*Australian classification* — *Podosol*
*USDA classification* — *Spodosol*



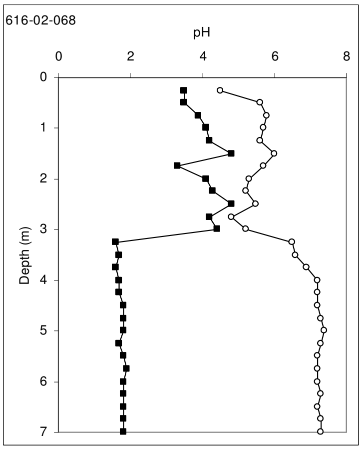
| | |
|---|---|
| A horizon (0-50 cm) | 10YR3/1 very dark gray |
| ▼ 100 cm | |
| E horizon (50-300 cm) | 10YR6/1 gray |
| B horizon (300-500 cm) | 5YR2/2 brownish black |



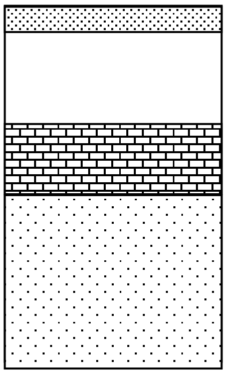

*Australian classification* — *Organosol*
*USDA classification* — *Histosol*



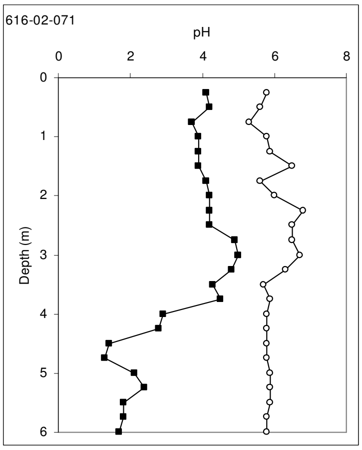
| | |
|---|---|
| Peat/ E horizon (PETZ) (0-180 cm) | 10YR2/1 black |
| ▼ 150 cm | |
| B horizon (180-480 cm) | 2.5YR2.5/2 very dusky red (180-350 cm)<br>2.5YR2.5/1 reddish black (350-480 cm) |
| Coffee rock (480-800 cm) | 2.5YR2.5/1 reddish black (480-560 cm)<br>10R2.5/1 reddish black (560-800 cm) |



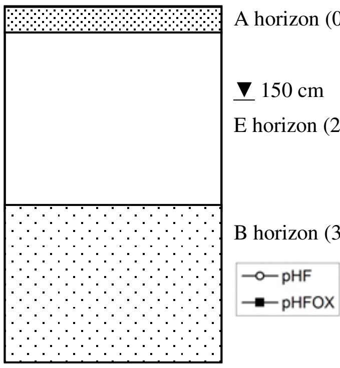

*Australian classification* — *Podosol*
*USDA classification* — *Spodosol*



| | |
|---|---|
| A horizon (0-25 cm) | 7.5YR3/1 very dark gray |
| E horizon (25-200 cm) | 10YR6/2 light brownish gray |
| ▼ 200 cm | |
| Coffee rock (200-300 cm) | 10YR2/1 black |
| B horizon (300-800 cm) | 10YR3/3 dark brown (300-400 cm)<br>10YR4/2 dark grayish brown (400-500 cm)<br>10YR3/2 very dark grayish brown (500-600 cm)<br>10YR4/2 dark grayish brown (600-800 cm) |

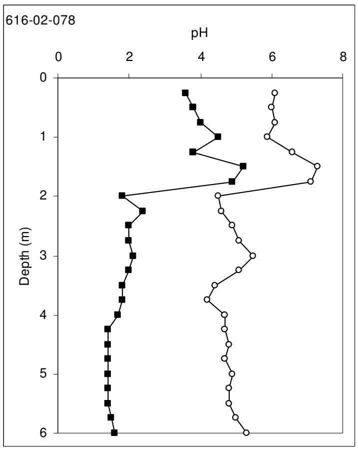


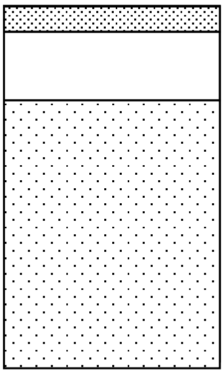

*Australian classification* — *Podosol*
*USDA classification* — *Spodosol*



| | |
|---|---|
| A horizon (0-25 cm) | 10YR4/1 dark gray |
| ▼ 150 cm | |
| E horizon (25-350 cm) | 7.5YR7/1 light brownish gray |
| B horizon (350-600 cm) | 7.5YR3/1 brownish black |

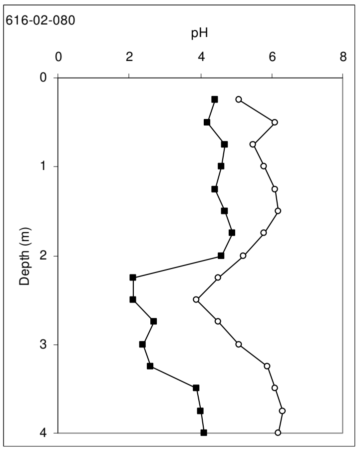
**Appendix Figure 1** (Cont.) Field $pHH_2O$, $pHH_2O_2$, soil colour with depth, an illustration of soil profiles and soil classification (▼ = groundwater level).

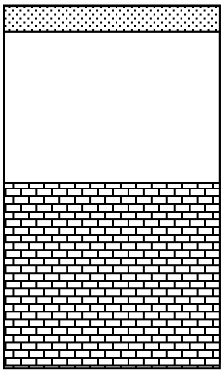


*Australian classification* *Podosol*
*USDA classification* *Spodosol*

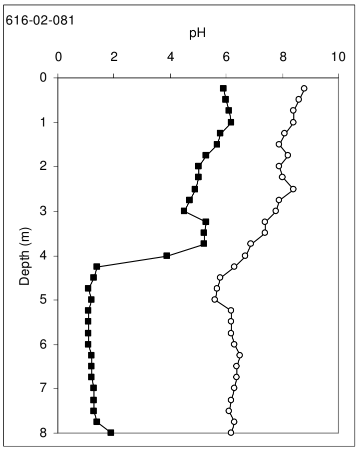
A horizon (0-25 cm) 10YR5/1 gray
E horizon (25-175 cm) 10YR8/1 white
▼ 200 cm
B horizon (175-600 cm) 7.5YR3/1 brownish black

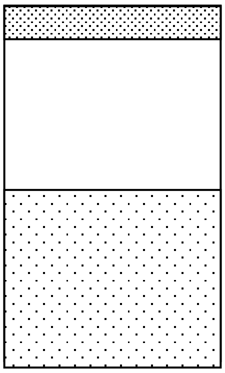


*Australian classification* *Podosol*
*USDA classification* *Spodosol*

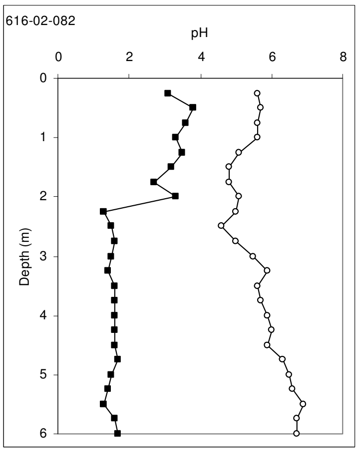
A horizon (0-25 cm) 10YR6/1 gray
E horizon (25-200 cm) 10YR7/1 light gray (25-50 cm)
10YR8/1 white (50-200 cm)
▼ 200 cm
Coffee rock (200-400 cm) 7.5YR3/2 brownish black

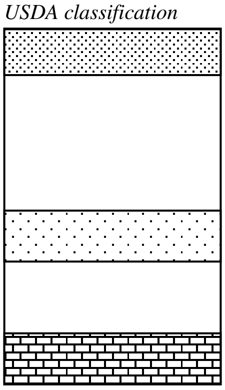


*Australian classification* *Podosol*
*USDA classification* *Spodosol*

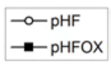
A horizon (0-75 cm) 10YR3/1 very dark gray
E horizon (75-400 cm) 10YR4/4 dark yellowish brown (75-150 cm)
10YR4/1 dark gray (150-200 cm)
▼ 300 cm 10YR5/1 gray (200-300 cm)
10YR4/2 dark grayish brown (300-375 cm)
10YR8/1 white (375-400 cm)
B horizon (400-800 cm) 7.5YR2.5/1 black



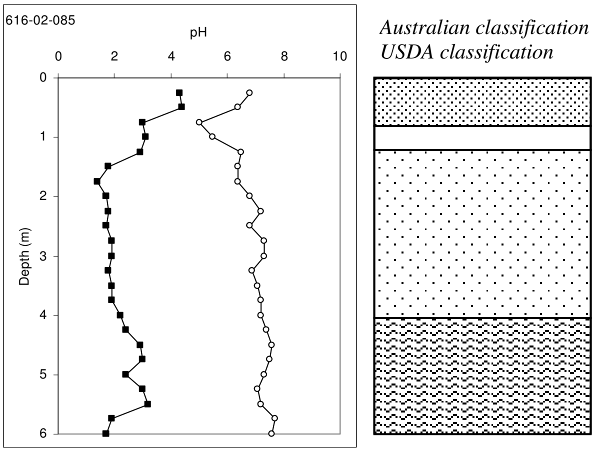



*Australian classification* *Podosol*
*USDA classification* *Spodosol*

A horizon (0-75 cm) 10YR8/1 white
▼ 50 cm
E horizon (75-300 cm) 7.5YR7/2 pinkish gray (75-200 cm)
10YR5/1 gray (200-300 cm)
B horizon (300-400 cm) 10YR5/2 grayish brown
2E horizon (400-500 cm) 10YR6/1 gray
Coffee rock (500-600 cm) 10YR4/2 dark grayish brown

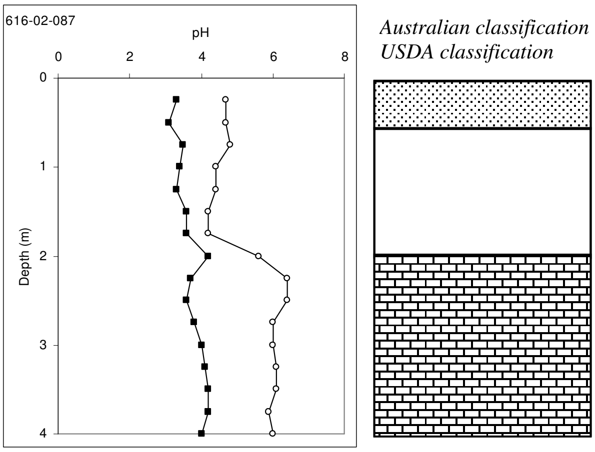



**Appendix Figure 1** (Cont.) Field $pHH_2O$, $pHH_2O_2$, soil colour with depth, an illustration of soil profiles and soil classification (▼ = groundwater level).



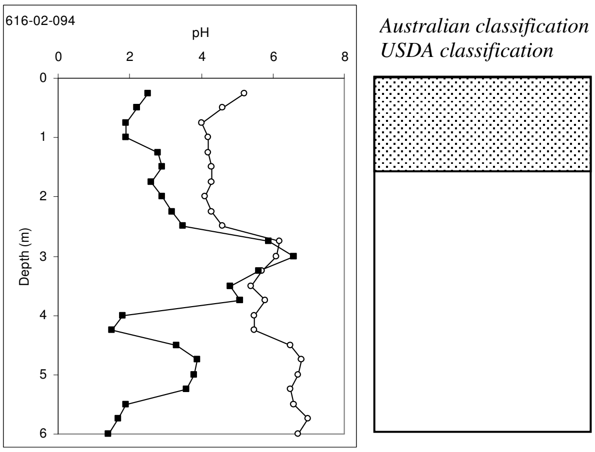

*Australian classification* *Podosol*
*USDA classification* *Spodosol*

A horizon (0-70 cm) 5YR4/2 dark reddish gray
E horizon (70-100 cm) 10YR7/1 light gray
▼ 150 cm
B horizon (100-400 cm) 7.5YR5/1 gray (100-300 cm)
10YR4/1 dark gray (300-400 cm)
Mud (400-600 cm) 10YR2/1 black



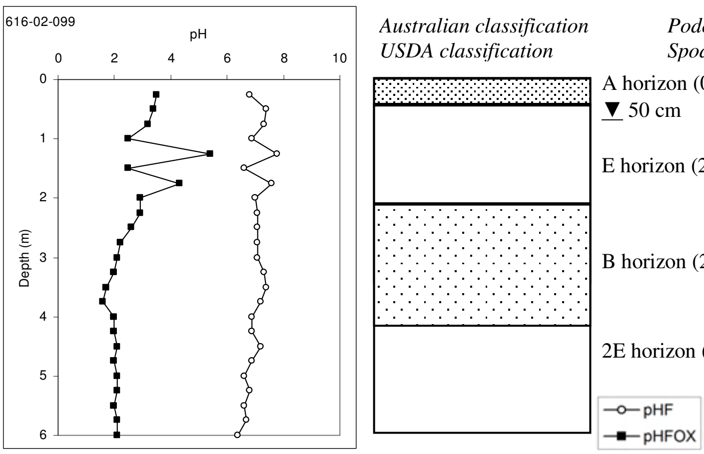

*Australian classification* *Podosol*
*USDA classification* *Spodosol*

A horizon (0-50 cm) 10YR4/1 dark gray
▼ 150 cm
E horizon (50-200 cm) 10YR7/1 light gray (50-135 cm)
10YR6/2 light brownish gray (135-200 cm)
Coffee rock (200-400 cm) 7.5YR2.5/2 very dark brown (200-300 cm)
5YR2.5/2 dark reddish brown (300-400 cm)




*Australian classification* *Tenosol*
*USDA classification* *Entisol*

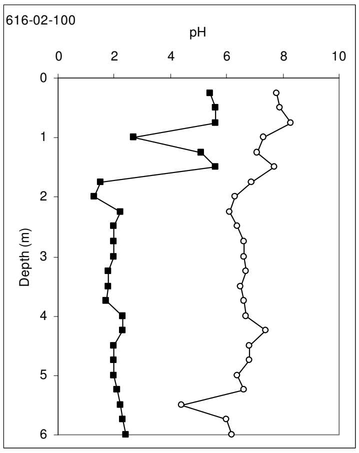
A horizon (0-175 cm) 10YR3/4 dark yellowish brown (0-100 cm)
10YR5/8 yellowish brown (100-175 cm)
▼ 350 cm
E horizon (175-600 cm) 10YR4/2 dark grayish brown



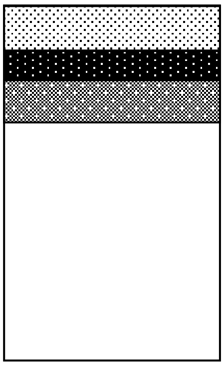

*Australian classification* *Podosol*
*USDA classification* *Spodosol*

A horizon (0-25 cm) 10YR7/2 light gray
▼ 50 cm
E horizon (25-200 cm) 7.5YR4/3 brown
B horizon (200-400 cm) 7.5YR2.5/2 very dark brown (200-300 cm)
7.5YR3/1 very dark gray (300-400 cm)
2E horizon (400-600 cm) 10YR5/2 grayish brown

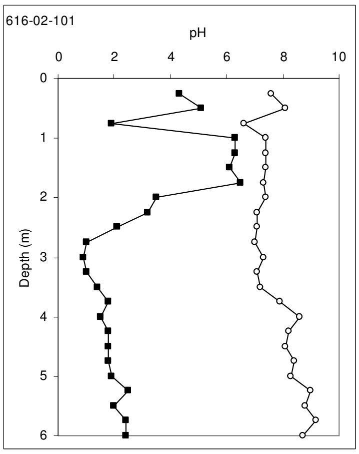
**Appendix Figure 1** (Cont.) Field $pHH_2O$, $pHH_2O_2$, soil colour with depth, an illustration of soil profiles and soil classification (▼ = groundwater level).



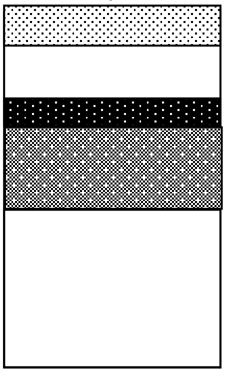

*Australian classification* *Organosol*
*USDA classification* *Histosol*



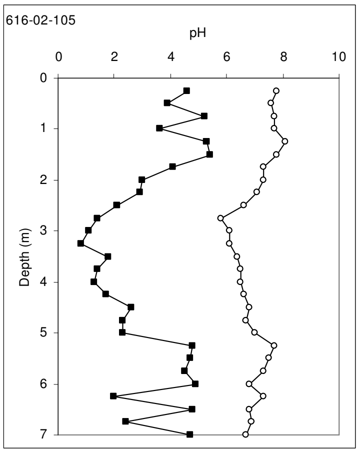
| | |
|---|---|
| A horizon (0-80 cm) | 7.5YR4/3 brown |
| Peat (80-110 cm) | Black |
| Peat/ E horizon (PETZ) (110-200 cm) ▼ 200 cm | 7.5YR2 5/1 black |
| E horizon (200-600 cm) | 10YR6/1 gray |



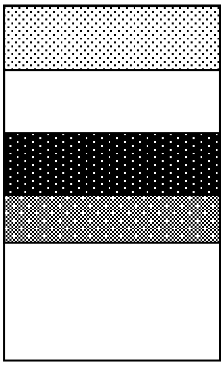

*Australian classification* *Organosol*
*USDA classification* *Histosol*



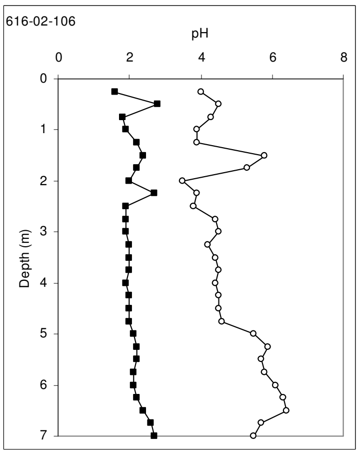
| | |
|---|---|
| A horizon (0-75 cm) | 7.5YR2 5/1 black |
| E horizon (75-150 cm) | 10YR4/1 dark gray |
| ▼ 150 cm | |
| Peat (150-200 cm) | 7.5YR2 5/1 black |
| Peat/ E horizon (PETZ) (200-350 cm) | 7.5YR2 5/1 black |
| 2E horizon (350-600 cm) | 7.5YR5/1 gray |



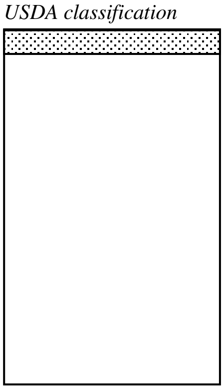

*Australian classification* *Organosol*
*USDA classification* *Histosol*



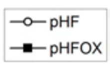
| | |
|---|---|
| A horizon (0-160 cm) | 7.5YR2 5/2 brown |
| ▼ 170 cm | |
| E horizon (160-250 cm) | 10YR5/4 yellowish brown |
| Peat (250-360 cm) | Black |
| Peat/ E horizon (PETZ) (360-480 cm) | Black |
| 2E horizon (480-700 cm) | 10YR5/4 yellowish brown |



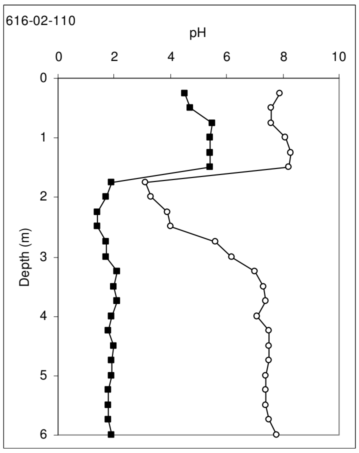

*Australian classification* *Tenosol*
*USDA classification* *Entisol*



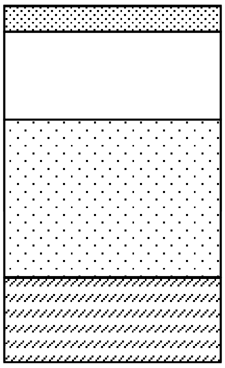
| | |
|---|---|
| A horizon (0-50 cm) | 7.5YR2 5/1 black |
| ▼ 180 cm | |
| E horizon (50-700 cm) | 7.5YR5/1 gray |



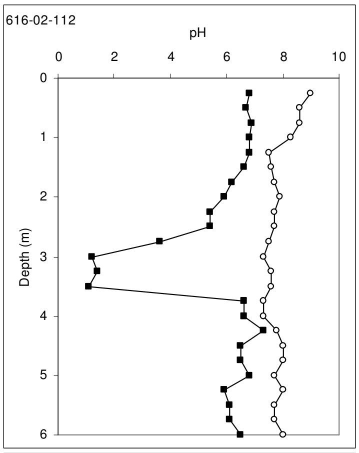

**Appendix Figure 1** (Cont.) Field $pHH_2O$, $pHH_2O_2$, soil colour with depth, an illustration of soil profiles and soil classification (▼ = groundwater level).



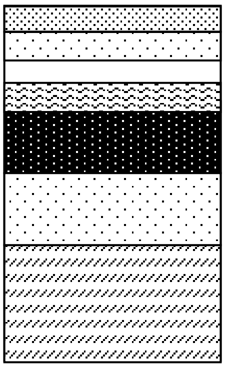

*Australian classification* *Podosol*
*USDA classification* *Spodosol*



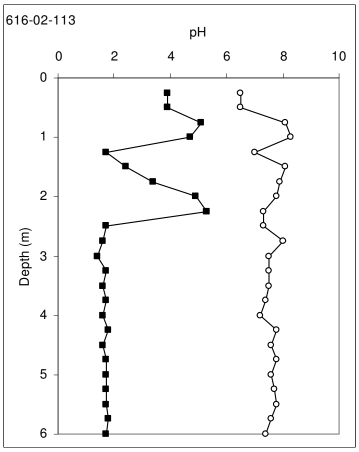
A horizon (0-25 cm) 10YR7/3 very pale brown
E horizon (25-200 cm) 10YR8/2 very pale brown
▼ 180 cm
B horizon (200-500 cm) 2.5Y4/2 dark grayish brown
C horizon (500-600 cm) 10YR5/1 gray



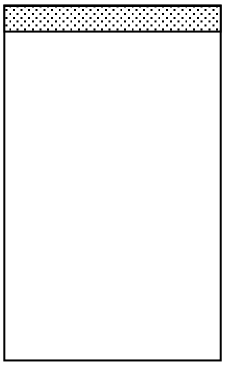

*Australian classification* *Podosol*
*USDA classification* *Spodosol (Buried soil)*



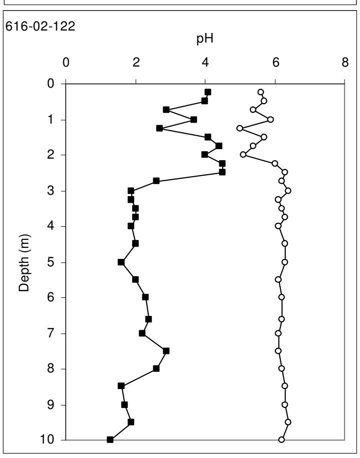
A horizon (0-25 cm) 10YR6/4 light yellowish brown
B horizon (25-80 cm) 7.5YR6/3 light brown
▼ 100 cm
E horizon (80-125 cm) 10YR6/1 gray
Mud (125-200 cm) 10YR4/1 dark gray
Peatb (200-300 cm) Black
Bb horizon (300-400 cm) 7.5YR4/1 dark gray
C horizon (400-600 cm) 10YR7/2 light gray



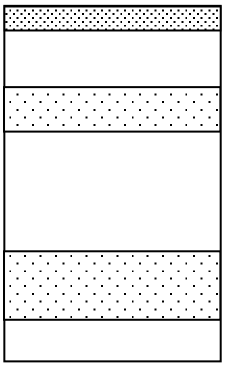

*Australian classification* *Tenosol*
*USDA classification* *Entisol*



A horizon (0-50 cm) 7.5YR3/1 very dark gray
▼ 50 cm
E horizon (50-600 cm) 7.5YR6/2 pinkish gray (50-250 cm)
7.5YR5/3 brown (250-300 cm)
7.5YR4/1 dark gray (300-600 cm)

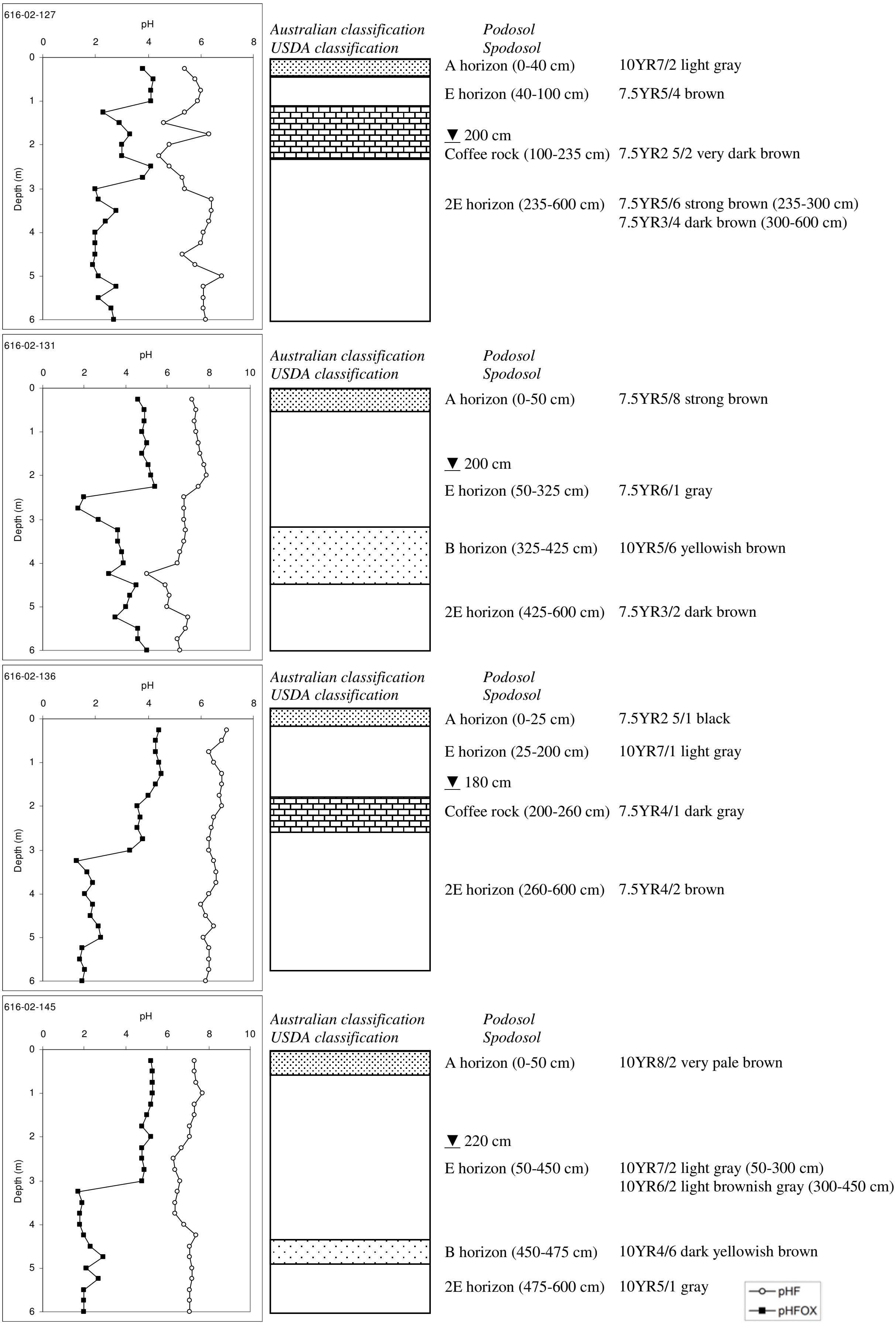



*Australian classification* *Podosol*
*USDA classification* *Spodosol*

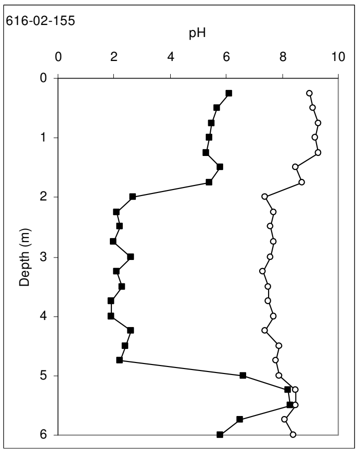


A horizon (0-20 cm) 10YR5/2 grayish brown
E horizon (20-235 cm) 7.5YR4/1 dark gray
▼ 240 cm
B horizon (235-315 cm) 7.5YR2 5/3 very dark brown
2E horizon (315-600 cm) 7.5YR5/2 (315-500 cm) brown
7.5YR6/2 (500-700 cm) pinkish gray
B/E horizon (700-900 cm) 5YR3/3 dark reddish brown
3E horizon (900-1000 cm) 7.5YR6/1 gray

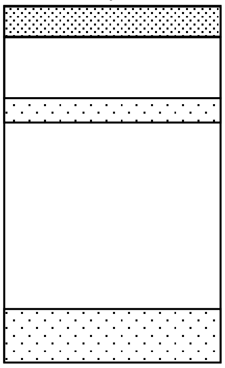
**Appendix Figure 1** (Cont.) Field $pHH_2O$, $pHH_2O_2$, soil colour with depth, an illustration of soil profiles and soil classification (▼ = groundwater level; b = buried soil).



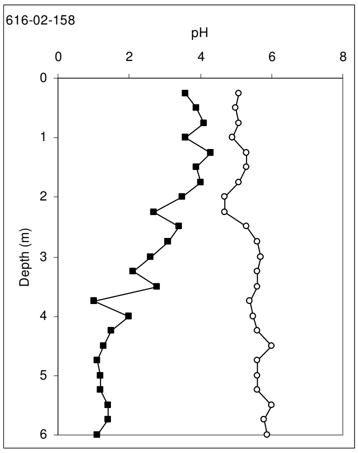

**Appendix Figure 1** (Cont.) Field $pHH_2O$, $pHH_2O_2$, soil colour with depth, an illustration of soil profiles and soil classification (▼ = groundwater level).



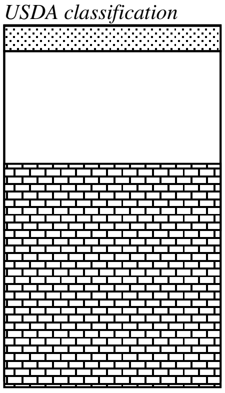

*Australian classification* *Podosol*
*USDA classification* *Spodosol*



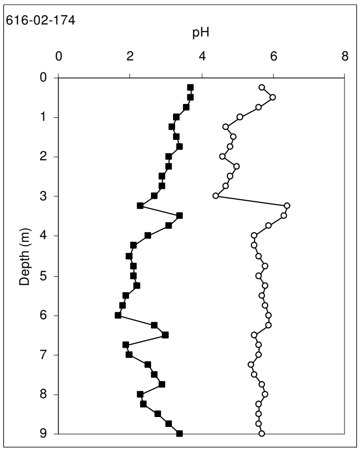
A horizon (0-50 cm) 10YR5/1 gray
E horizon (50-150 cm) 7.5YR6/1 gray
B horizon (150-200 cm) 10YR6/1 gray
▼ 250 cm
2E horizon (200-500 cm) 10YR4/2 dark grayish brown
2B horizon (500-600 cm) 10YR5/6 yellowish brown



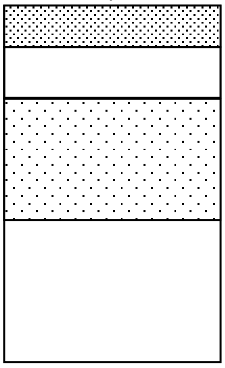

*Australian classification* *Podosol*
*USDA classification* *Spodosol*



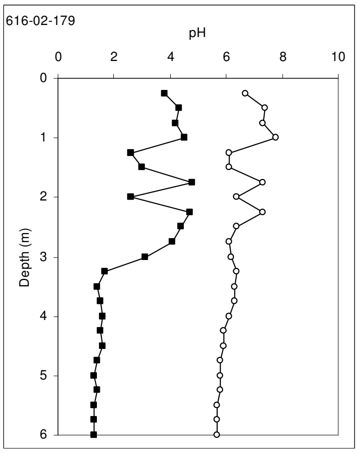
A horizon (0-25 cm) 10YR7/1 light gray
E horizon (25-225 cm) 7.5YR6/2 pinkish gray
▼ 290 cm
Coffee rock (225-600 cm) 7.5YR2.5/2 very dark brown (225-300 cm)
7.5YR2.5/1 black (300-400 cm)
10YR4/2 dark grayish brown (400-600 cm)



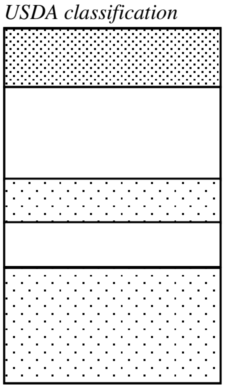

*Australian classification* *Podosol*
*USDA classification* *Spodosol*



A horizon (0-100 cm) 10YR5/1 gray
E horizon (100-250 cm) 10YR6/2 light brownish gray
▼ 310 cm
B horizon (250-550 cm) 7.5YR2.5/1 black
C horizon (550-900 cm) 10YR6/3 pale brown




*Australian classification* *Podosol*
*USDA classification* *Spodosol*

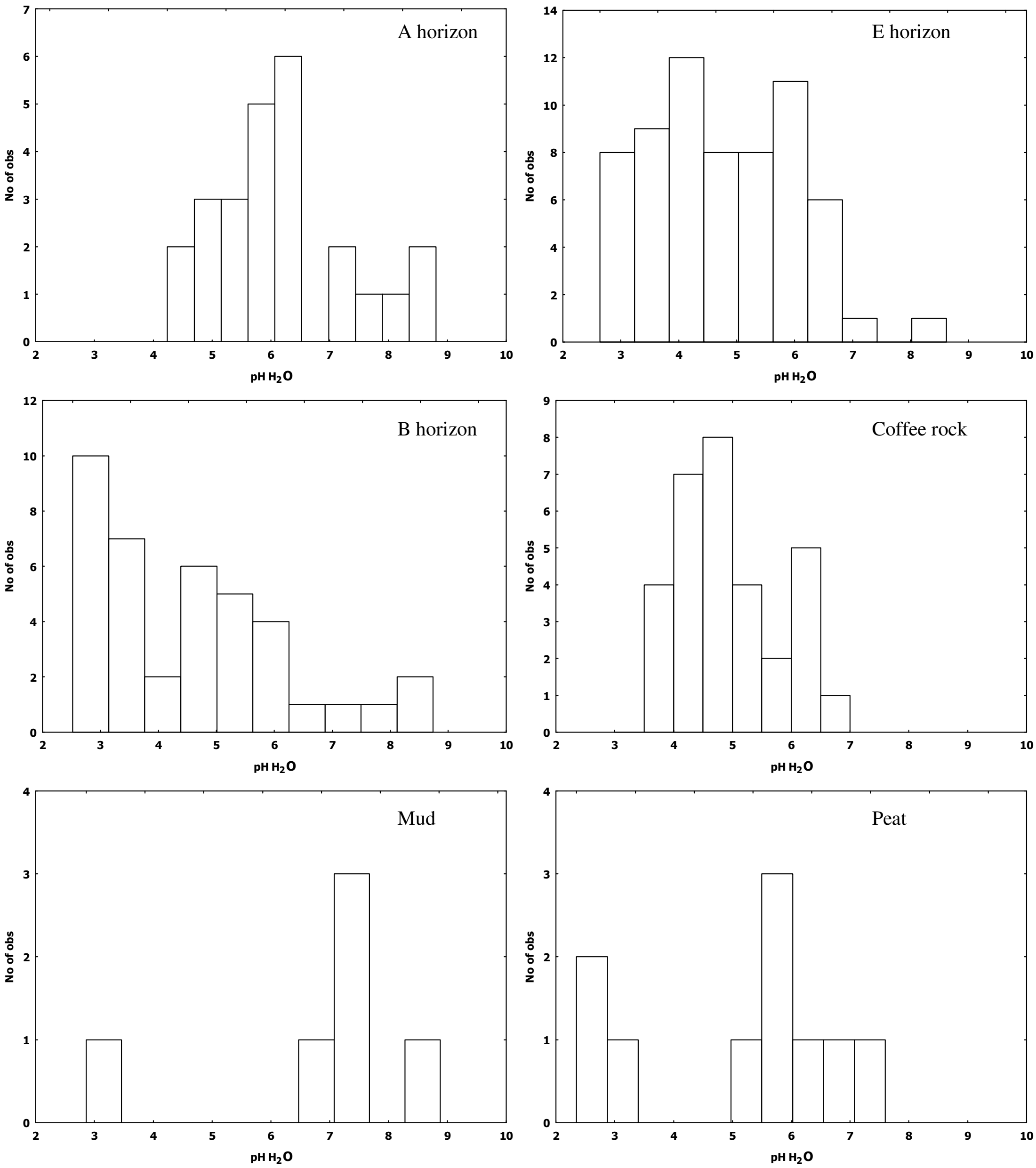


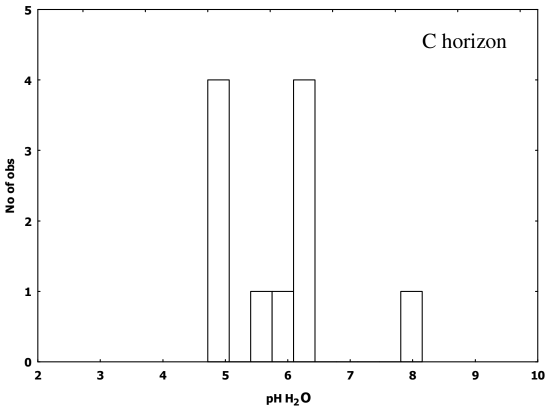
A horizon (0-100 cm) 10YR6/1 gray (0-50 cm)
10YR7/2 light gray (50-100 cm)
E horizon (100-225 cm) 10YR7/1 light gray
B horizon (225-300 cm) 10YR3/2 very dark grayish brown
▼ 320 cm
B/E horizon (300-400 cm) 7.5YR3/3 dark brown
2B horizon (400-600cm) 10YR7/3 very pale brown

pHF
pHFOX

**Appendix Figure 1** (Cont.) Field $pHH_2O$, $pHH_2O_2$, soil colour with depth, an illustration of soil profiles and soil classification (▼ = groundwater level).

pH $H_2O$

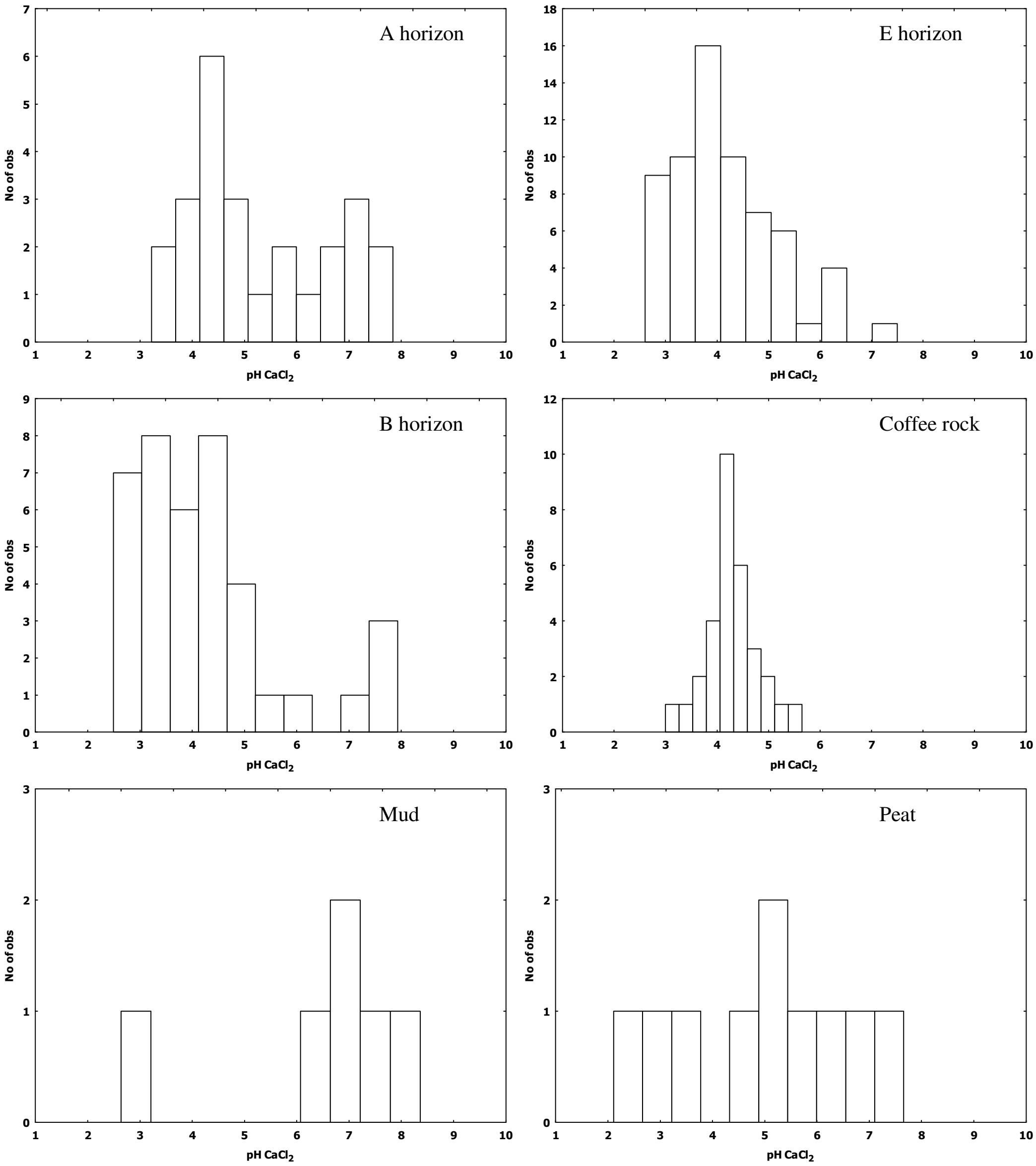


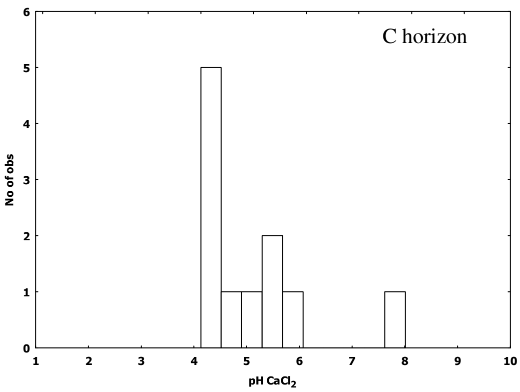




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 25 | 6.00 | 4.24 | 8.81 | 1.21 |
| E horizon | 64 | 4.59 | 2.64 | 8.62 | 1.28 |
| B horizon | 39 | 4.48 | 2.52 | 8.74 | 1.70 |
| Coffee rock | 31 | 4.84 | 3.56 | 6.58 | 0.86 |
| Mud | 6 | 7.32 | 2.86 | 8.88 | 2.04 |
| Peat | 10 | 5.79 | 2.35 | 7.60 | 1.79 |
| C horizon | 11 | 5.75 | 4.72 | 8.15 | 0.99 |

**Appendix Figure 2** Histograms of the frequency of pH$H_2O$ values for A, E, B, coffee rock, mud, peat and C horizons.

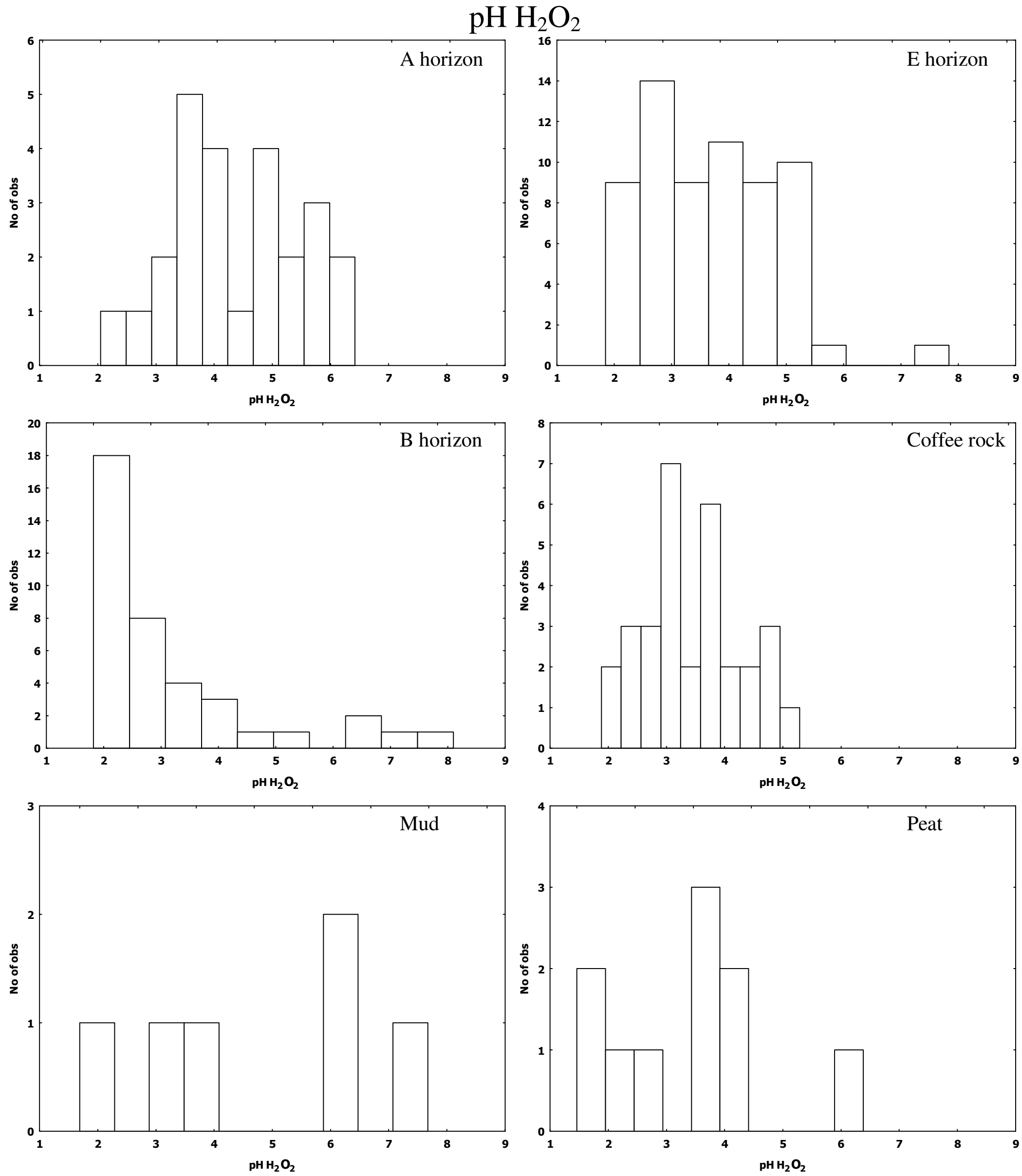
pH $CaCl_2$

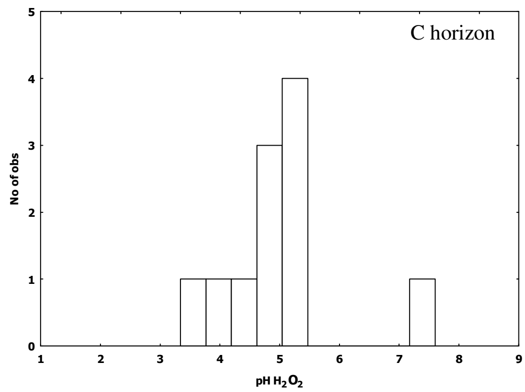



| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 25 | 4.77 | 3.22 | 7.84 | 1.34 |
| E horizon | 64 | 3.97 | 2.60 | 7.50 | 1.01 |
| B horizon | 39 | 3.92 | 2.49 | 7.93 | 1.39 |
| Coffee rock | 31 | 4.24 | 3.00 | 5.65 | 0.55 |
| Mud | 6 | 7.20 | 2.64 | 8.36 | 2.01 |
| Peat | 10 | 5.04 | 2.11 | 7.66 | 1.83 |
| C horizon | 11 | 4.68 | 4.13 | 8.01 | 1.12 |

**Appendix Figure 3** Histograms of the frequency of pH$CaCl_2$ values for A, E, B, coffee rock, mud, peat and C horizons.

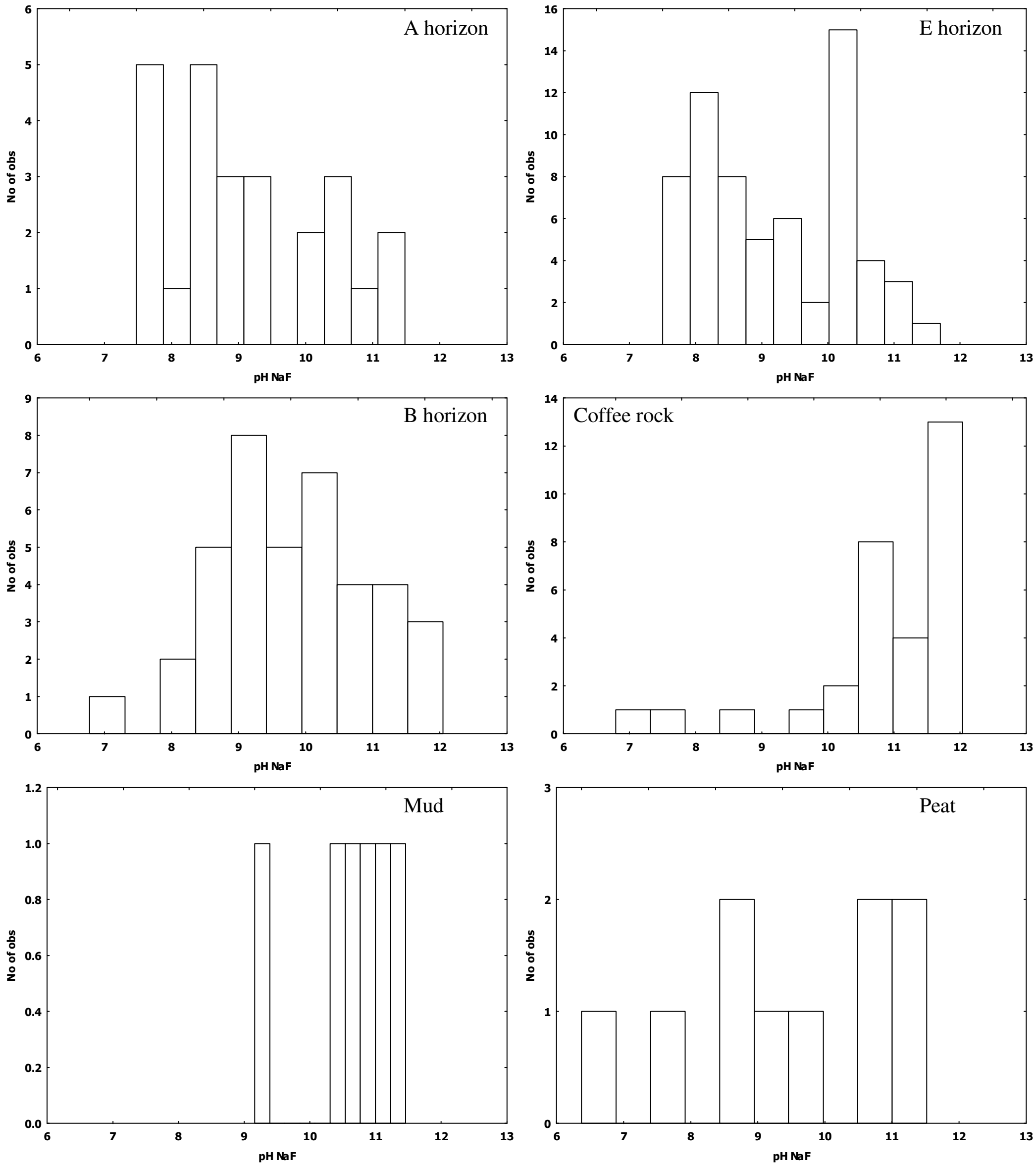


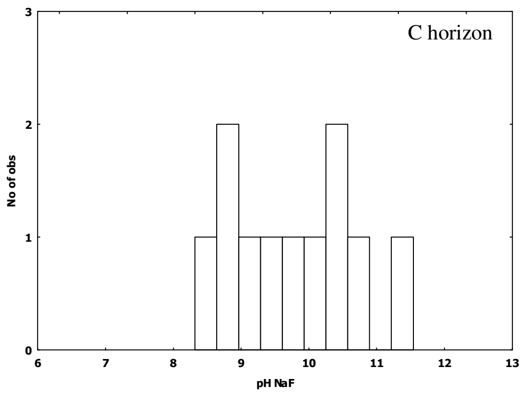




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 25 | 4.12 | 2.05 | 6.42 | 1.13 |
| E horizon | 64 | 3.57 | 1.85 | 7.84 | 1.19 |
| B horizon | 39 | 2.52 | 1.82 | 8.10 | 1.61 |
| Coffee rock | 31 | 3.29 | 1.88 | 5.29 | 0.88 |
| Mud | 6 | 4.80 | 1.69 | 7.67 | 2.28 |
| Peat | 10 | 3.86 | 1.46 | 6.38 | 1.42 |
| C horizon | 11 | 4.95 | 3.34 | 7.60 | 1.11 |

**Appendix Figure 4** Histograms of the frequency of $pHH_2O_2$ values for A, E, B, coffee rock, mud, peat and C horizons.

pH NaF

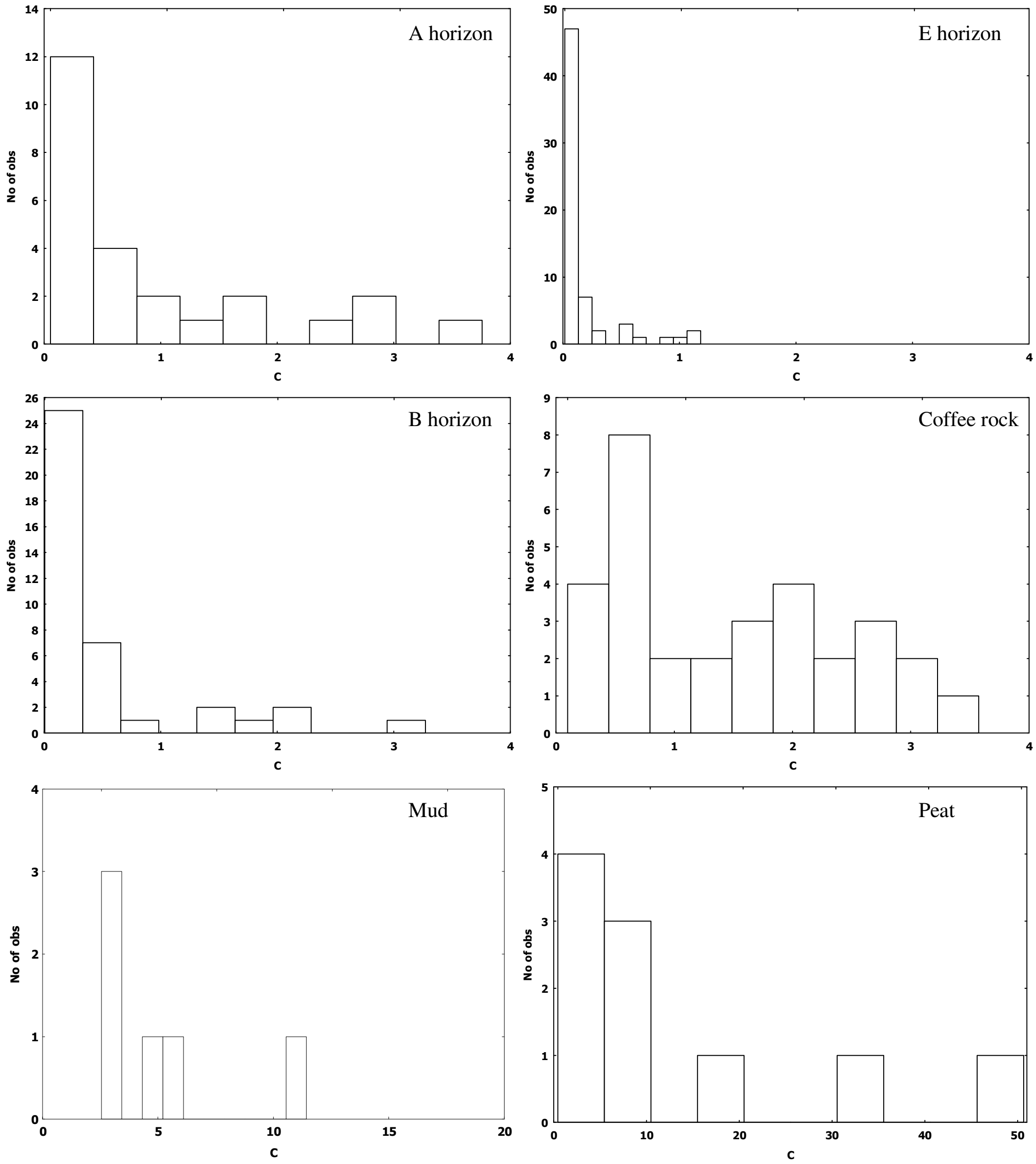


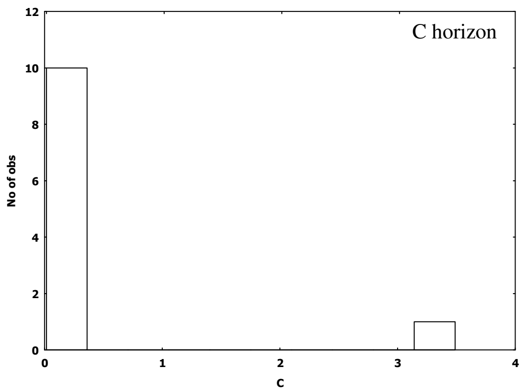




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 25 | 8.88 | 7.48 | 11.48 | 1.22 |
| E horizon | 64 | 9.01 | 7.50 | 11.70 | 1.12 |
| B horizon | 39 | 9.70 | 6.78 | 12.05 | 1.15 |
| Coffee rock | 31 | 11.32 | 6.79 | 12.04 | 1.21 |
| Mud | 6 | 10.87 | 9.16 | 11.46 | 0.81 |
| Peat | 10 | 9.58 | 6.37 | 11.52 | 1.61 |
| C horizon | 11 | 9.63 | 8.32 | 11.54 | 0.98 |

**Appendix Figure 5** Histograms of the frequency of pHNaF values for A, E, B, coffee rock, mud, peat and C horizons.

Carbon

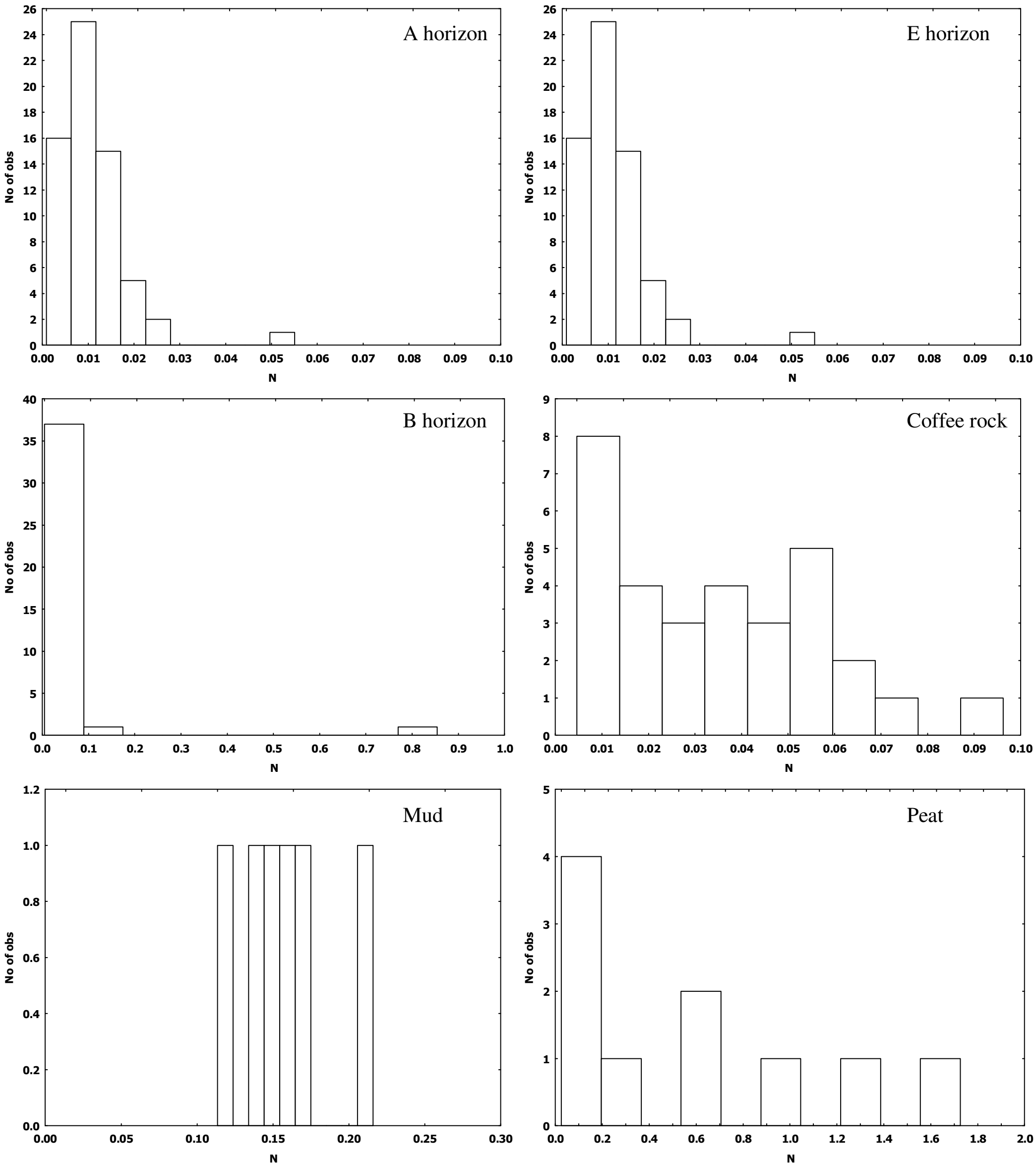


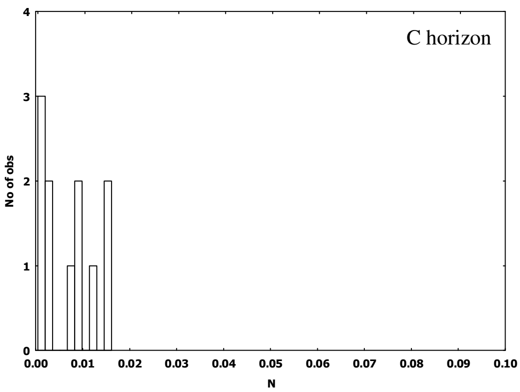




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 25 | 0.58 | 0.054 | 3.76 | 1.03 |
| E horizon | 64 | 0.07 | 0.017 | 1.18 | 0.27 |
| B horizon | 39 | 0.20 | 0.0042 | 3.27 | 0.74 |
| Coffee rock | 31 | 1.40 | 0.098 | 3.57 | 0.98 |
| Mud | 6 | 3.78 | 2.55 | 11 | 3.38 |
| Peat | 10 | 7.22 | 0.41 | 51 | 17 |
| C horizon | 11 | 0.07 | 0.016 | 3.49 | 1.03 |

**Appendix Figure 6** Histograms of the frequency of carbon values for A, E, B, coffee rock, mud, peat and C horizons (in percentage unit).

Nitrogen

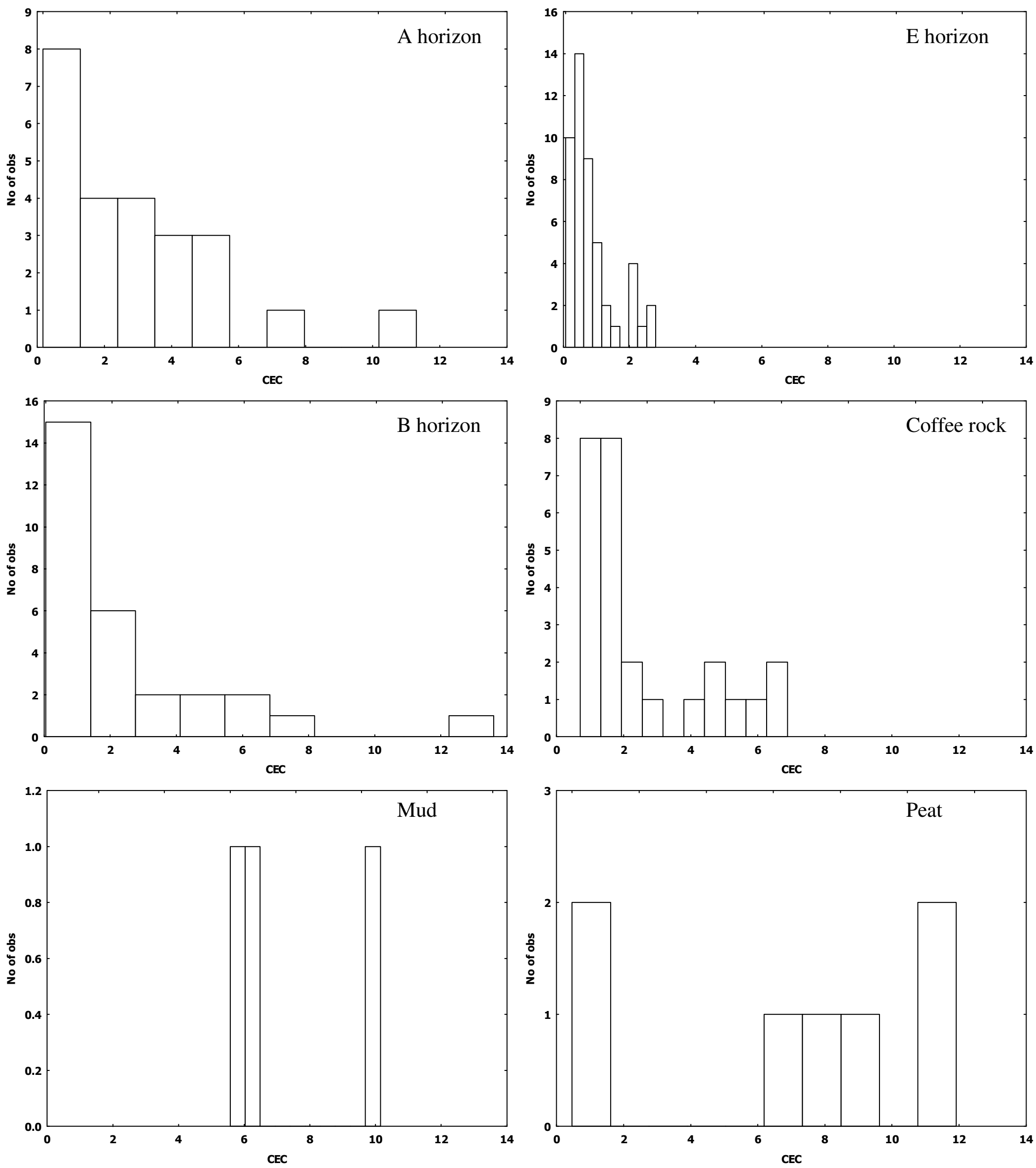


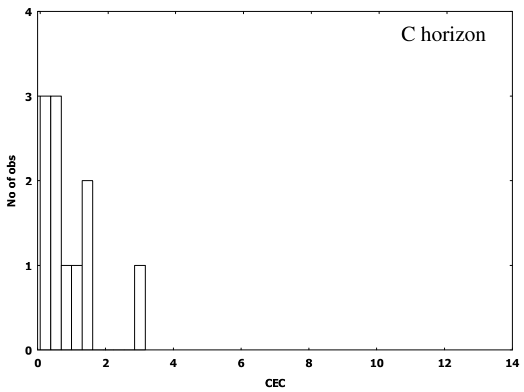




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 25 | 0.025 | 0.010 | 0.26 | 0.055 |
| E horizon | 64 | 0.010 | 0.00088 | 0.055 | 0.0080 |
| B horizon | 39 | 0.022 | 0.0045 | 0.85 | 0.13 |
| Coffee rock | 31 | 0.033 | 0.0046 | 0.10 | 0.023 |
| Mud | 6 | 0.16 | 0.11 | 0.22 | 0.034 |
| Peat | 10 | 0.45 | 0.025 | 1.73 | 0.58 |
| C horizon | 11 | 0.0083 | 0.0005 | 0.02 | 0.0059 |

**Appendix Figure 7** Histograms of the frequency of nitrogen values for A, E, B, coffee rock, mud, peat and C horizons (in percentage unit).

Cation exchange capacity

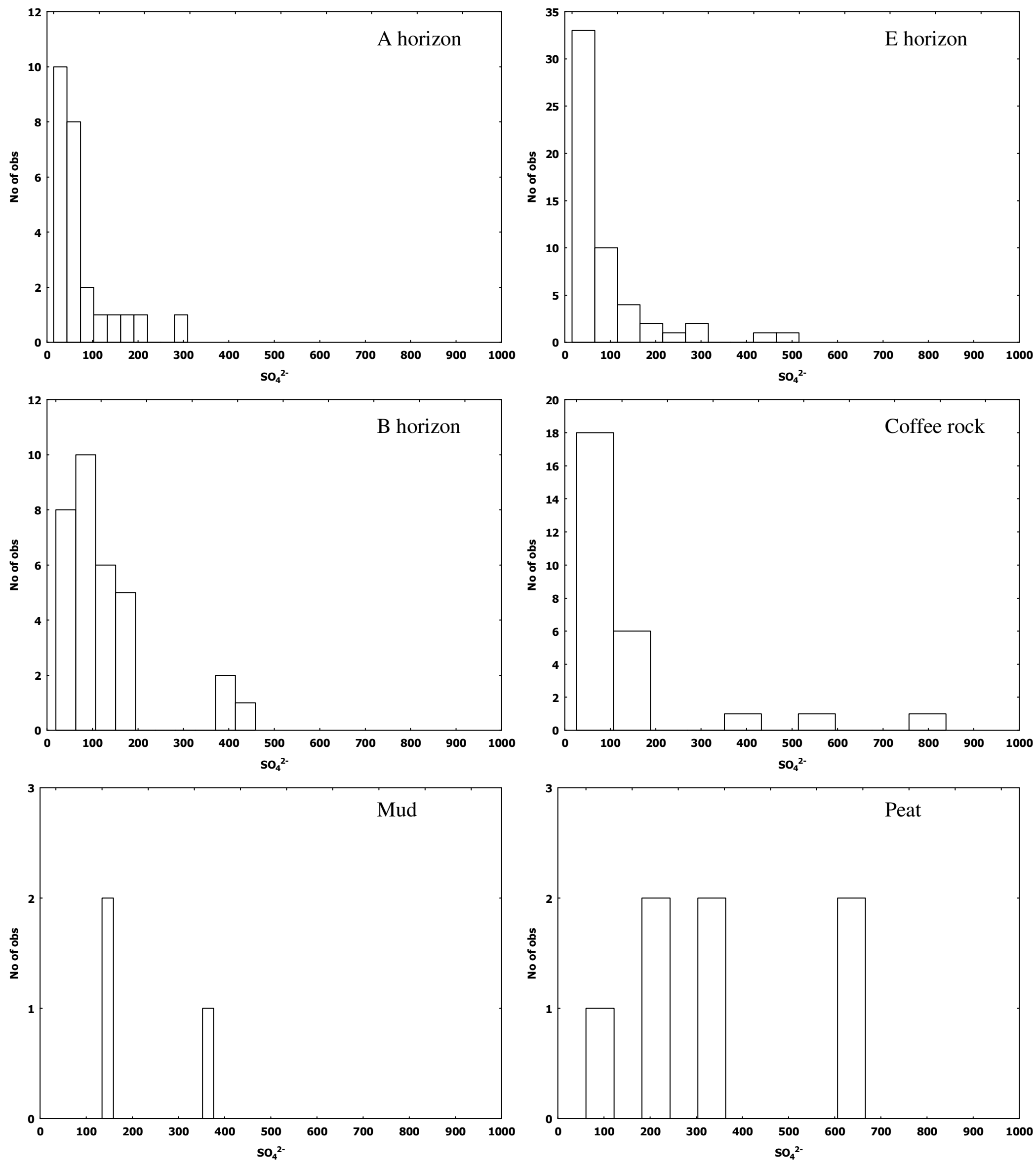


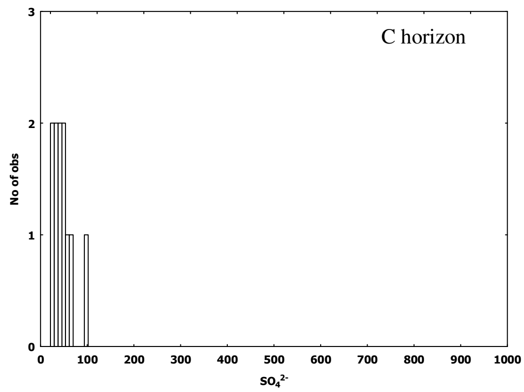




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 24 | 2.54 | 0.17 | 11.30 | 2.54 |
| E horizon | 48 | 0.60 | 0.068 | 2.79 | 0.69 |
| B horizon | 29 | 1.39 | 0.051 | 13.60 | 2.91 |
| Coffee rock | 26 | 1.78 | 0.70 | 6.88 | 1.92 |
| Mud | 3 | 6.15 | 5.57 | 10.15 | 2.49 |
| Peat | 7 | 8.00 | 0.46 | 11.92 | 4.55 |
| C horizon | 11 | 0.69 | 0.072 | 3.17 | 0.86 |

**Appendix Figure 8** Histograms of the frequency of cation exchange capacity values for A, E, B, coffee rock, mud, peat and C horizons (in meq/100g unit).

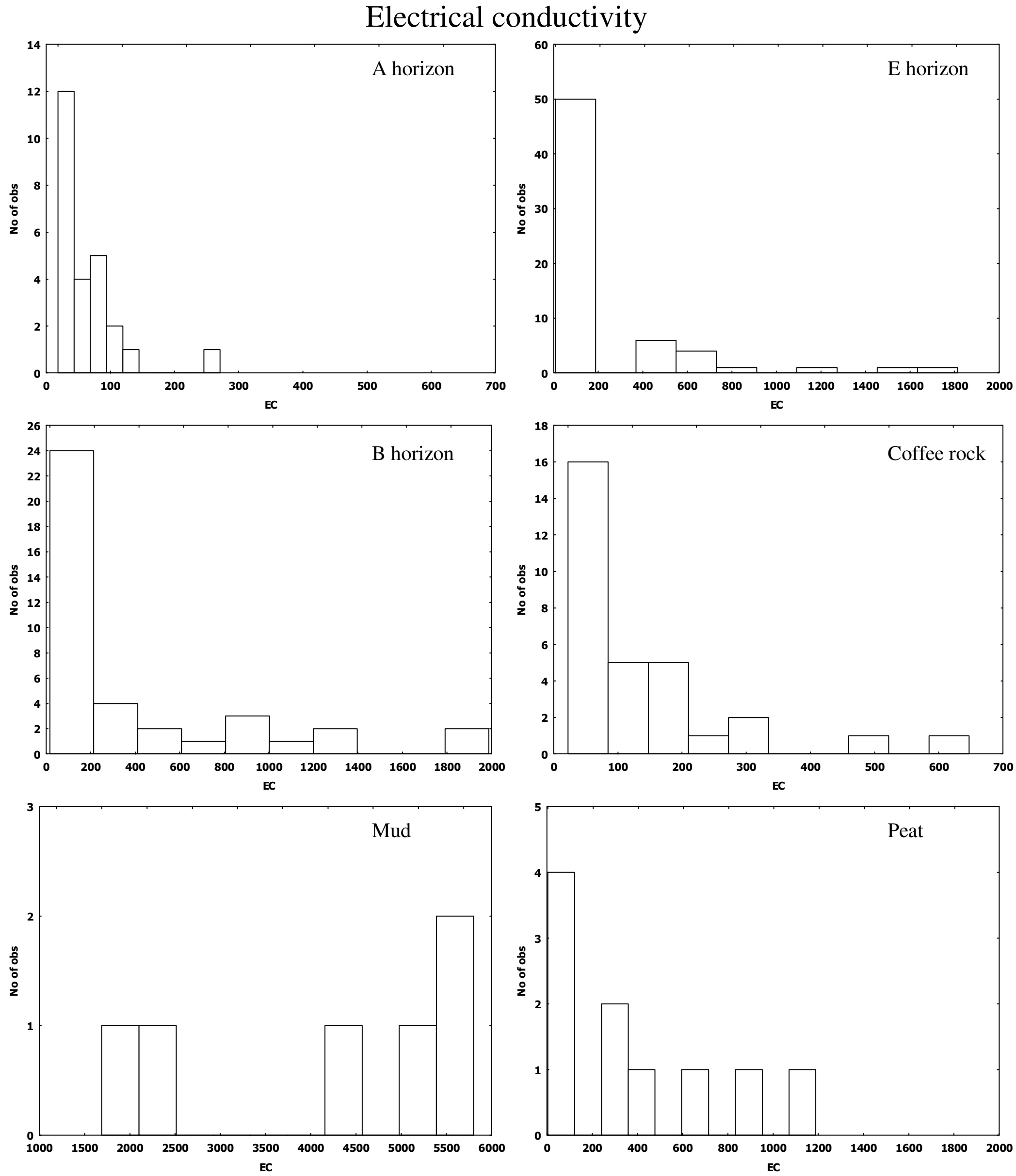
Soluble $SO_4^{2-}$

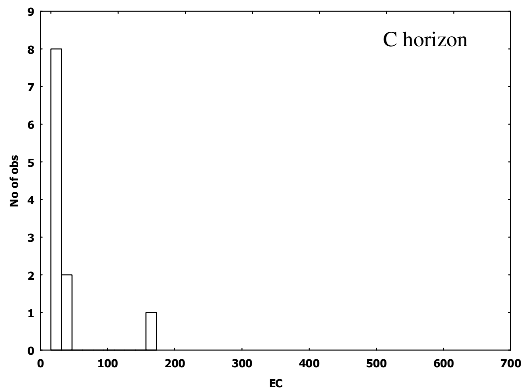



| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 25 | 59 | 14 | 310 | 72 |
| E horizon | 54 | 61 | 16 | 515 | 100 |
| B horizon | 32 | 103 | 19 | 458 | 107 |
| Coffee rock | 27 | 71 | 26 | 839 | 177 |
| Mud | 3 | 135 | 134 | 376 | 140 |
| Peat | 7 | 351 | 61 | 667 | 221 |
| C horizon | 11 | 45 | 21 | 102 | 22 |

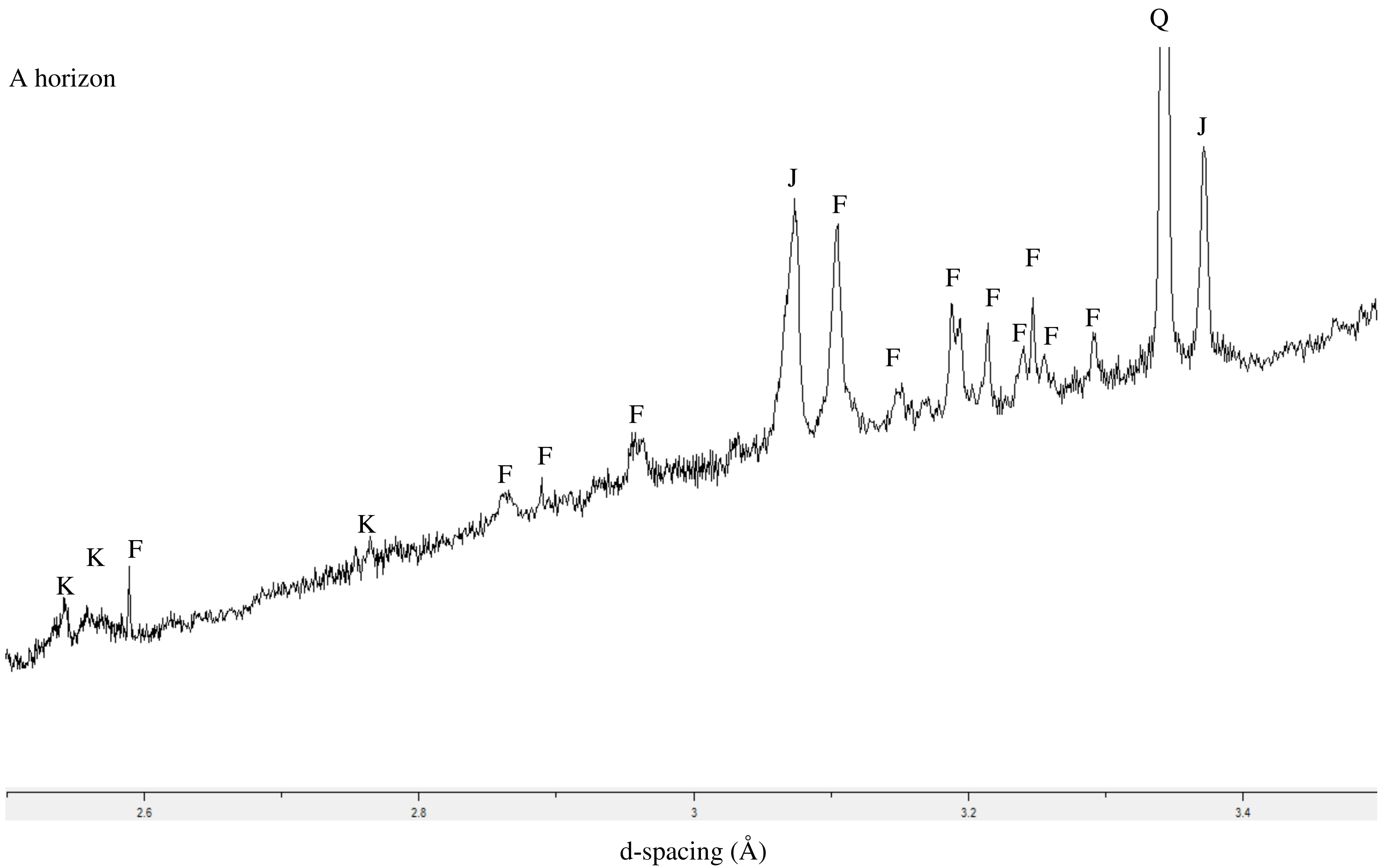
**Appendix Figure 9** Histograms of the frequency of soluble $SO_4^{2-}$ concentrations for A, E, B, coffee rock, mud, peat and C horizons (in mg $kg^{-1}$unit).



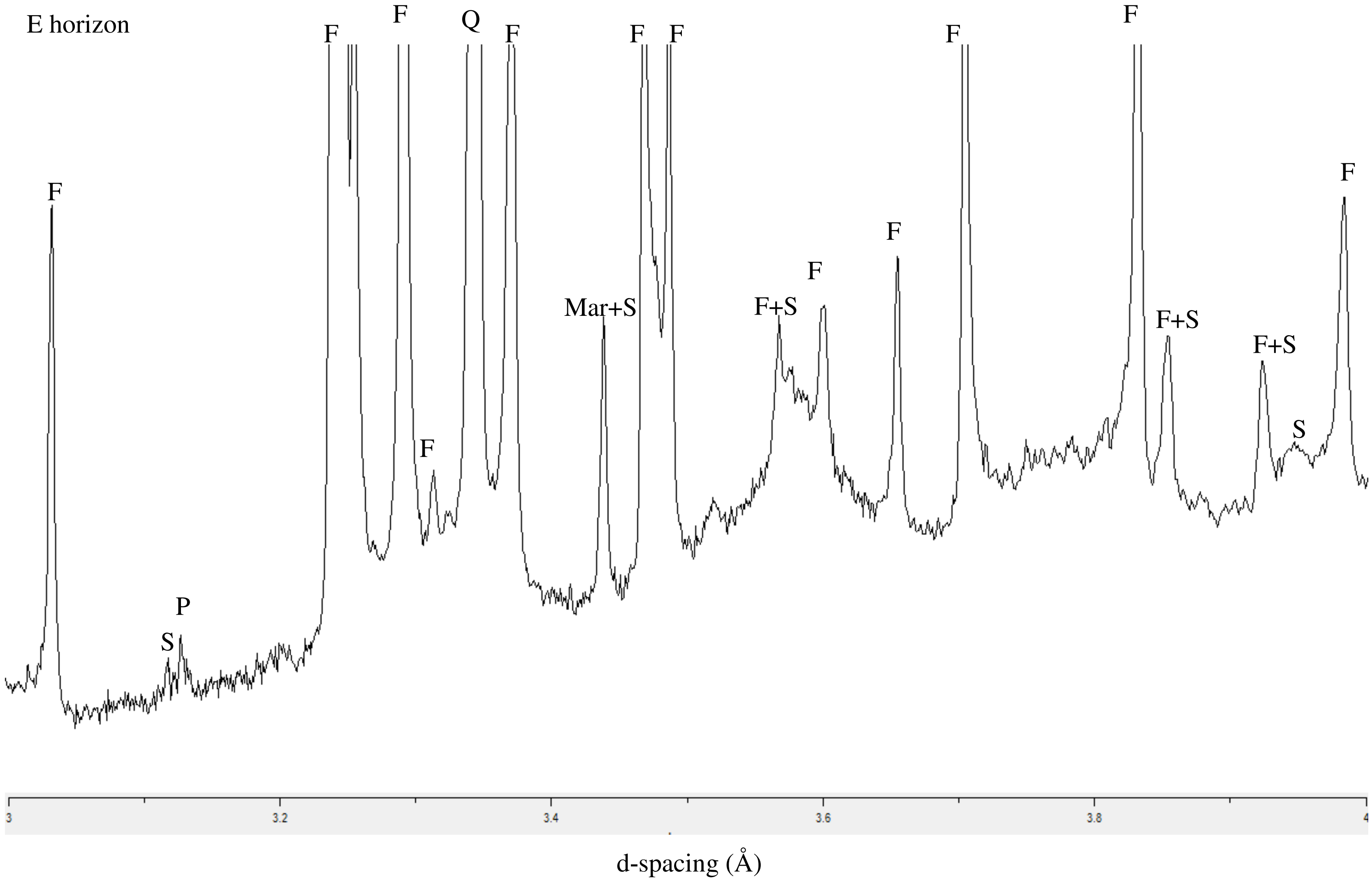




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 25 | 44 | 18 | 271 | 53 |
| E horizon | 64 | 50 | 8 | 1814 | 361 |
| B horizon | 39 | 150 | 17 | 1988 | 507 |
| Coffee rock | 31 | 84 | 23 | 647 | 137 |
| Mud | 6 | 4805 | 1691 | 5800 | 1750 |
| Peat | 10 | 309 | 4 | 1189 | 405 |
| C horizon | 11 | 20 | 16 | 173 | 46 |

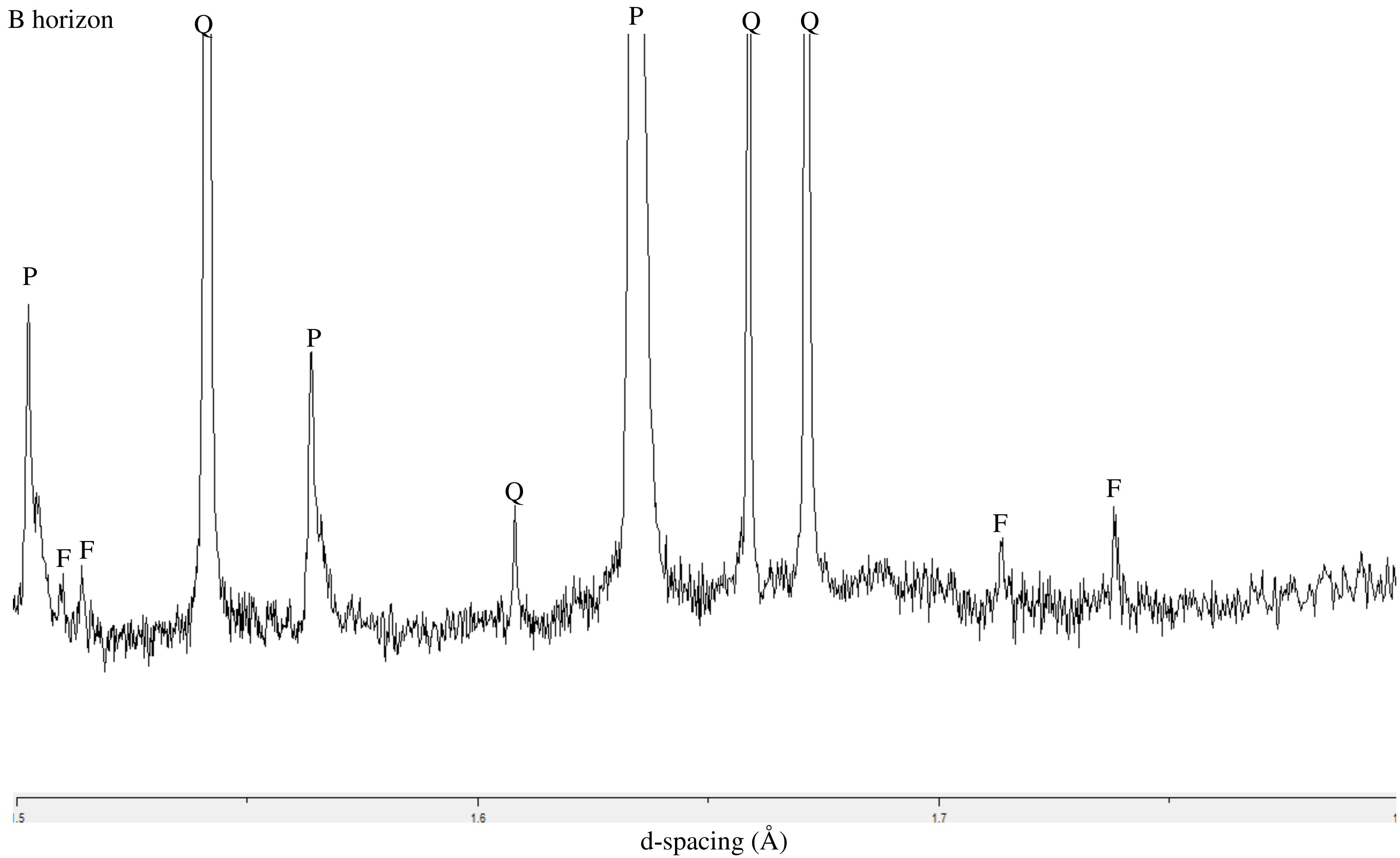
**Appendix Figure 10** Histograms of the frequency of electrical conductivity values for A, E, B, coffee rock, mud, peat and C horizons (in µS/ cm unit).



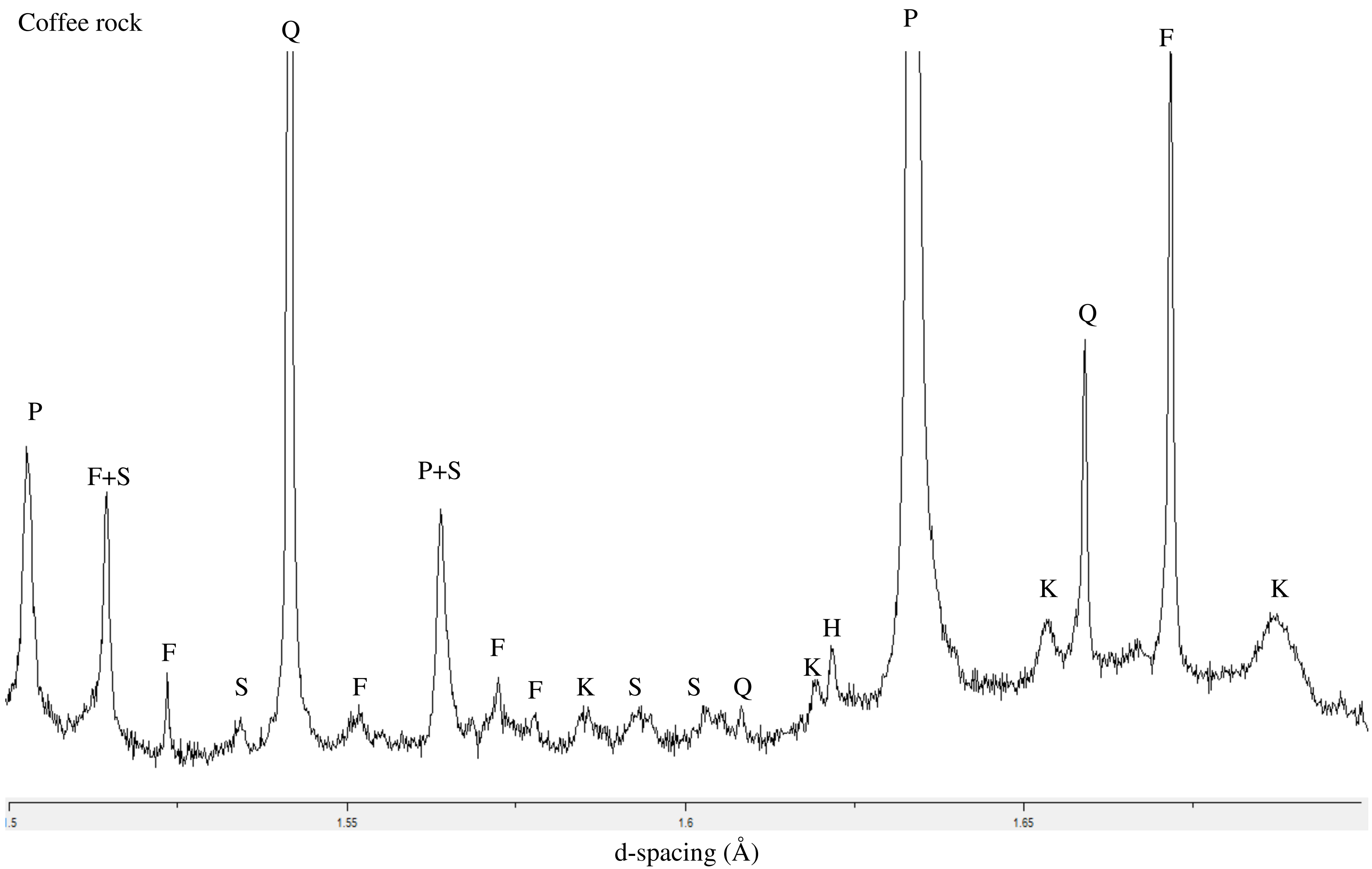

**Appendix Figure 11** Synchrotron XRD pattern of the fine fraction from the A horizon (0-100 cm, site 616-02-094) (pHF = 4.5, pHFOX = 2.1, Scr = 0.09%) (Q = Quartz, F = Feldspar, K = Kaolin, J = Jarosite).



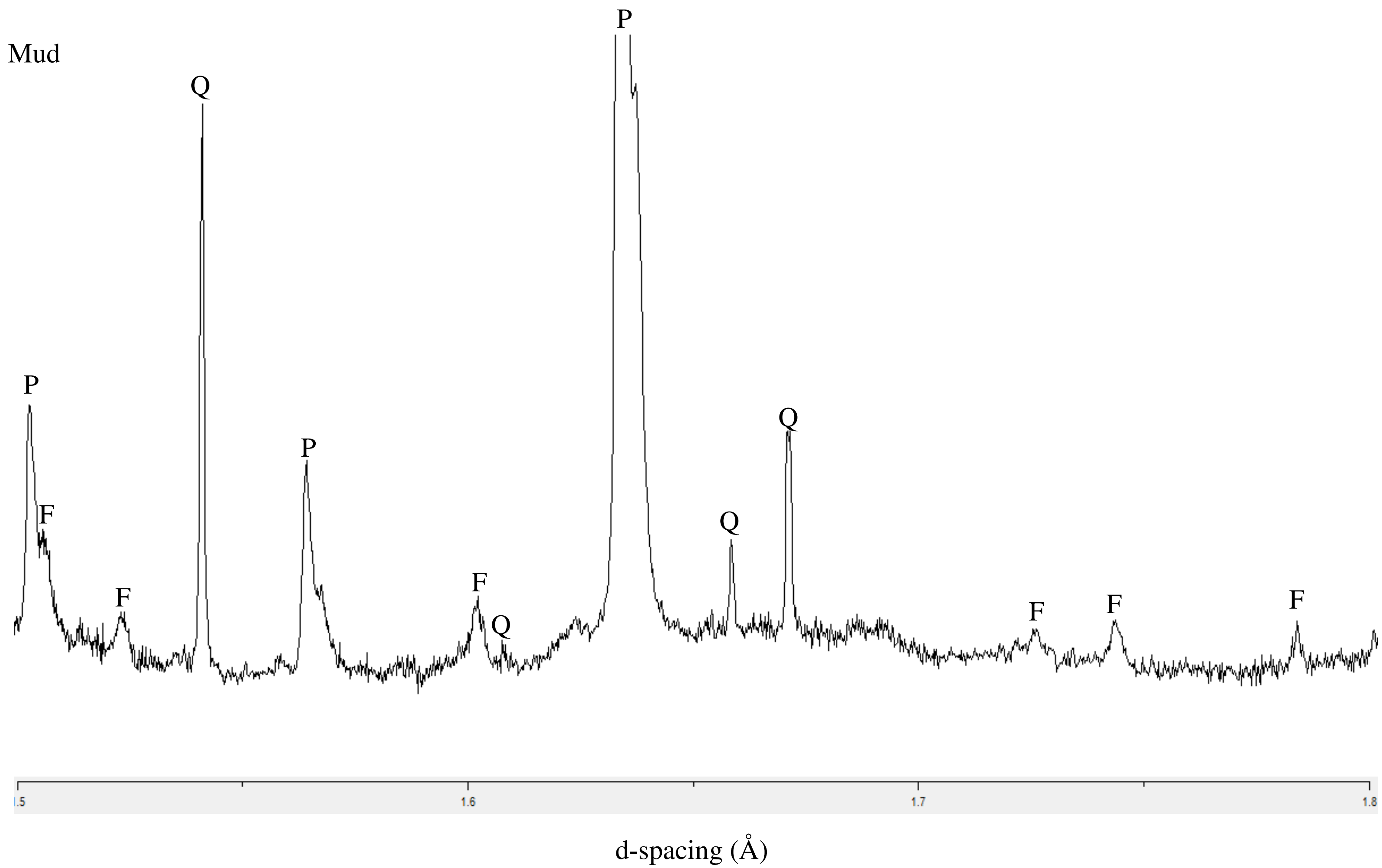

**Appendix Figure 12** Synchrotron XRD pattern of the fine fraction from the E horizon (260-600 cm, site 616-02-136) (pHF = 6.3, pHFOX = 2.0, Scr = 0.02%) (Q = Quartz, F = Feldspar, K = Kaolin, P = Pyrite, S = Elemental S, Mar = Marcasite).



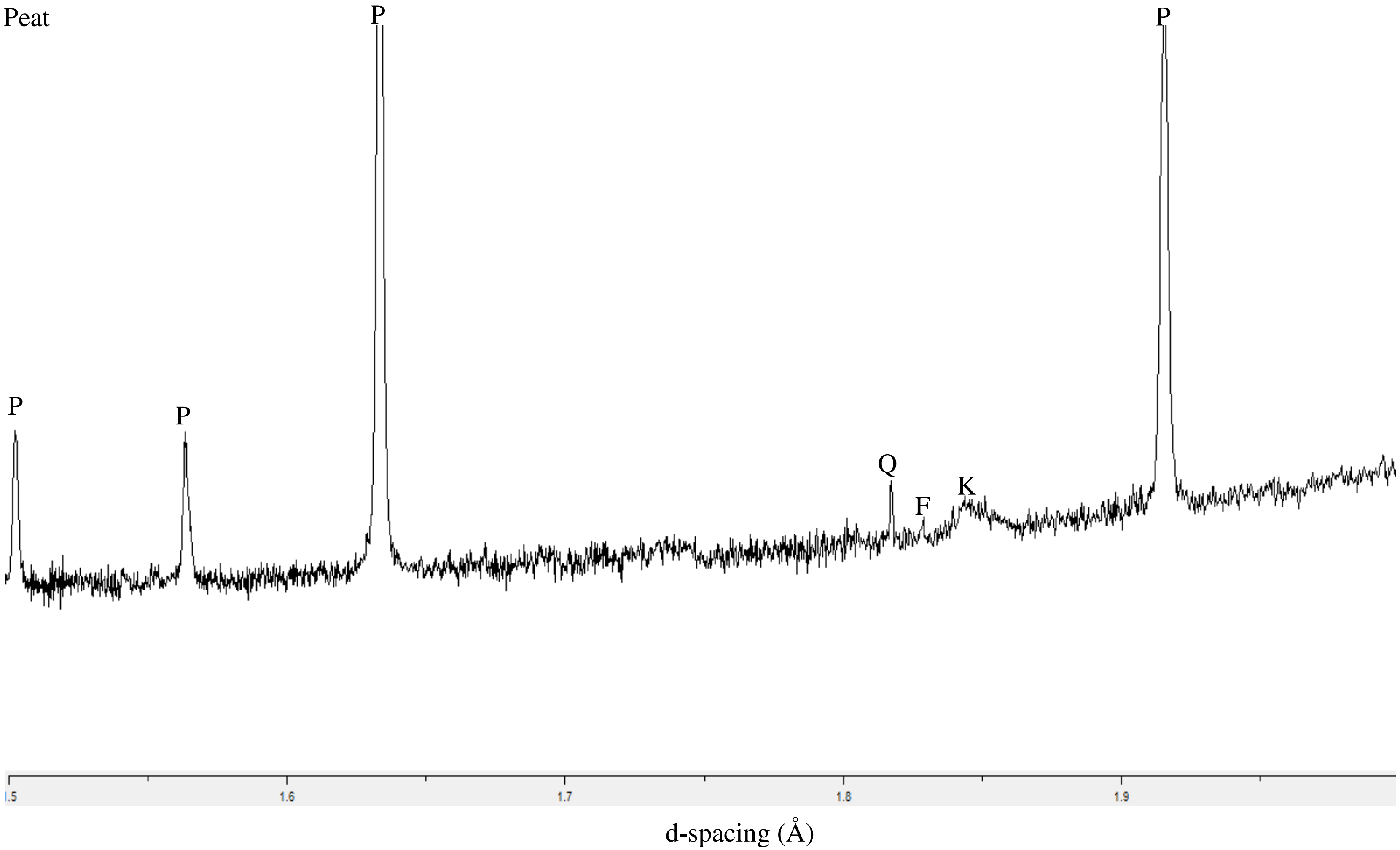

**Appendix Figure 13** Synchrotron XRD pattern of the fine fraction from the B horizon (300-400 cm, site 616-02-099) (pHF = 7.2, pHFOX = 1.8, Scr = 0.12%) (Q = Quartz, F = Feldspar, K = Kaolin, P = Pyrite).



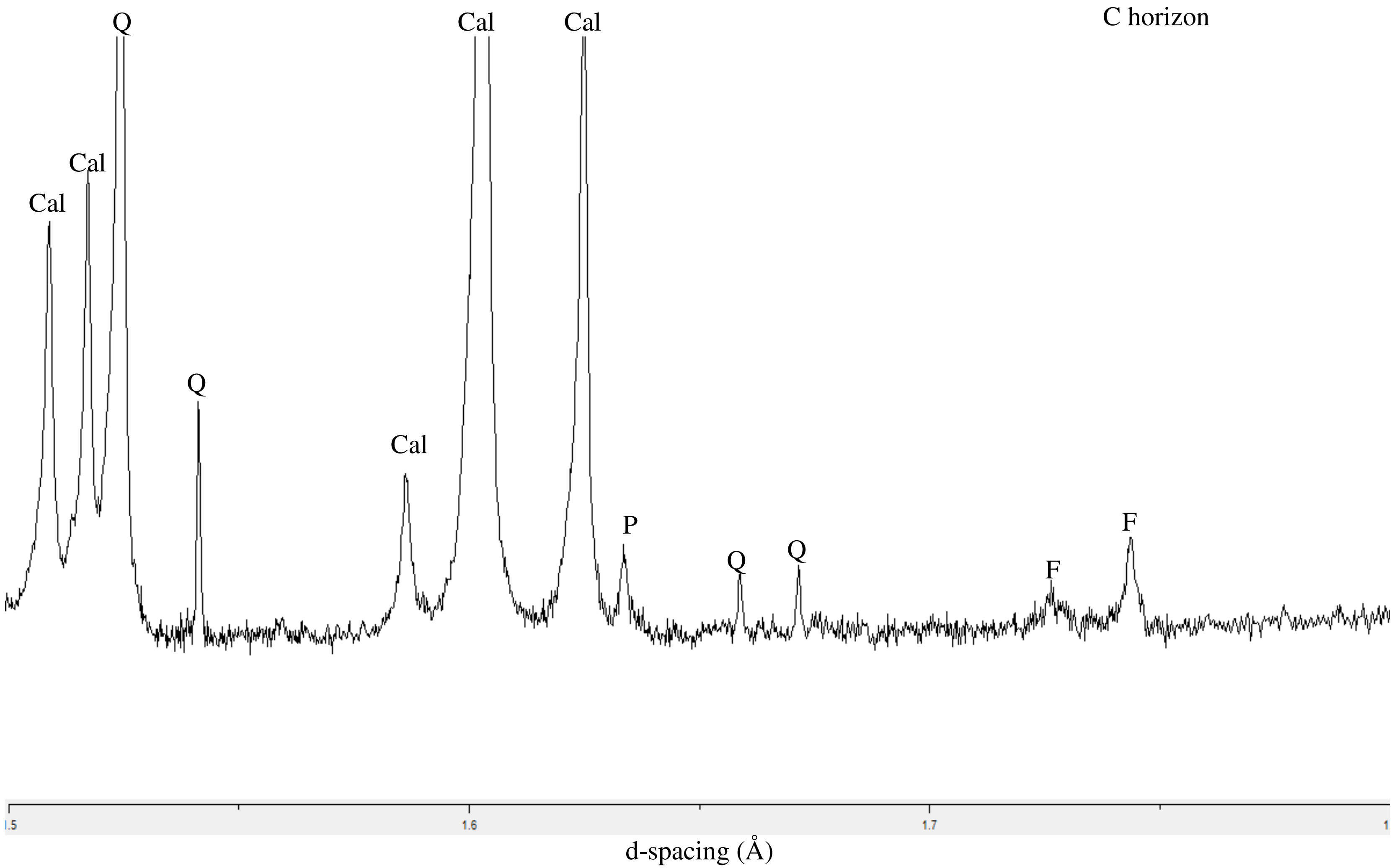

**Appendix Figure 14** Synchrotron XRD pattern of the fine fraction from the coffee rock (500-600 cm, site 616-02-082) (pHF = 6.7, pHFOX = 1.5, No Scr data) (Q = Quartz, F = Feldspar, K = Kaolin, P = Pyrite, S = Elemental S, H = Halite).




**Appendix Figure 15** Synchrotron XRD pattern of the fine fraction from the mud of (200-250 m, site 616-02-028) (pHF = 7.4, pHFOX = 6.0, No Scr data) (Q = Quartz, F = Feldspar, P = Pyrite).

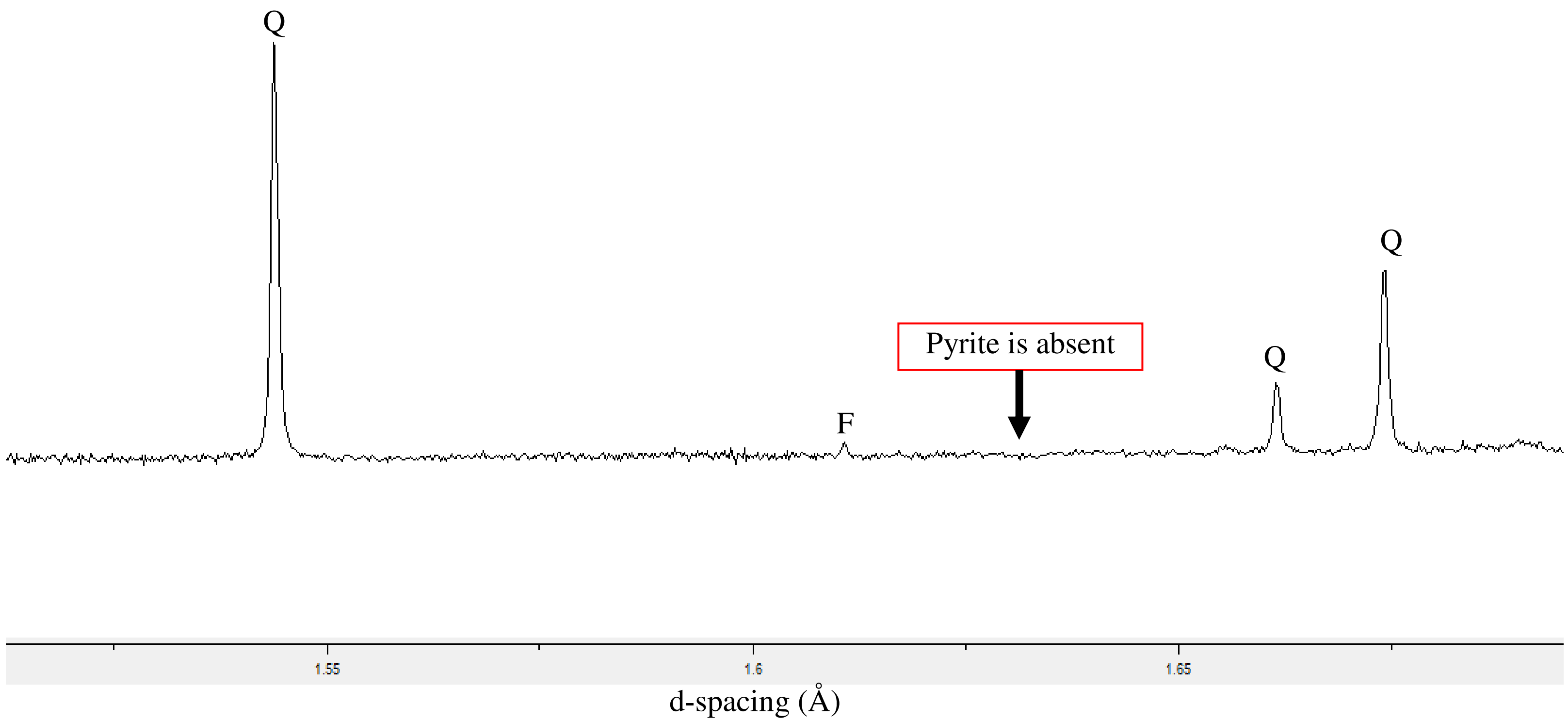



**Appendix Figure 16** Synchrotron XRD pattern of the fine fraction from the peat (250-360 cm, site 616-02-105) (pHF = 6.3, pHFOX = 1.4, Scr = 1.97%) (Q = Quartz, F = Feldspar, K = Kaolin, P = Pyrite).

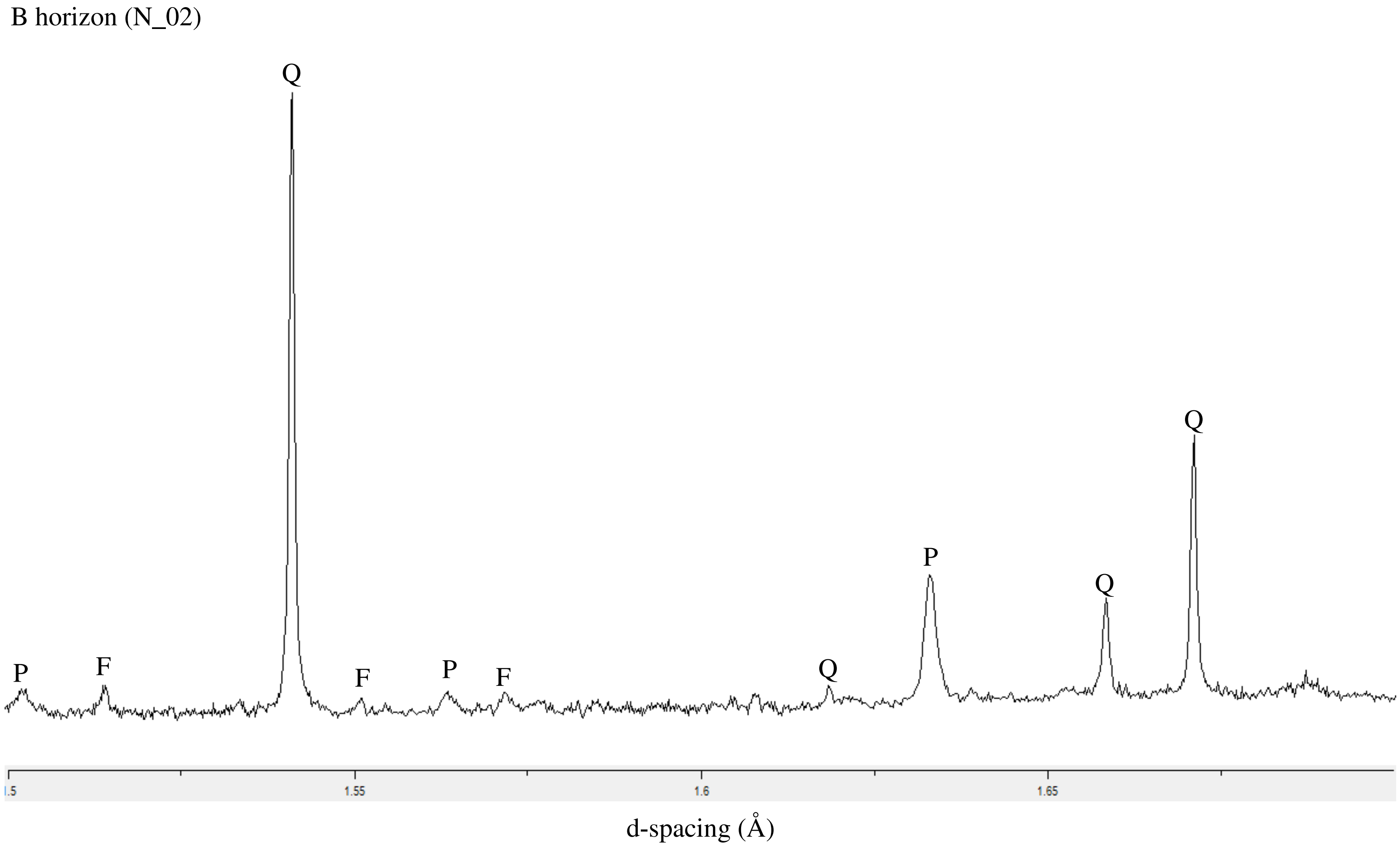



**Appendix Figure 17** Synchrotron XRD pattern of the fine fraction from the C horizon (400-600 cm, site 616-02-112) (pHF = 7.9, pHFOX = 6.5, No Scr data) (Q = Quartz, F = Feldspar, P = Pyrite, Cal = Calcite).

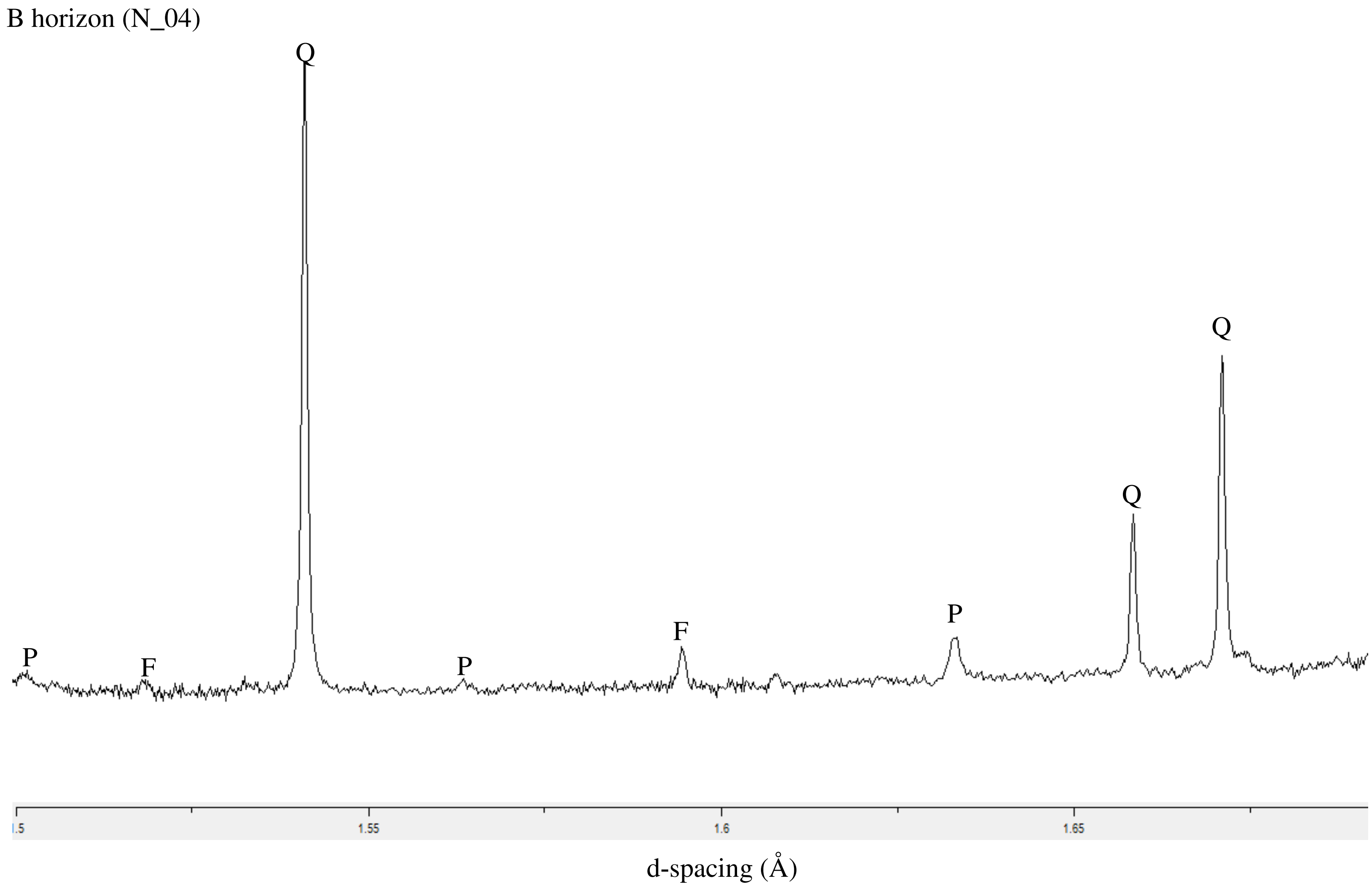
B horizon (N_01)



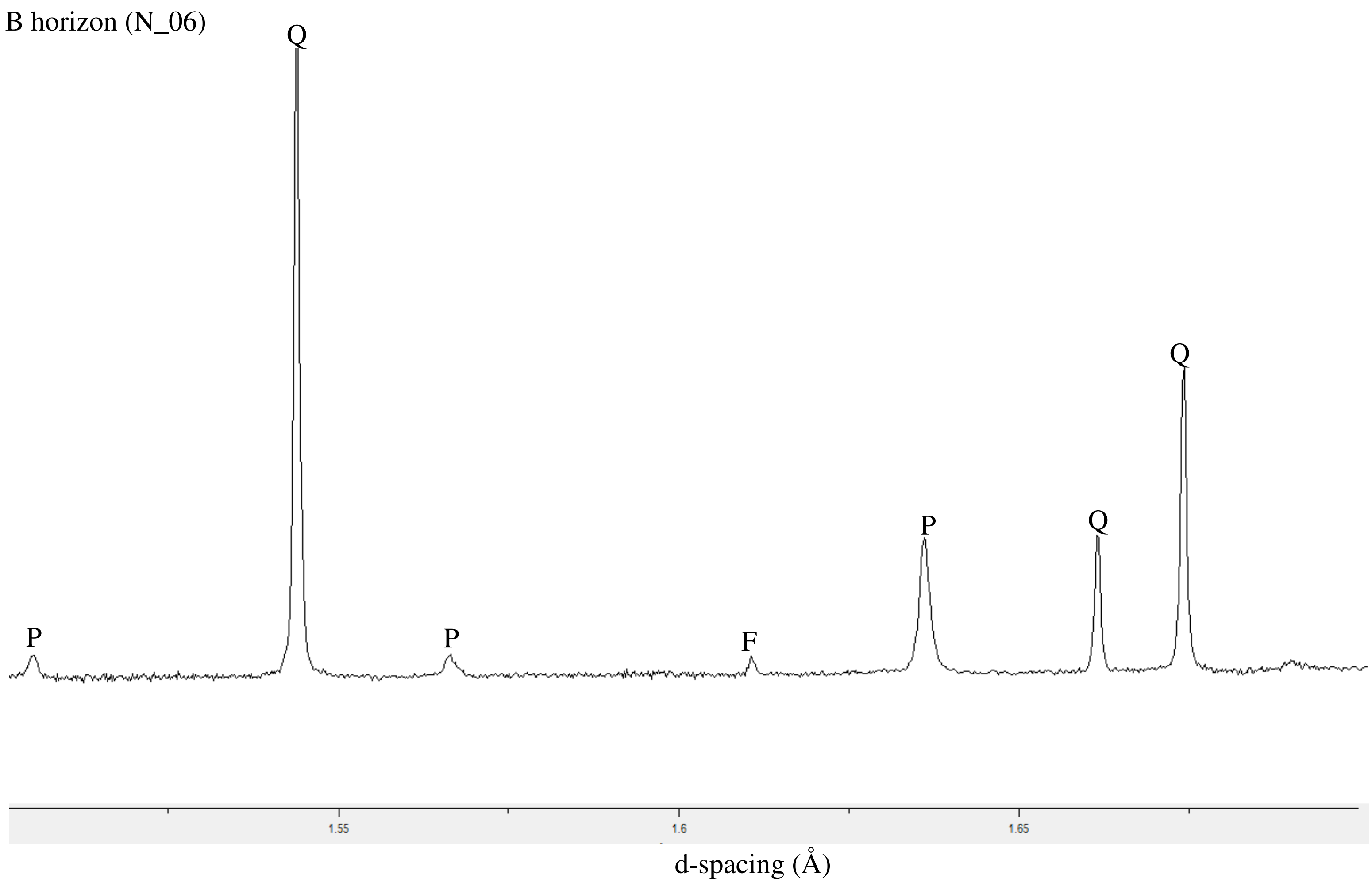

**Appendix Figure 18** Synchrotron XRD pattern of the fine fraction from the B horizon (620-630 cm, site 616-01-005) (pHF = 5.5, pHFOX = 2.7, Scr = 0.014%) (Q = Quartz; F = Feldspar).



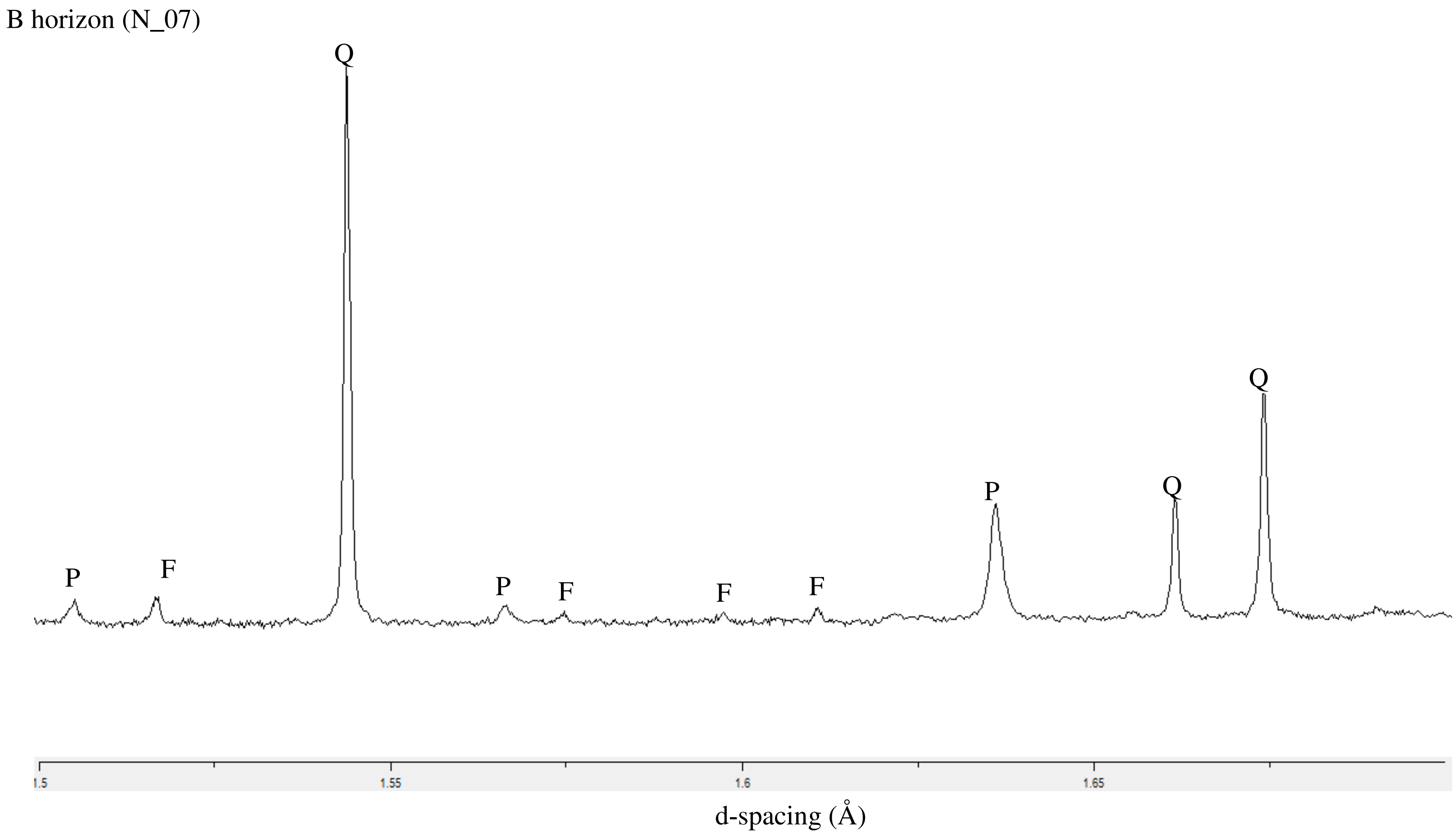

**Appendix Figure 19** Synchrotron XRD pattern of the fine fraction from the B horizon (450 cm, site 616-02-068) (pHF = 7.2, pHFOX = 1.8, Scr = 0.027%) (Q = Quartz, F = Feldspar, P =Pyrite).



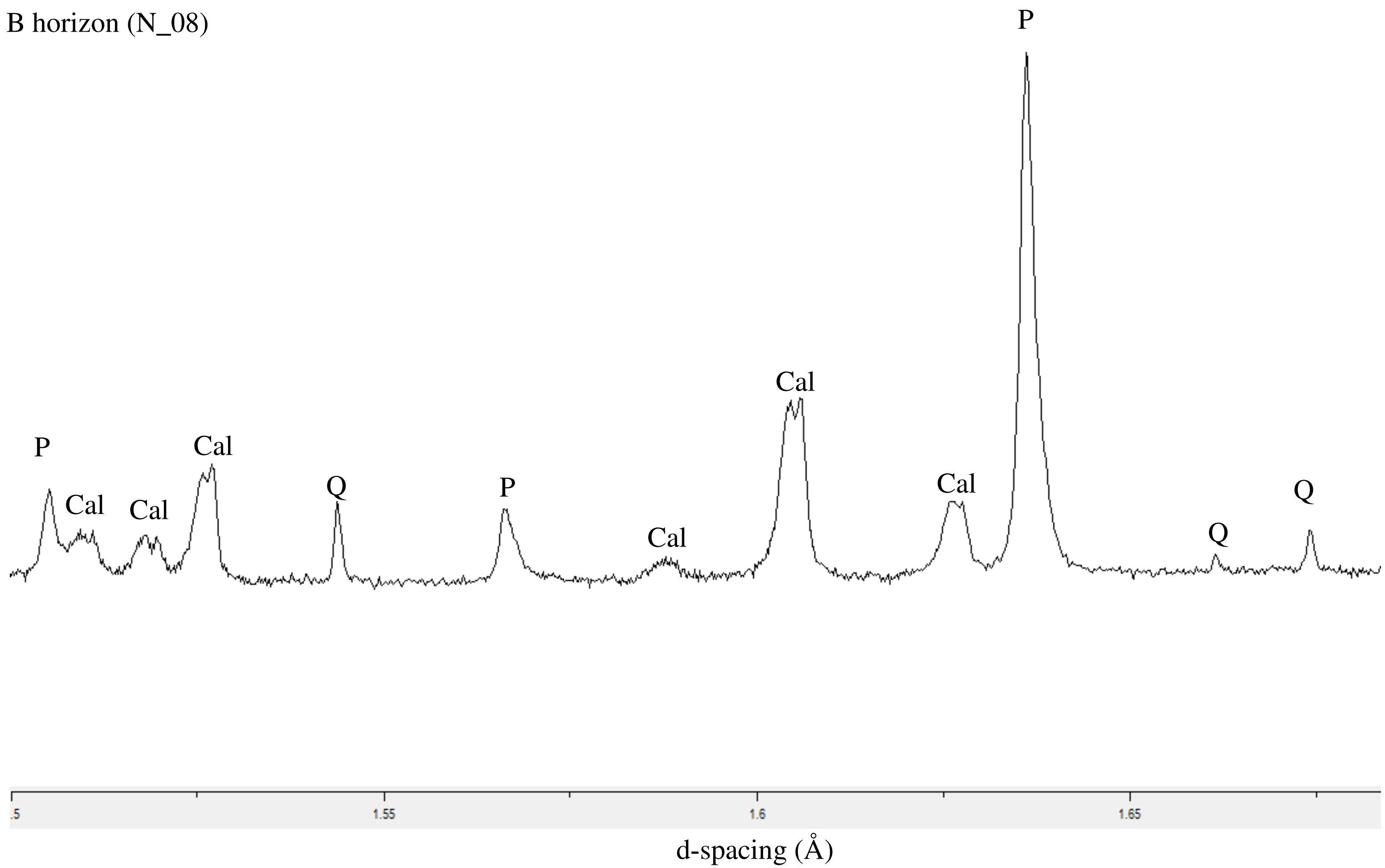

**Appendix Figure 20** Synchrotron XRD pattern of the fine fraction from the B horizon (375-400 cm, site 616-02-179) (pHF = 6.1, pHFOX = 1.6, Scr = 0.013%) (Q = Quartz, F = Feldspar, P =Pyrite).



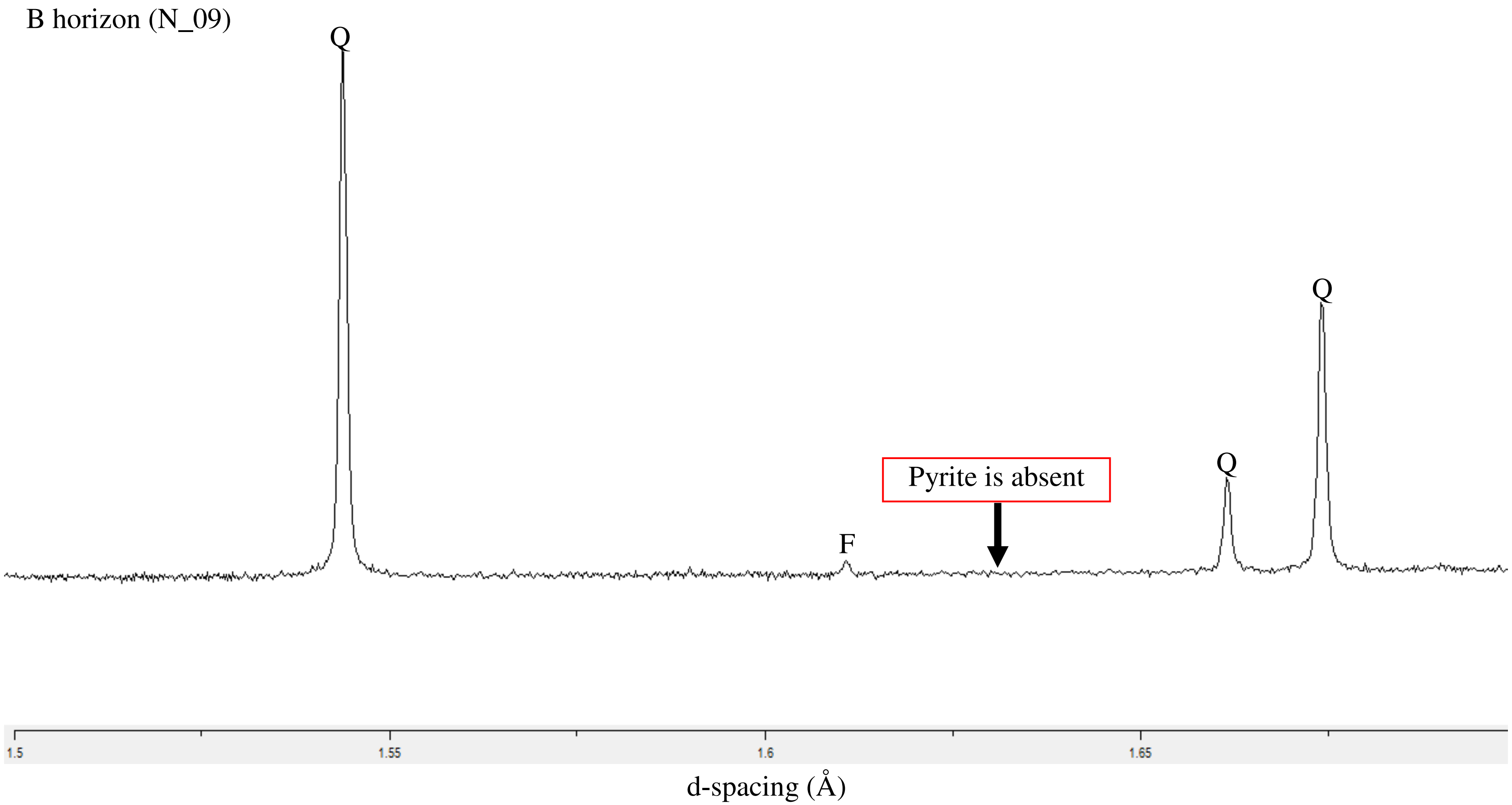

**Appendix Figure 21** Synchrotron XRD pattern of the fine fraction from the B horizon (400-500 cm, site 616-02-078) (pHF = 4.8, pHFOX = 1.5, Scr = 0.014%) (Q = Quartz, F = Feldspar, P =Pyrite).



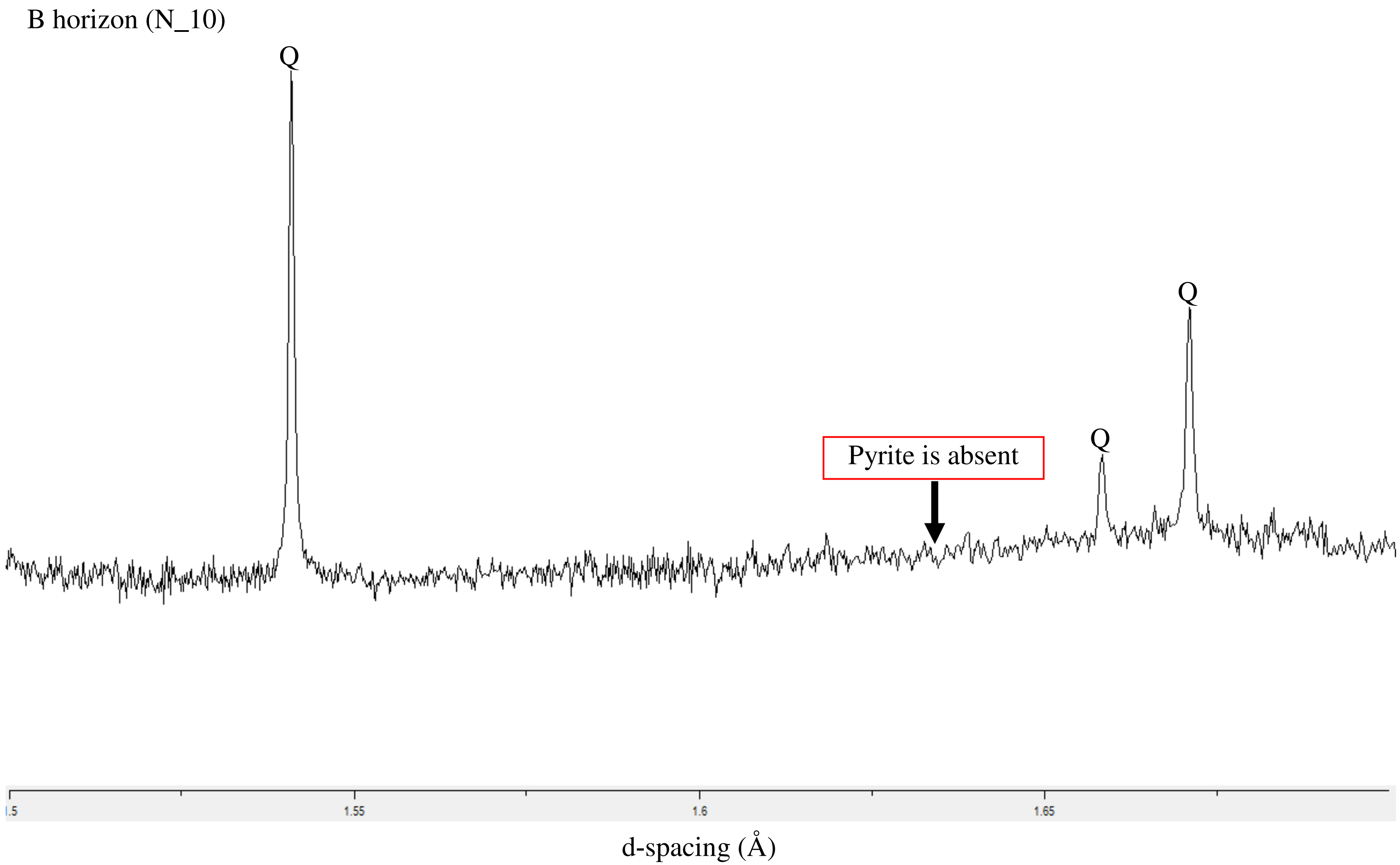

**Appendix Figure 22** Synchrotron XRD pattern of the fine fraction from the B horizon (400-800 cm, site 616-02-081) (pHF = 6.2, pHFOX = 1.4, Scr = 0.052%) (Q = Quartz, F = Feldspar, P =Pyrite).




**Appendix Figure 23** Synchrotron XRD pattern of the fine fraction from the B horizon (200-500 cm, site 616-02-110) (pHF = 6.3, pHFOX = 1.8, Scr = 0.036%) (Q = Quartz, Cal = Calcite, P =Pyrite).

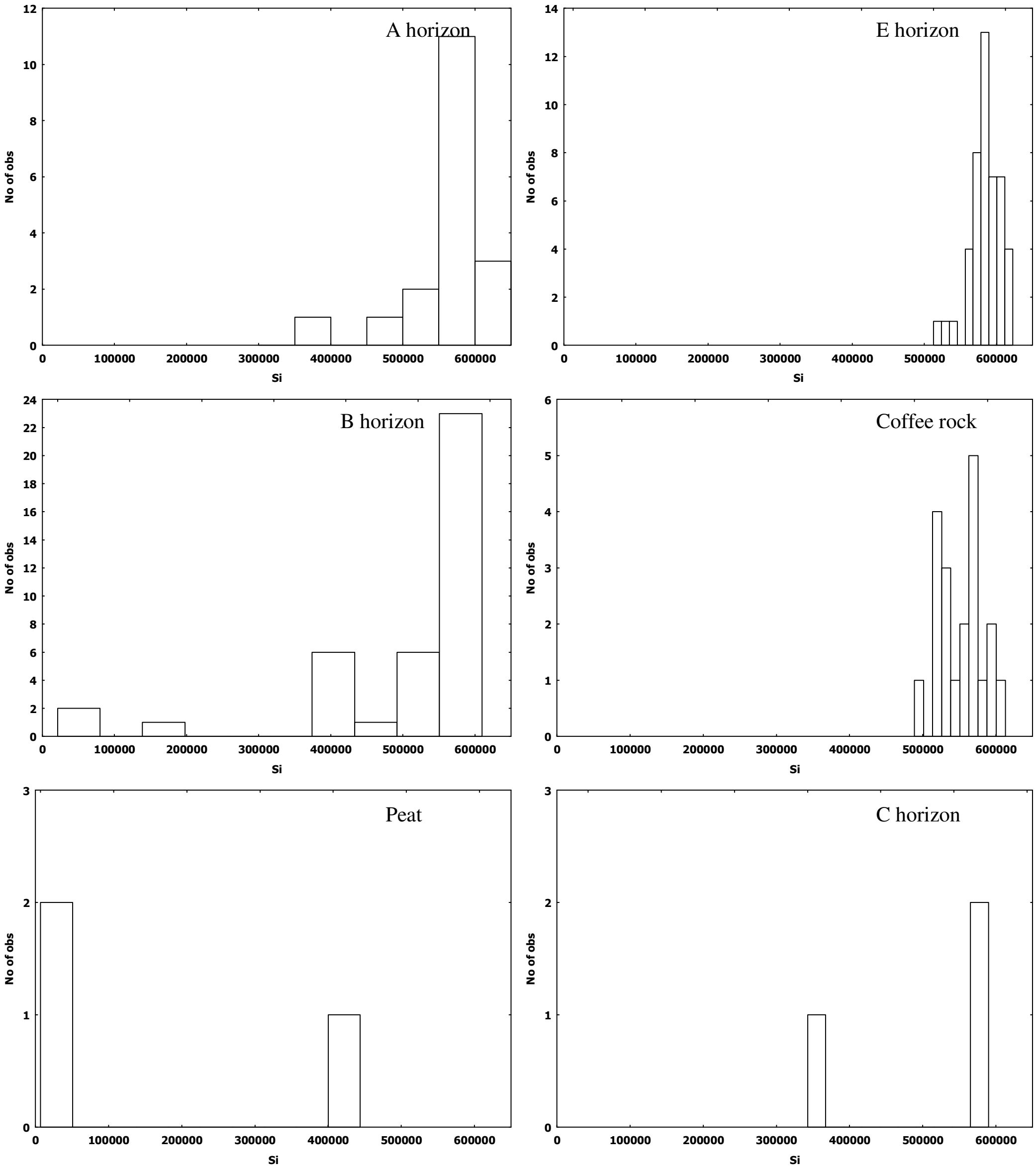



**Appendix Figure 24** Synchrotron XRD pattern of the fine fraction from the B horizon (250-550 cm, site 616-02-174) (pHF = 5.5, pHFOX = 2.5, Scr = <0.005%) (Q = Quartz, F = Feldspar).




**Appendix Figure 25** Synchrotron XRD pattern of the fine fraction from the B horizon (200 cm, site 616-02-065) (pHF = 5.7, pHFOX = 3.0, Scr = 0.005%) (Q = Quartz)

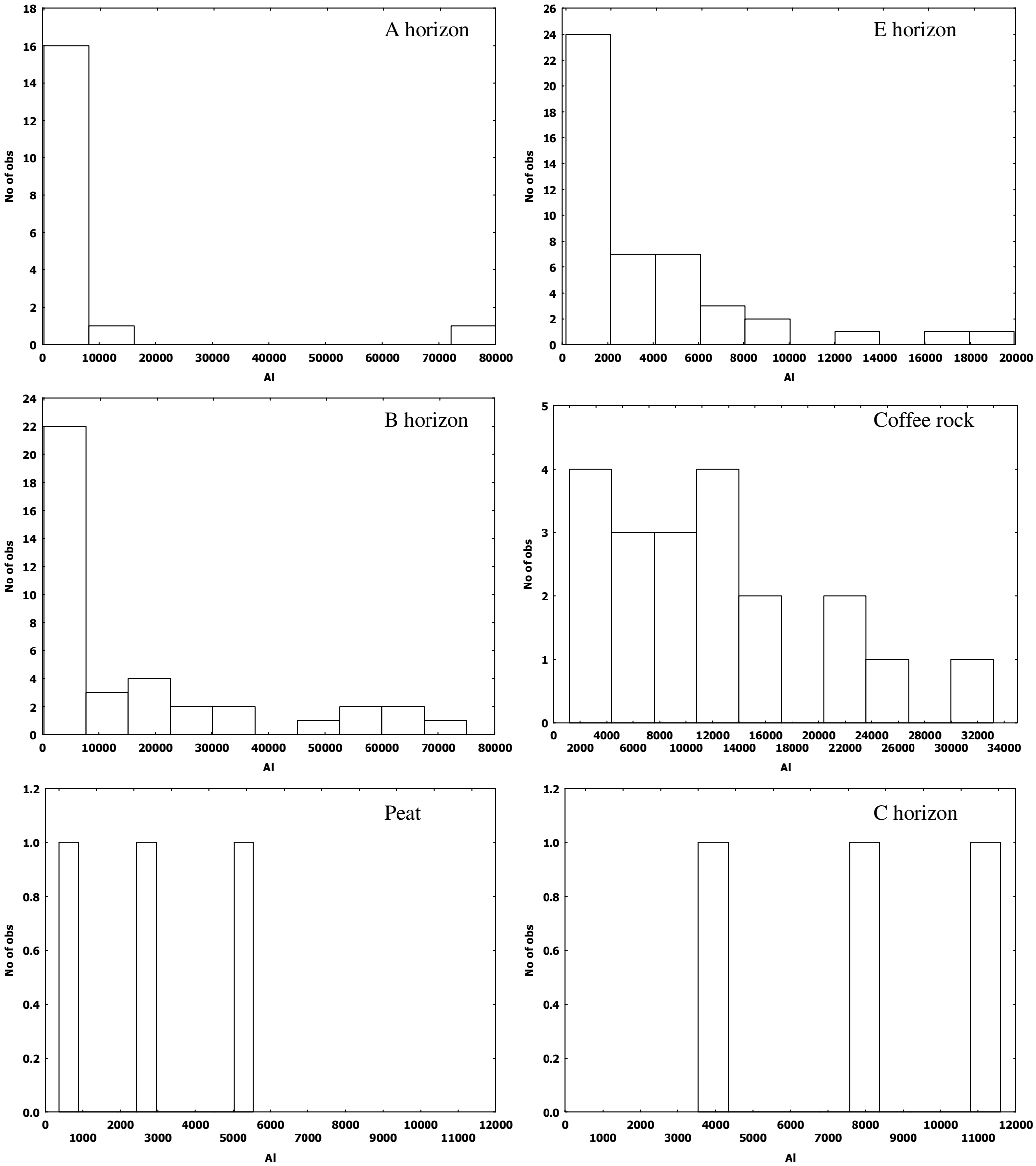
## Si




| Horizon | Valid N | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 586724 | 372001 | 625790 | 61105 |
| E horizon | 46 | 585509 | 512696 | 622488 | 21920 |
| B horizon | 39 | 557836 | 21030 | 609737 | 138732 |
| Coffee rock | 20 | 558393 | 488632 | 612839 | 30877 |
| Peat | 3 | 36140 | 6914 | 443875 | 244280 |
| C horizon | 3 | 581823 | 342593 | 589859 | 140497 |
| Mean values for normal surface soils worldwide 250000-410000 mg $kg^{-1}$* | | | | | |

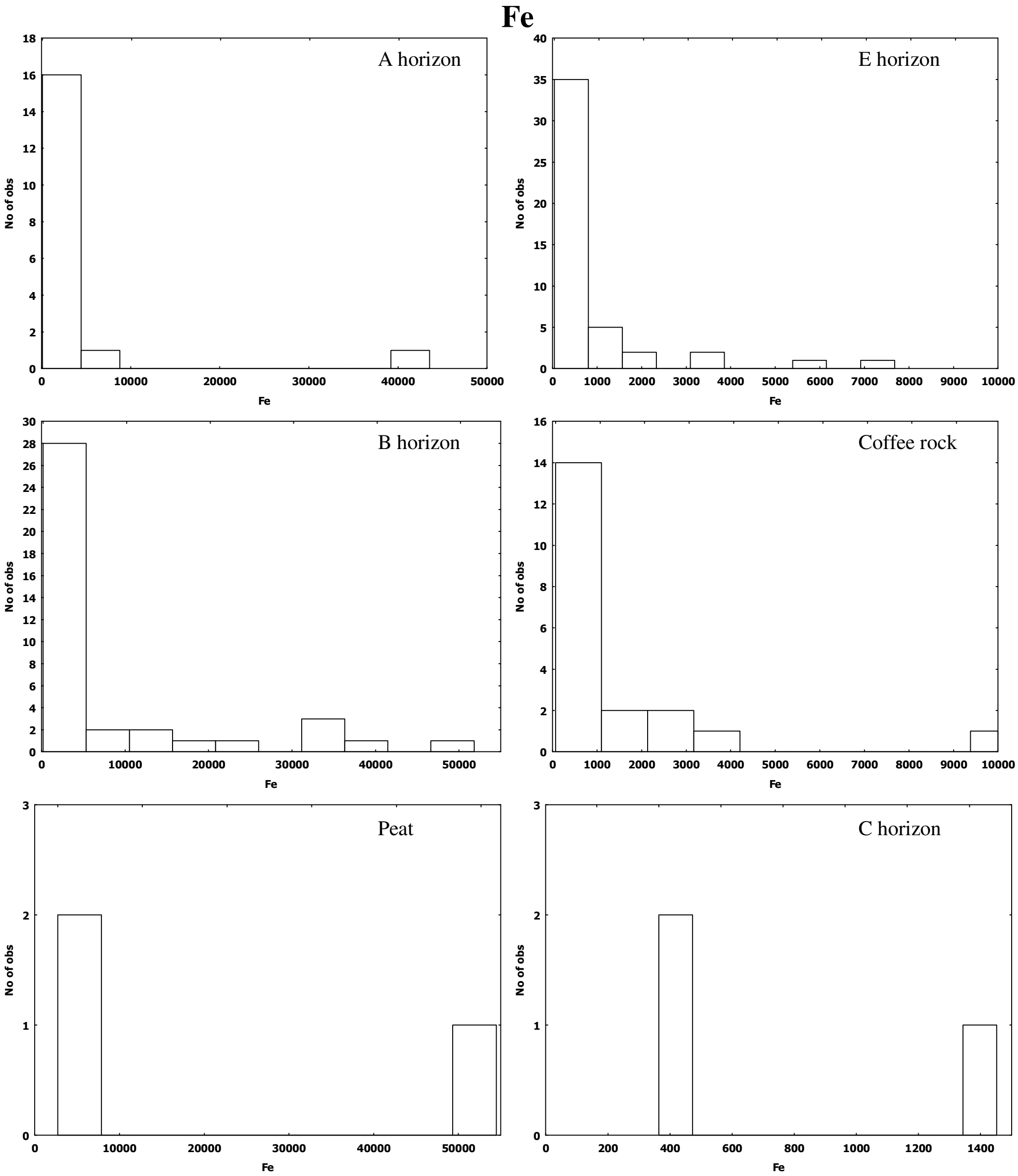
**Appendix Figure 26** Histograms for the concentration of silicon (Si) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (fusion acid digestion method; ICP-OES).
* Data are from Kabata-Pendias (2001), Essington (2004).

**Al**



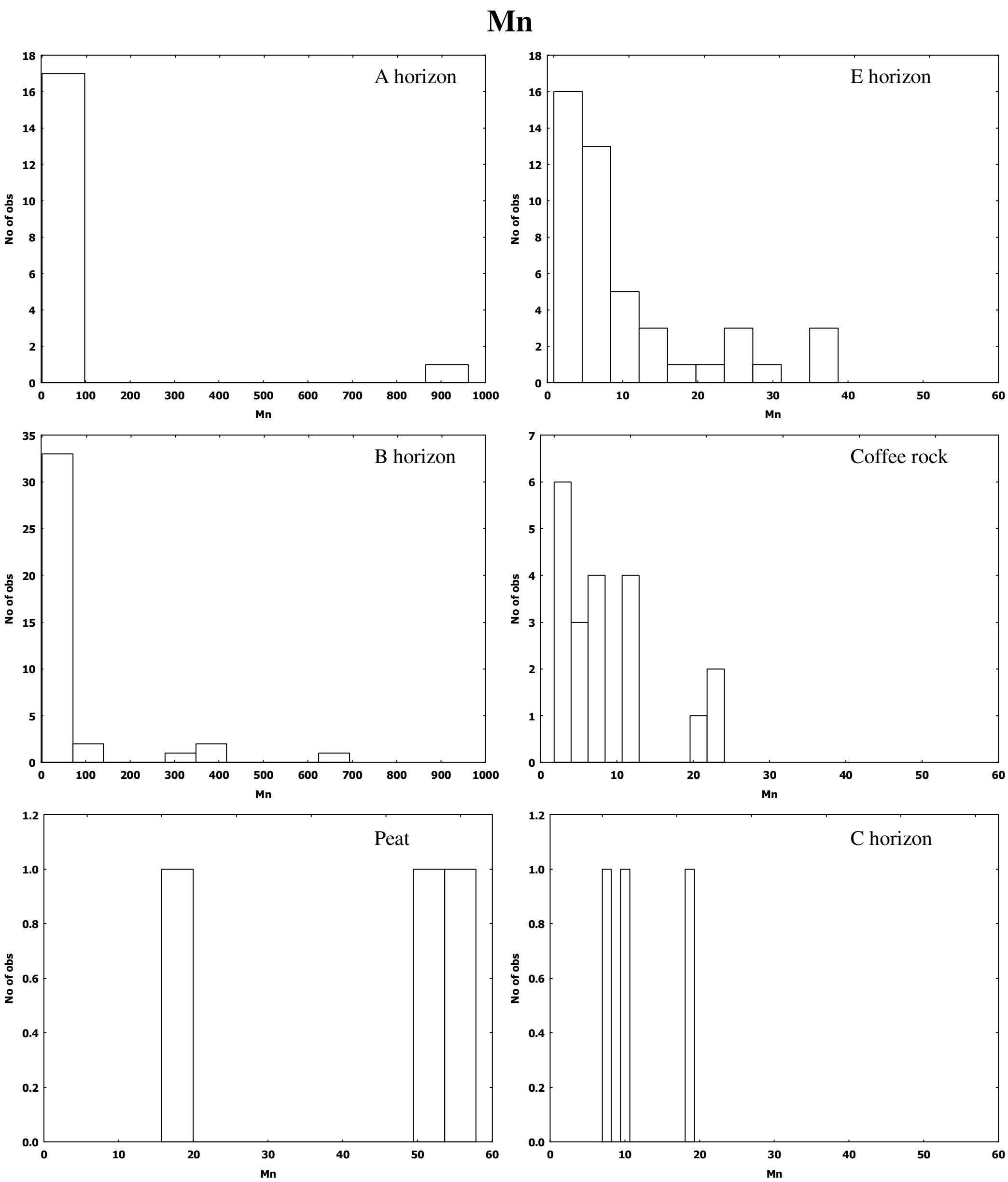

| Horizon | Valid N | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 846 | 276 | 80116 | 18574 |
| E horizon | 46 | 1683 | 162 | 19930 | 4342 |
| B horizon | 39 | 6365 | 303 | 74968 | 20838 |
| Coffee rock | 20 | 10695 | 1201 | 33192 | 8406 |
| Peat | 3 | 2478 | 363 | 5547 | 2607 |
| C horizon | 3 | 8304 | 3542 | 11603 | 4053 |
| Mean values for normal surface soils worldwide 10000-300000 mg $kg^{-1*}$ | | | | | |

**Appendix Figure 27** Histograms for the concentration of aluminium (Al) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (fusion acid digestion method; ICP-OES). * Data are from Kabata-Pendias (2001), Essington (2004).



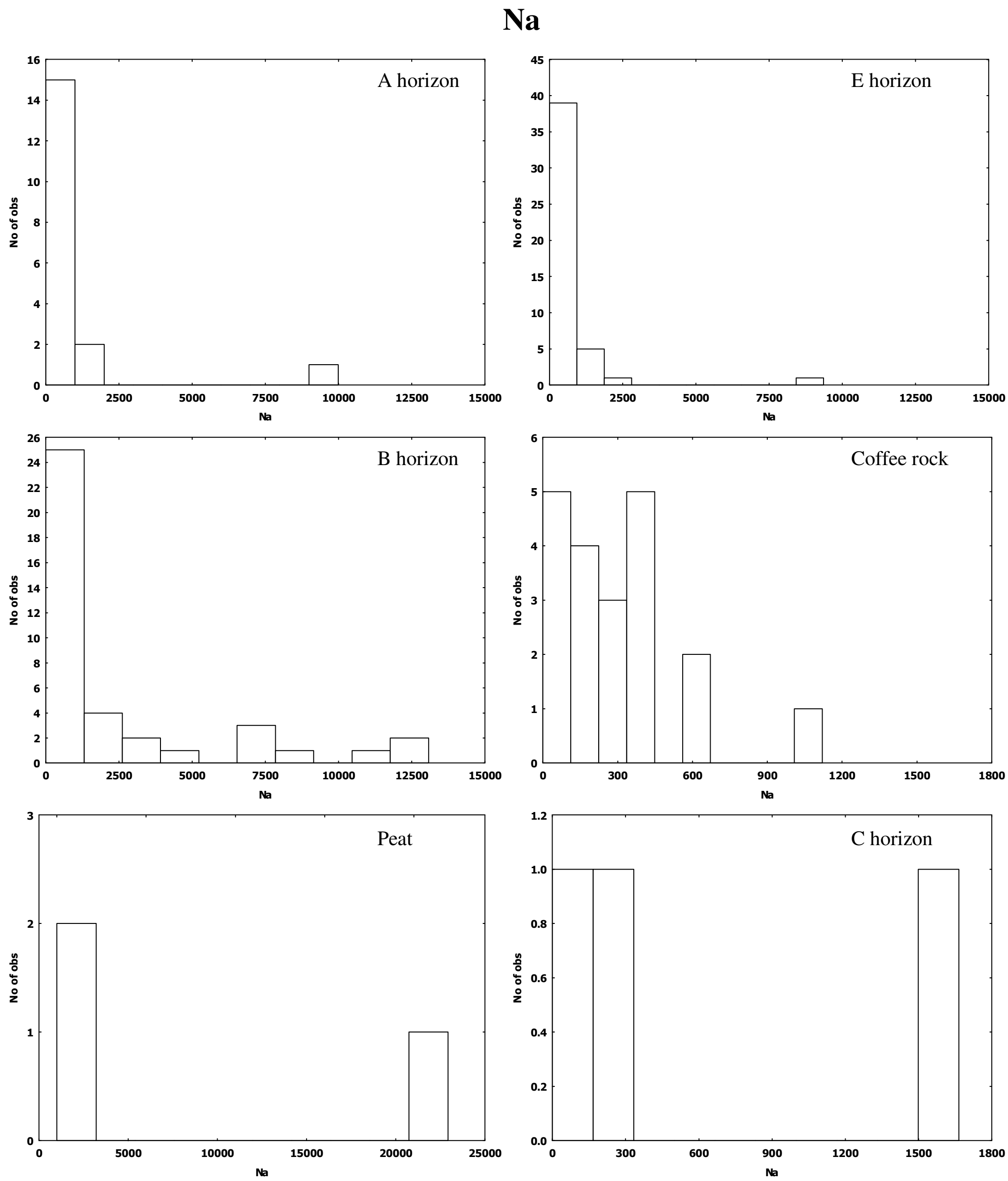

| Horizon | Valid N | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 315 | 106 | 43557 | 10154 |
| E horizon | 46 | 231 | 43 | 7677 | 1485 |
| B horizon | 39 | 1003 | 198 | 51808 | 13434 |
| Coffee rock | 20 | 694 | 67 | 10415 | 2283 |
| Peat | 3 | 4198 | 2699 | 54503 | 29486 |
| C horizon | 3 | 408 | 364 | 1452 | 616 |
| Mean values for normal surface soils worldwide 2000-550000 mg $kg^{-1*}$ | | | | | |

**Appendix Figure 28** Histograms for the concentration of iron (Fe) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES). * Data are from Kabata-Pendias (2001), Essington (2004).




| Horizon | Valid N | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 6.8 | 2.0 | 961 | 225 |
| E horizon | 46 | 6.6 | 0.87 | 39 | 10 |
| B horizon | 39 | 13 | 2.3 | 694 | 139 |
| Coffee rock | 20 | 7.0 | 1.8 | 24 | 6.9 |
| Peat | 3 | 50 | 16 | 58 | 22 |
| C horizon | 3 | 10 | 7.0 | 19 | 6.4 |
| Mean values for normal surface soils worldwide 270-530 mg $kg^{-1*}$ | | | | | |
| Critical soil concentration 1500-3000 mg $kg^{-1**}$ | | | | | |

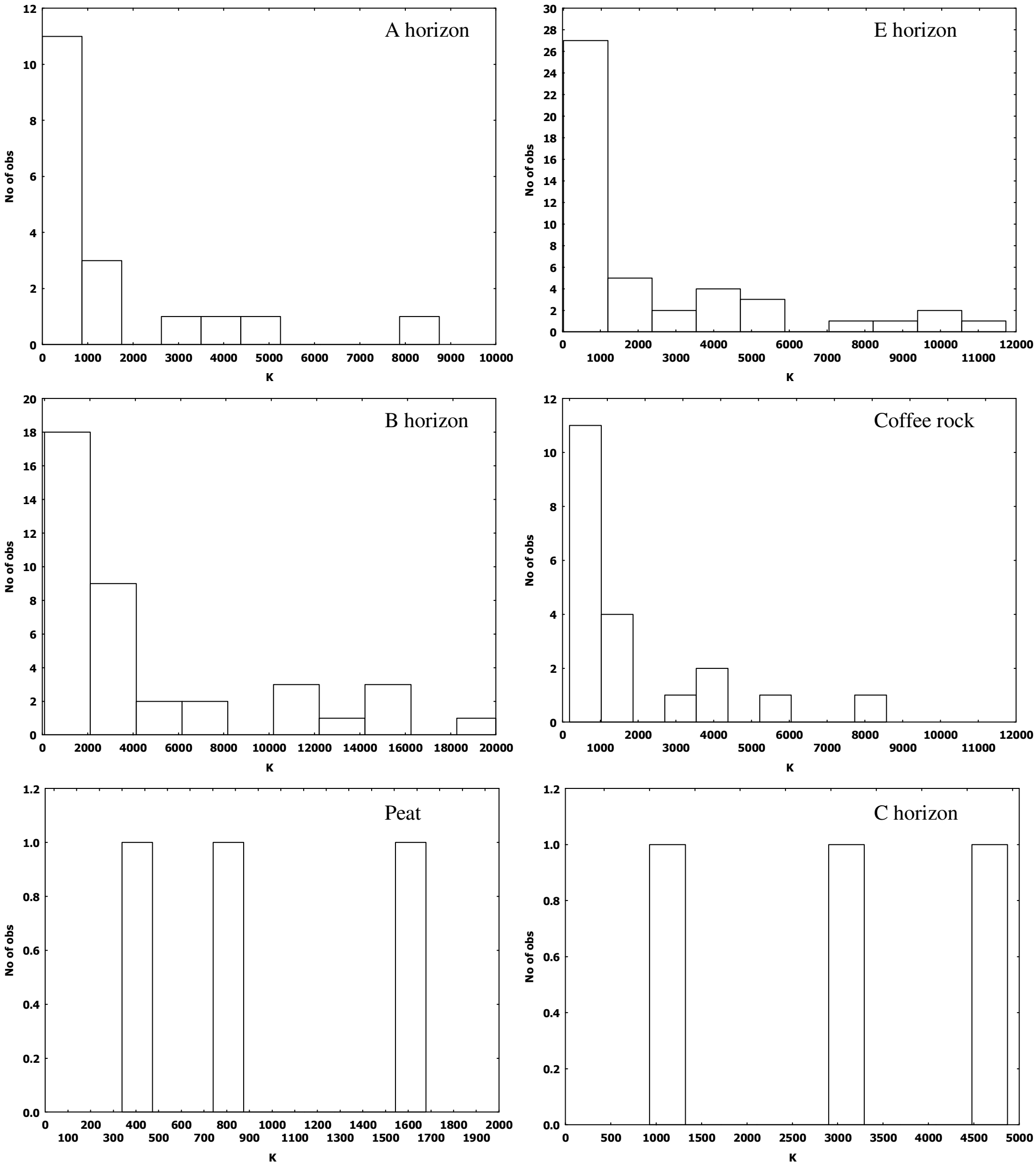
**Appendix Figure 29** Histograms for the concentration of manganese (Mn) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES). * Data are from Kabata-Pendias (2001), Essington (2004); ** Data are from (Alloway, 1995).




| Horizon | Valid N | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 187 | nd | 9982 | 2315 |
| E horizon | 46 | 219 | nd | 9357 | 1425 |
| B horizon | 39 | 529 | nd | 13070 | 3756 |
| Coffee rock | 20 | 258 | nd | 1120 | 276 |
| Peat | 3 | 1488 | 1002 | 22932 | 12524 |
| C horizon | 3 | 300 | nd | 1666 | 888 |
| Mean values for normal surface soils worldwide 150-25000 mg kg$^{-1}$* | | | | | |

**Appendix Figure 30** Histograms for the concentration of sodium (Na) in A, E, B, coffee rock, peat and C horizon materials (in mg kg$^{-1}$ unit) (fusion acid digestion method; ICP-OES).
* Data are from Kabata-Pendias (2001), Essington (2004).

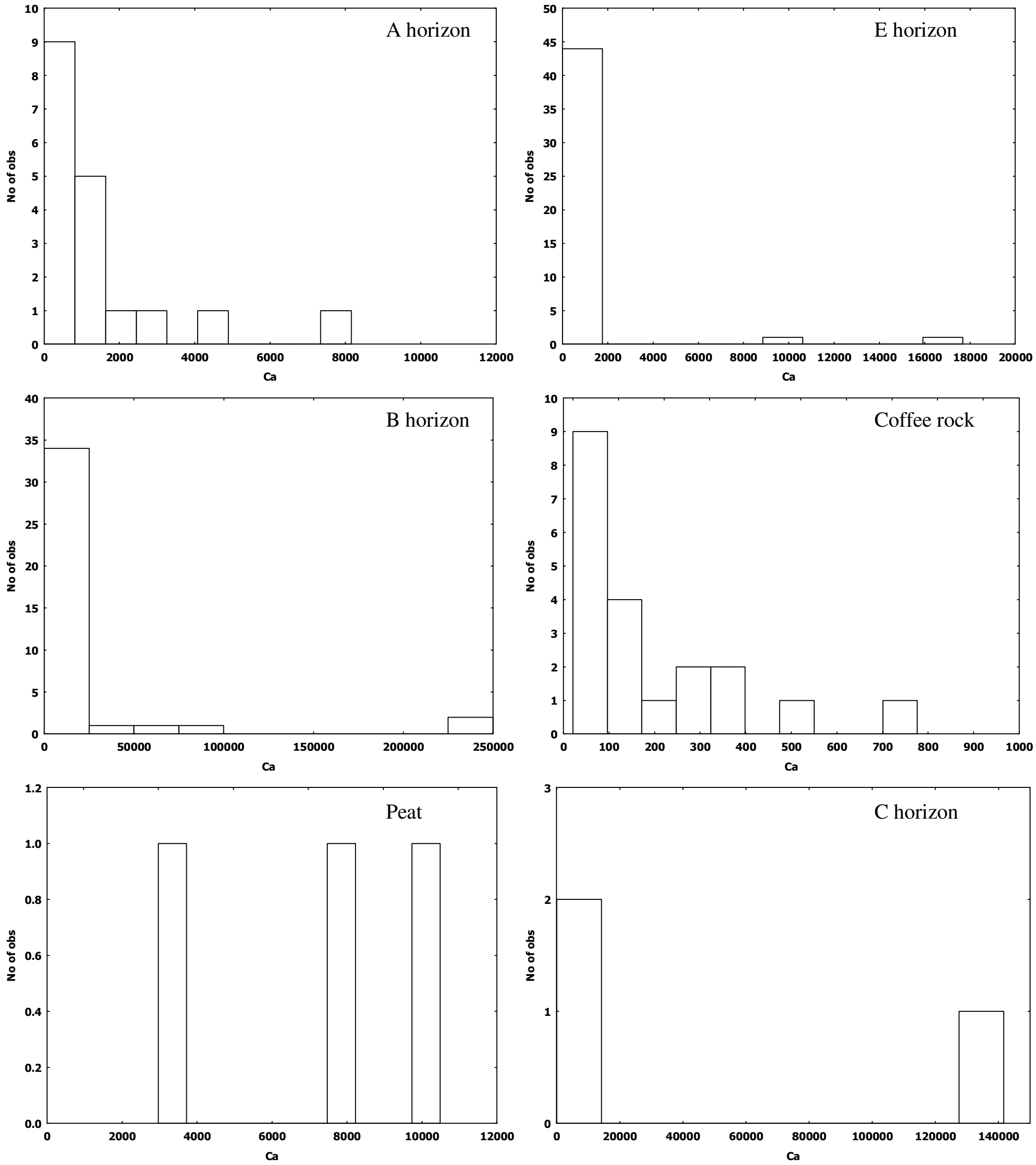
**K**




| Horizon | Valid N | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 360 | nd | 8753 | 2268 |
| E horizon | 46 | 741 | 28 | 11731 | 3044 |
| B horizon | 39 | 2227 | 99 | 20288 | 5299 |
| Coffee rock | 20 | 899 | 188 | 8566 | 2200 |
| Peat | 3 | 842 | 339 | 1678 | 676 |
| C horizon | 3 | 2927 | 926 | 4873 | 1974 |
| Mean values for normal surface soils worldwide 80-37000 mg kg$^{-1}$* | | | | | |

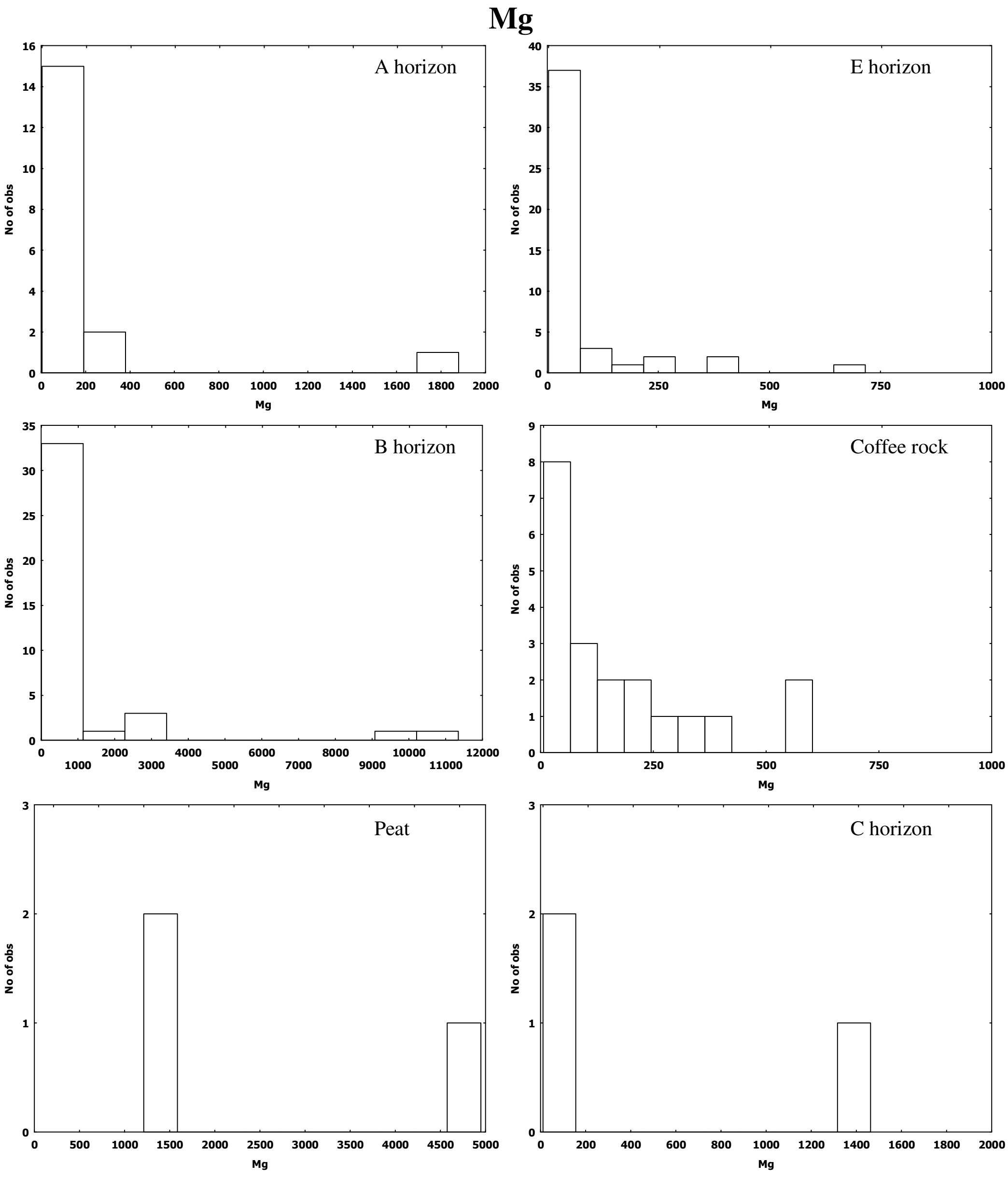
**Appendix Figure 31** Histograms for the concentration of potassium (K) in A, E, B, coffee rock, peat and C horizon materials (in mg kg$^{-1}$ unit) (fusion acid digestion method; ICP-OES).
* Data are from Kabata-Pendias (2001), Essington (2004).

## Ca




| Horizon | Valid N | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 642 | nd | 8155 | 2009 |
| E horizon | 46 | 28 | nd | 17689 | 2982 |
| B horizon | 39 | 225 | 11 | 249900 | 55932 |
| Coffee rock | 20 | 112 | 21 | 777 | 193 |
| Peat | 3 | 7622 | 2968 | 10479 | 3791 |
| C horizon | 3 | 30 | 24 | 141627 | 81753 |
| Mean values for normal surface soils worldwide 700-500000 mg $kg^{-1}$* | | | | | |

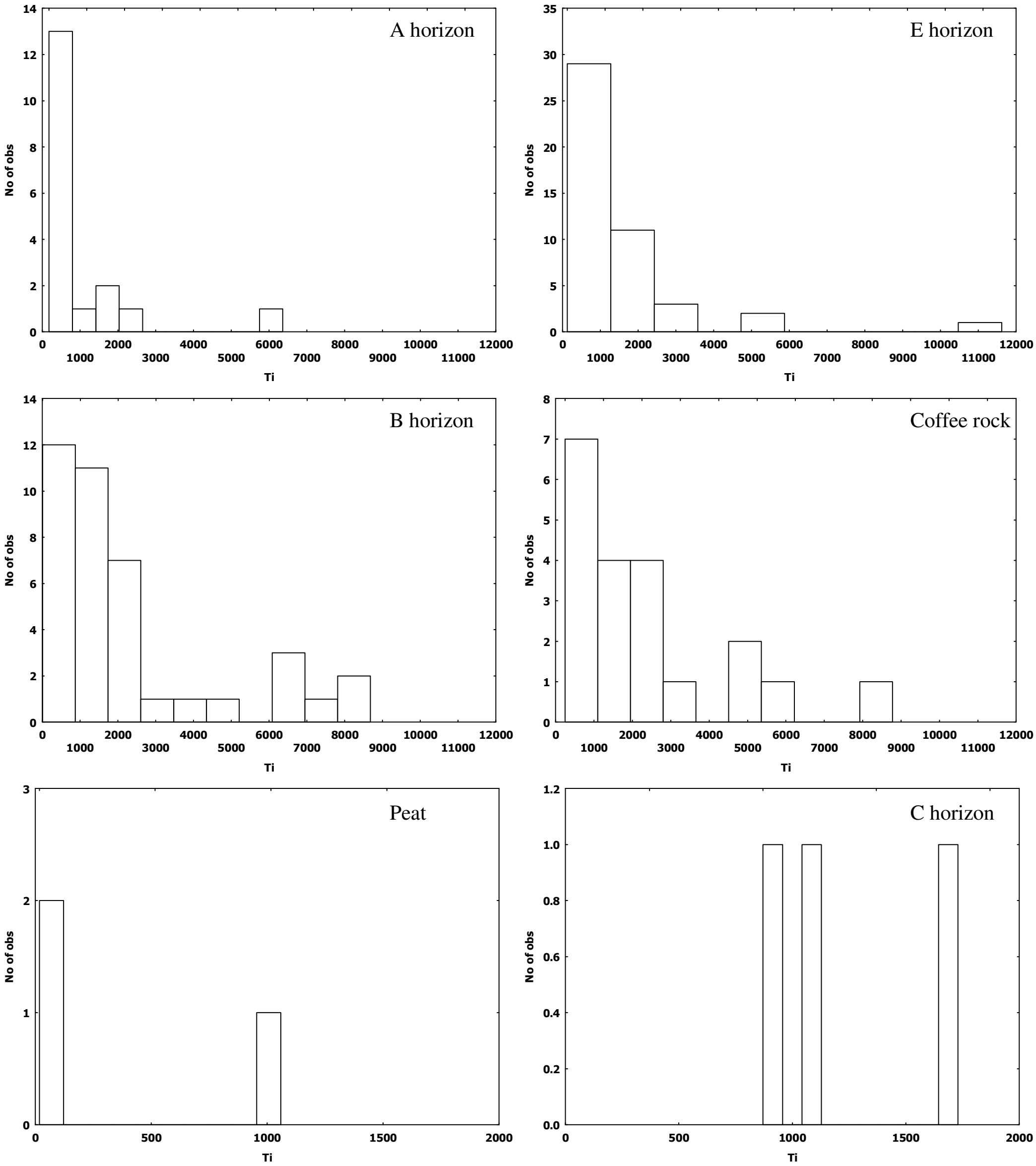
**Appendix Figure 32** Histograms for the concentration of calcium (Ca) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES). * Data are from Kabata-Pendias (2001), Essington (2004).




| Horizon | Valid N | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 77 | 4.3 | 1879 | 428 |
| E horizon | 46 | 15 | 2.8 | 716 | 137 |
| B horizon | 39 | 83 | 10 | 11338 | 2371 |
| Coffee rock | 20 | 105 | 6.7 | 603 | 175 |
| Peat | 3 | 1216 | 1212 | 4950 | 2157 |
| C horizon | 3 | 14 | 10 | 1462 | 837 |
| Mean values for normal surface soils worldwide 400-9000 mg $kg^{-1*}$ | | | | | |

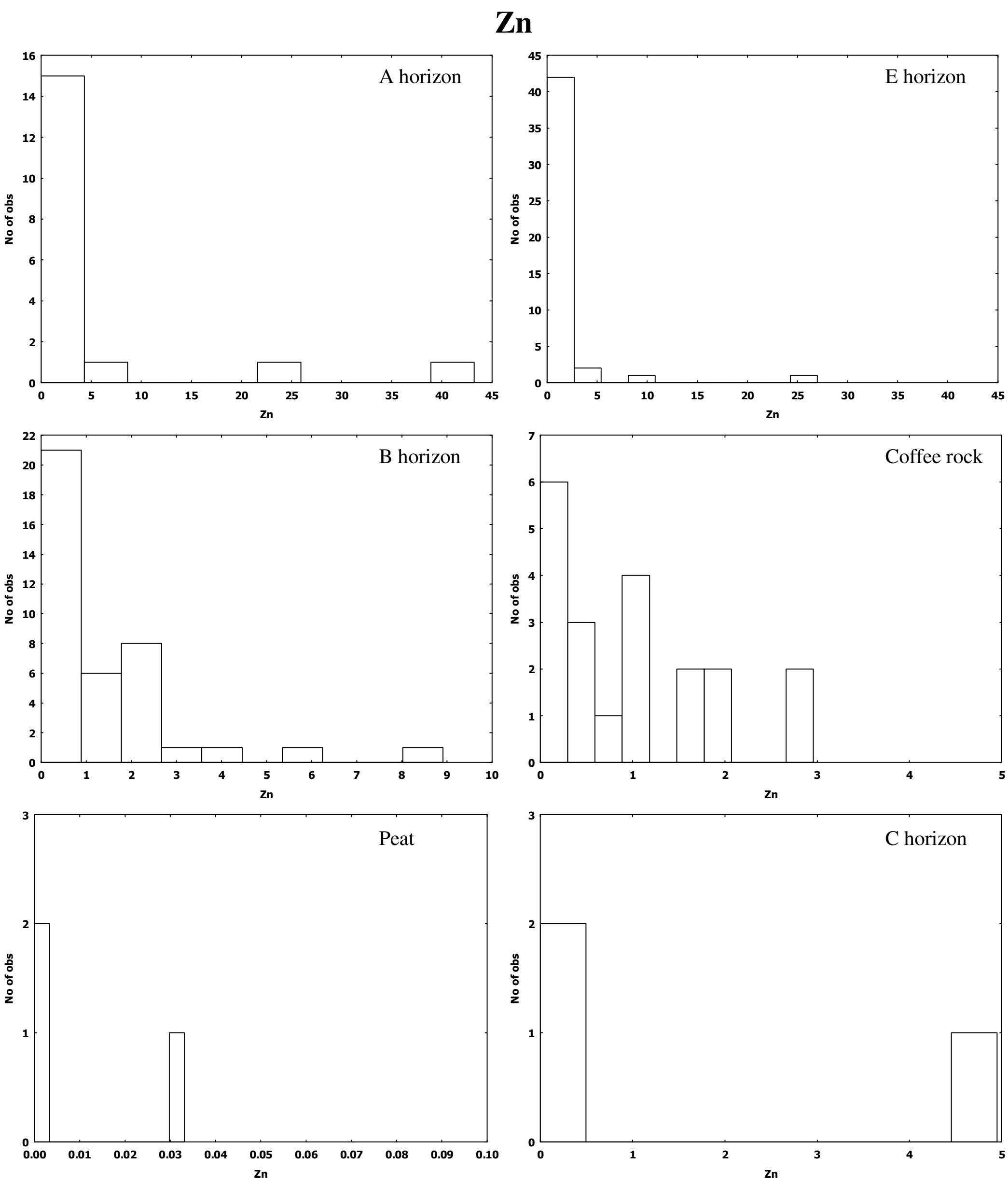
**Appendix Figure 33** Histograms for the concentration of magnesium (Mg) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES). * Data are from Kabata-Pendias (2001), Essington (2004).

**Ti**




| Horizon | Valid N | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 614 | 179 | 6362 | 1441 |
| E horizon | 46 | 874 | 126 | 11621 | 1858 |
| B horizon | 39 | 1497 | 5.04 | 8681 | 2390 |
| Coffee rock | 20 | 1639 | 248 | 8773 | 2224 |
| Peat | 3 | 68 | 17 | 1058 | 587 |
| C horizon | 3 | 1098 | 871 | 1730 | 445 |
| Mean values for normal surface soils worldwide 2300-26000 mg $kg^{-1*}$ | | | | | |

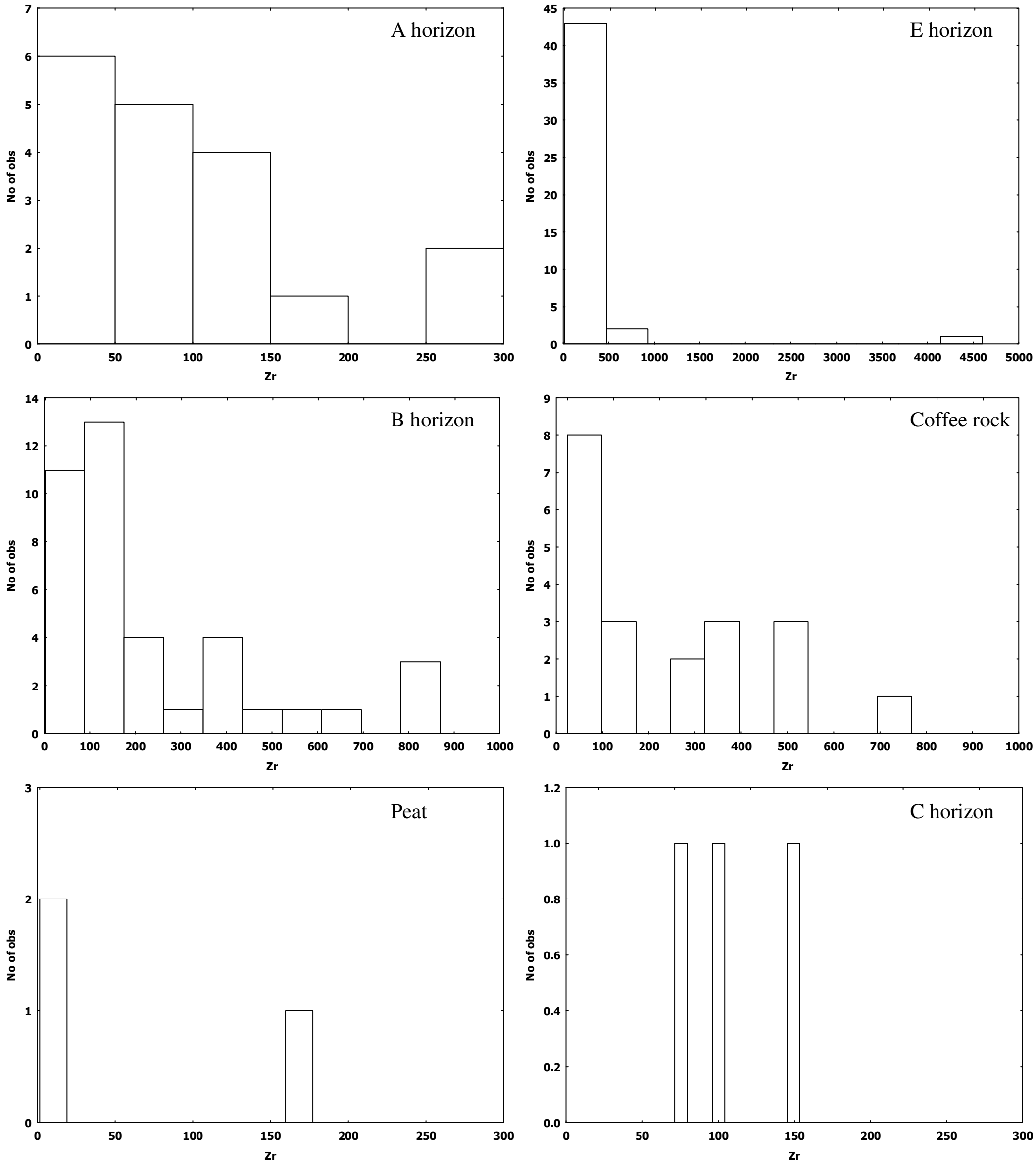
**Appendix Figure 34** Histograms for the concentration of titanium (Ti) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (fusion acid digestion method; ICP-OES).
* Data are from Kabata-Pendias (2001), Essington (2004).




| Horizon | Valid N | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 0.98 | nd | 43 | 11 |
| E horizon | 46 | 0.23 | nd | 27 | 4.2 |
| B horizon | 39 | 0.54 | nd | 8.9 | 1.8 |
| Coffee rock | 20 | 0.93 | nd | 3.0 | 0.93 |
| Peat | 3 | nd | nd | 0.033 | 0.019 |
| C horizon | 3 | 0.34 | nd | 5.0 | 2.8 |
| Mean values for normal surface soils worldwide 45-100 mg $kg^{-1}$* | | | | | |
| Critical soil concentration 70-400 mg $kg^{-1}$** | | | | | |

**Appendix Figure 35** Histograms for the concentration of zinc (Zn) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES). * Data are from Kabata-Pendias (2001), Essington (2004); ** Data are from (Alloway, 1995).

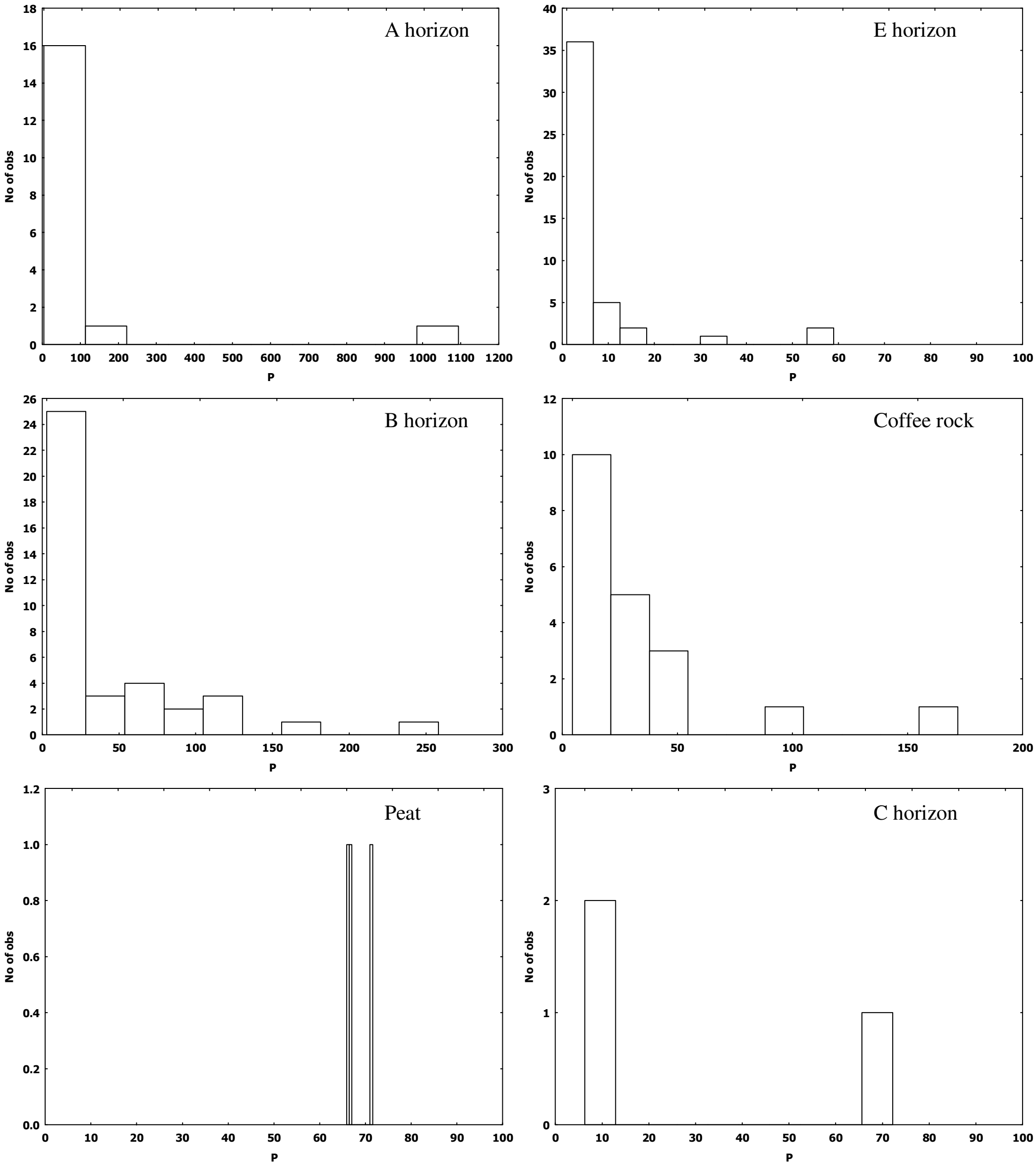
## Zr




| Horizon | Valid N | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 69 | 15 | 279 | 79 |
| E horizon | 46 | 94 | 17 | 4600 | 672 |
| B horizon | 39 | 135 | 1.8 | 869 | 237 |
| Coffee rock | 20 | 136 | 24 | 768 | 210 |
| Peat | 3 | 7.9 | 1.6 | 177 | 100 |
| C horizon | 3 | 104 | 71 | 154 | 41 |

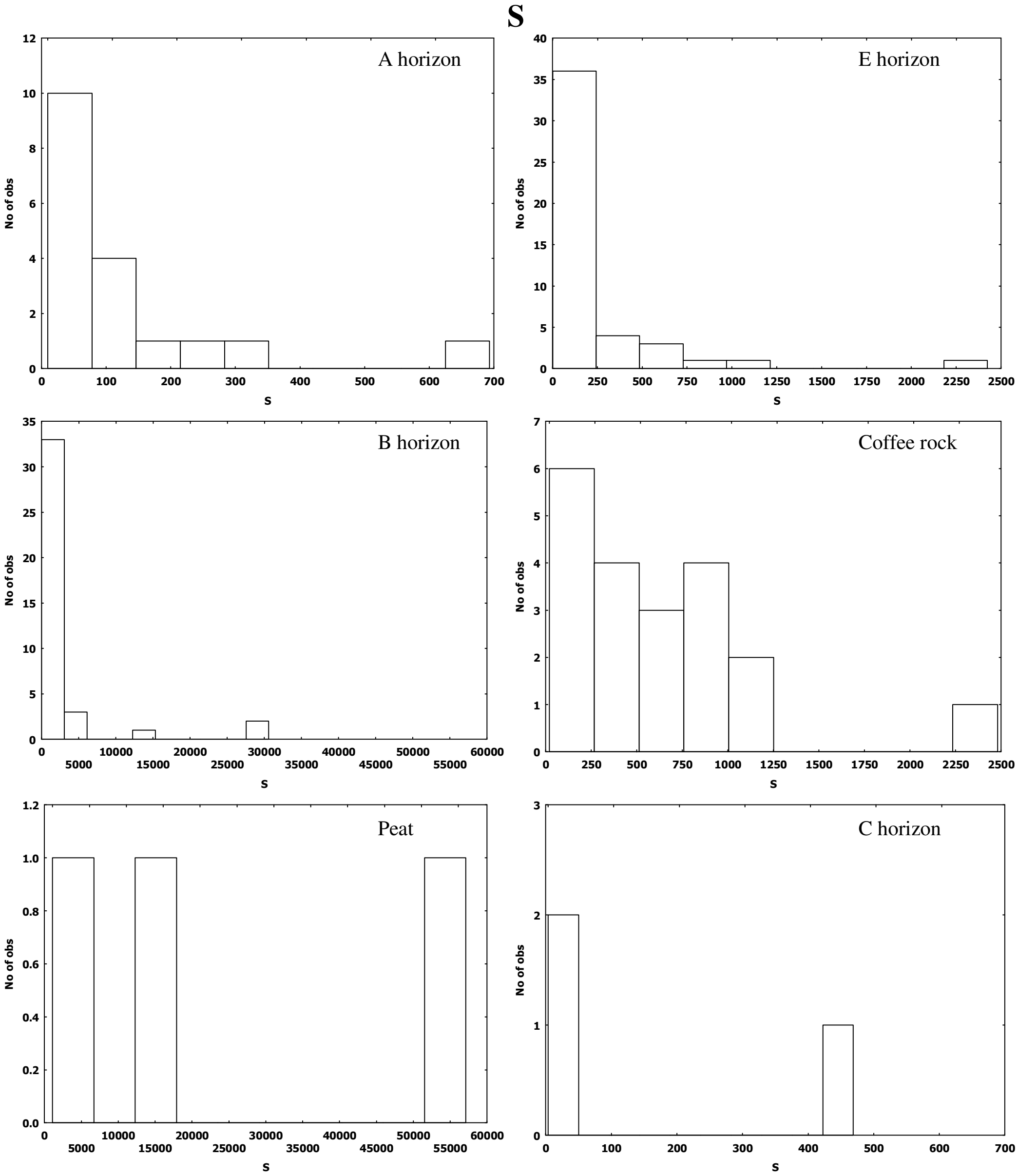
**Appendix Figure 36** Histograms for the concentration of zirconium (Zr) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (fusion acid digestion method; ICP-OES).

## P




| Horizon | Valid N | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 12 | 4.3 | 1094 | 254 |
| E horizon | 46 | 3.8 | 1.0 | 59 | 12 |
| B horizon | 39 | 13 | 2.8 | 258 | 55 |
| Coffee rock | 20 | 21 | 4.4 | 172 | 39 |
| Peat | 3 | 67 | 66 | 72 | 3.0 |
| C horizon | 3 | 7.4 | 6.3 | 72 | 38 |
| Mean values for normal surface soils worldwide 35-5300 mg $kg^{-1*}$ | | | | | |

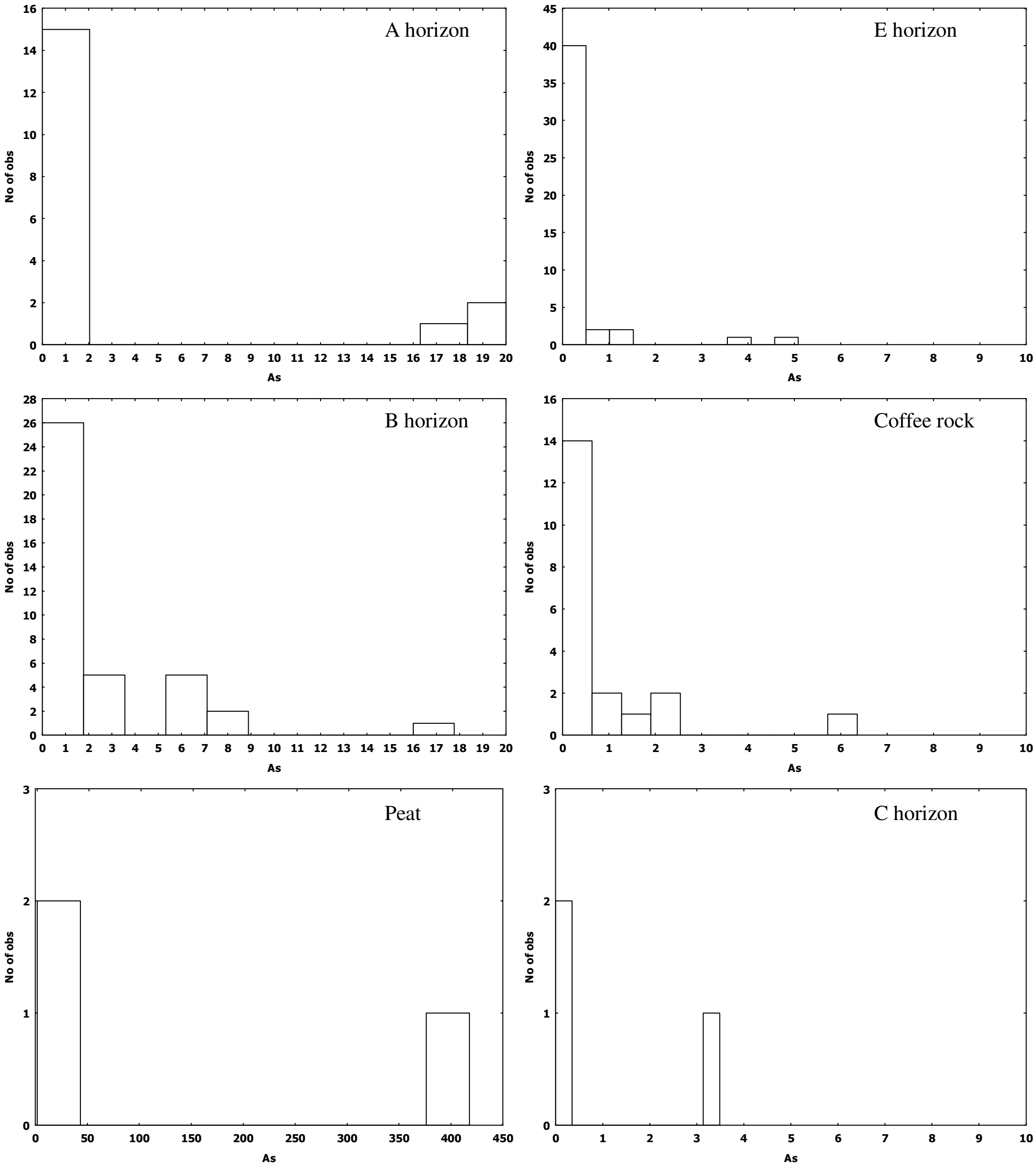
**Appendix Figure 37** Histograms for the concentration of phosphorus (P) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES). * Data are from Kabata-Pendias (2001), Essington (2004).




| Horizon | Valid N | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 56 | 10 | 693 | 167 |
| E horizon | 46 | 37 | 1.3 | 2424 | 410 |
| B horizon | 39 | 308 | 17 | 30601 | 6860 |
| Coffee rock | 20 | 541 | 21 | 2482 | 559 |
| Peat | 3 | 12948 | 1102 | 57117 | 29521 |
| C horizon | 3 | 16 | 3.7 | 469 | 265 |
| Mean values for normal surface soils worldwide 30-1600 mg $kg^{-1*}$ | | | | | |

**Appendix Figure 38** Histograms for the concentration of sulfur (S) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES). * Data are from Kabata-Pendias (2001), Essington (2004).

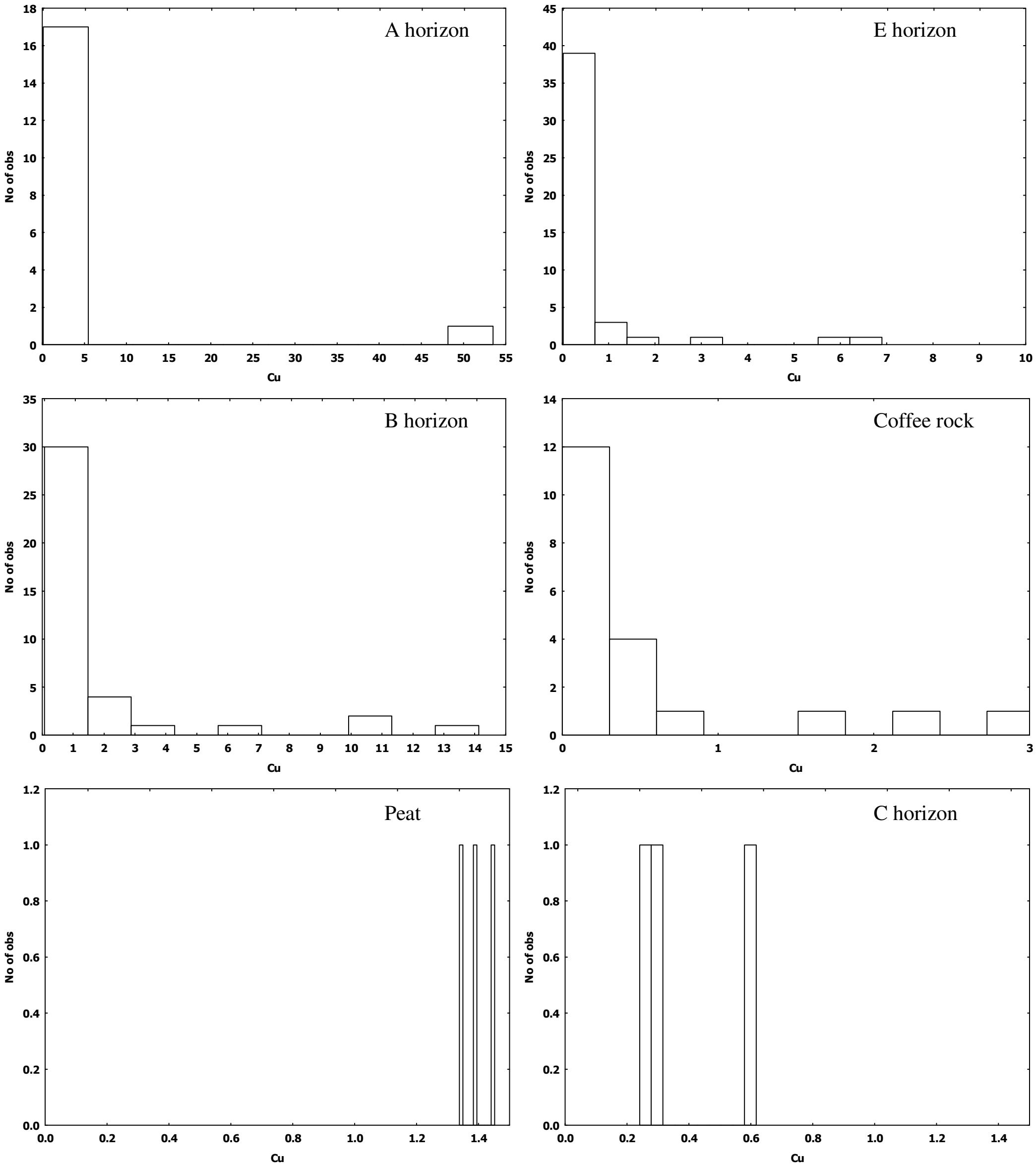
**As**




| Horizon | Valid N | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 0.0021 | nd | 20 | 7.2 |
| E horizon | 46 | 0.070 | nd | 5.1 | 1.0 |
| B horizon | 39 | 0.29 | nd | 18 | 3.6 |
| Coffee rock | 20 | 0.20 | nd | 6.4 | 1.5 |
| Peat | 3 | 35 | 1.68 | 418 | 231 |
| C horizon | 3 | nd | nd | 3.5 | 2.0 |
| Mean values for normal surface soils worldwide 4.4-9.3 mg kg$^{-1}$* | | | | | |
| Critical soil concentration 20-50 mg kg$^{-1}$** | | | | | |

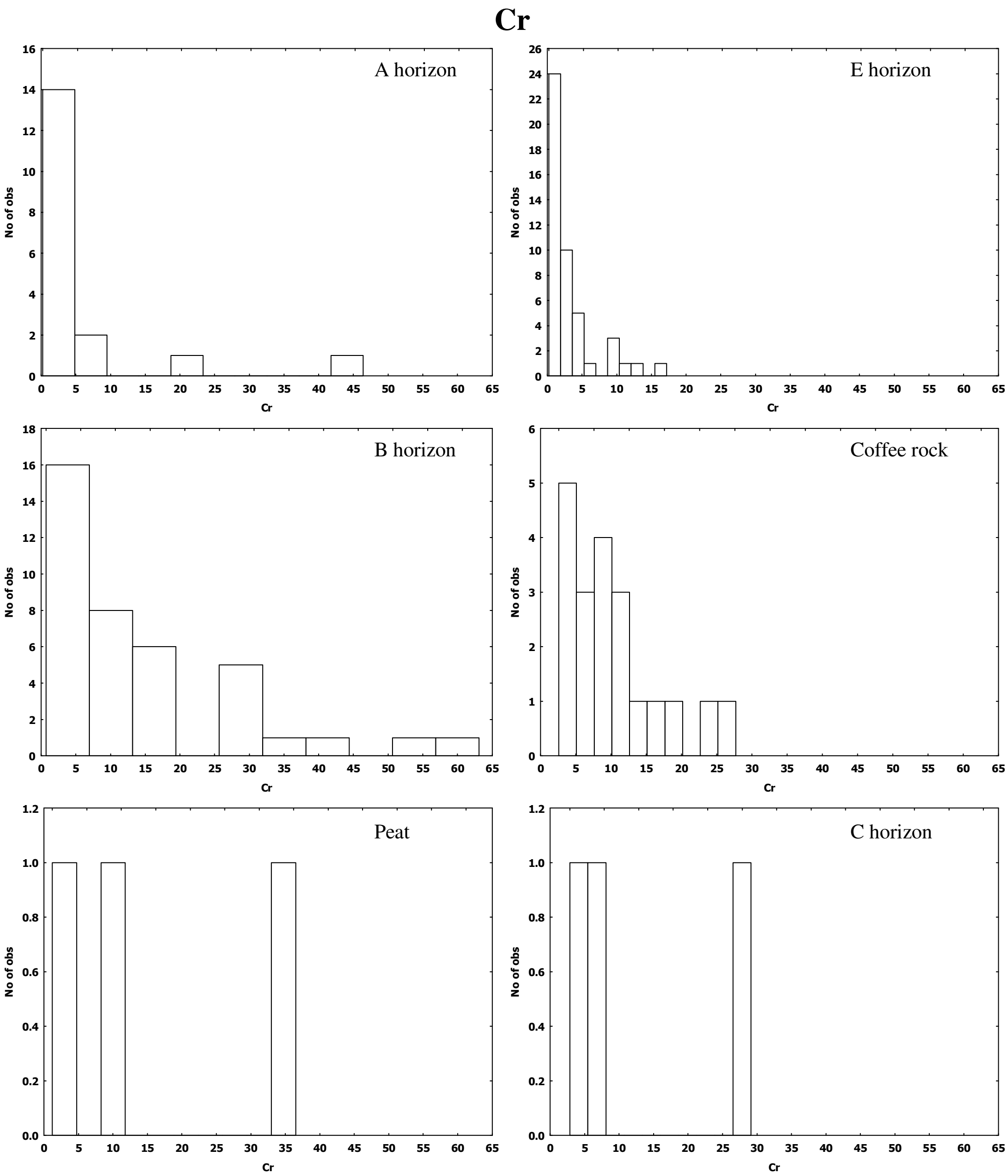
**Appendix Figure 39** Histograms for the concentration of arsenic (As) in A, E, B, coffee rock, peat and C horizon materials (in mg kg$^{-1}$ unit) (aqua regia method; ICP-OES). * Data are from Kabata-Pendias (2001), Essington (2004); ** Data are from (Alloway, 1995).

**Cu**



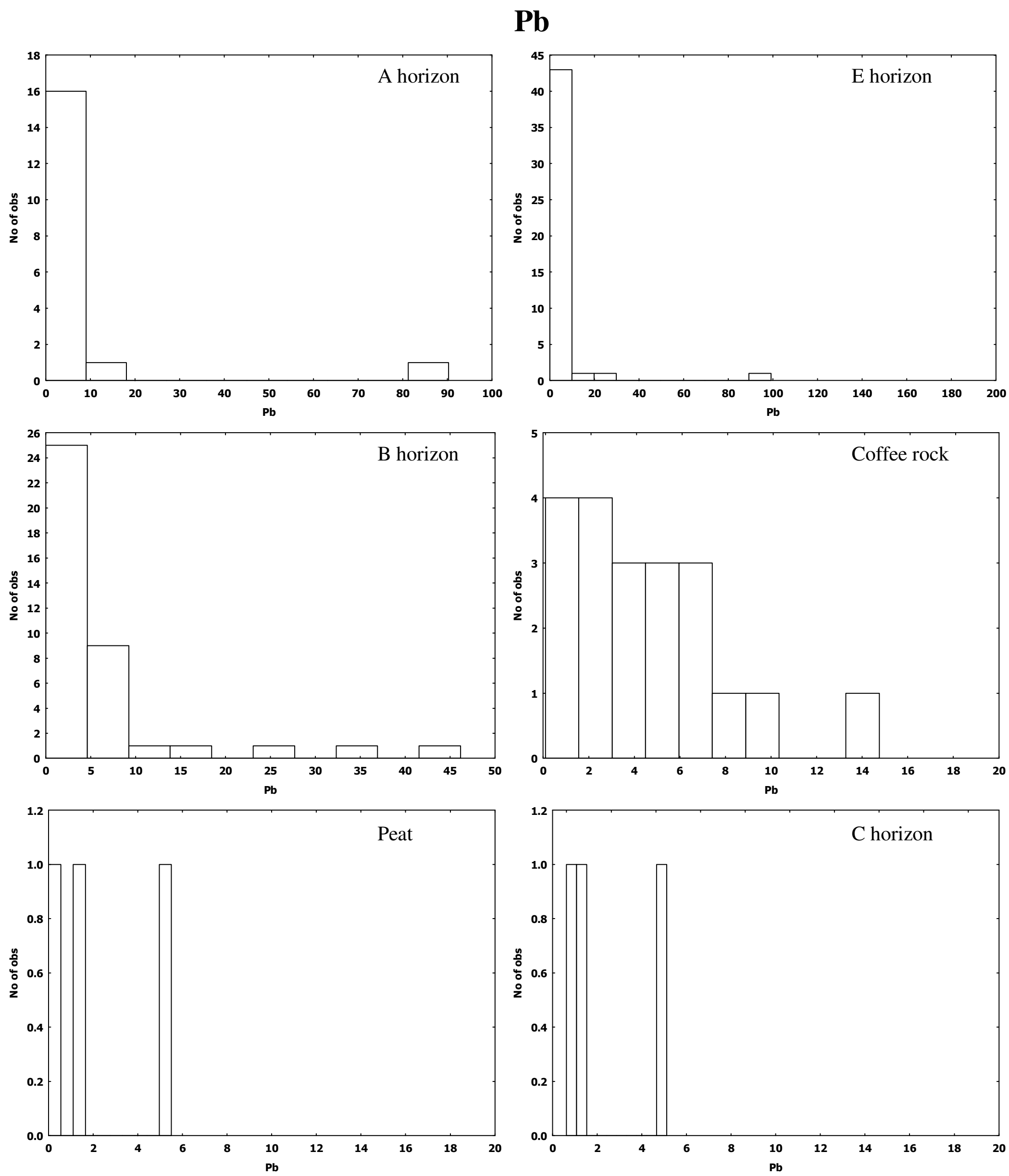

| Horizon | Valid N | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 0.73 | 0.11 | 54 | 12 |
| E horizon | 46 | 0.17 | 0.019 | 6.9 | 1.3 |
| B horizon | 39 | 0.40 | 0.069 | 14 | 3.2 |
| Coffee rock | 20 | 0.28 | nd | 3.0 | 0.79 |
| Peat | 3 | 1.4 | 1.34 | 1.5 | 0.057 |
| C horizon | 3 | 0.31 | 0.24 | 0.62 | 0.20 |
| Mean values for normal surface soils worldwide 13-24 mg $kg^{-1*}$ | | | | | |
| Critical soil concentration 60-125 mg $kg^{-1**}$ | | | | | |

**Appendix Figure 40** Histograms for the concentration of copper (Cu) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES). * Data are from Kabata-Pendias (2001), Essington (2004); ** Data are from (Alloway, 1995).




| Horizon | Valid N | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 0.89 | 0.23 | 46 | 11 |
| E horizon | 46 | 1.8 | 0.22 | 17 | 3.7 |
| B horizon | 39 | 10 | 0.70 | 63 | 15 |
| Coffee rock | 20 | 8.8 | 2.6 | 28 | 6.8 |
| Peat | 3 | 9.7 | 1.2 | 36 | 18 |
| C horizon | 3 | 7.2 | 2.8 | 29 | 14 |
| Mean values for normal surface soils worldwide 12-83 mg $kg^{-1}$* | | | | | |
| Critical soil concentration 75-100 mg $kg^{-1}$** | | | | | |

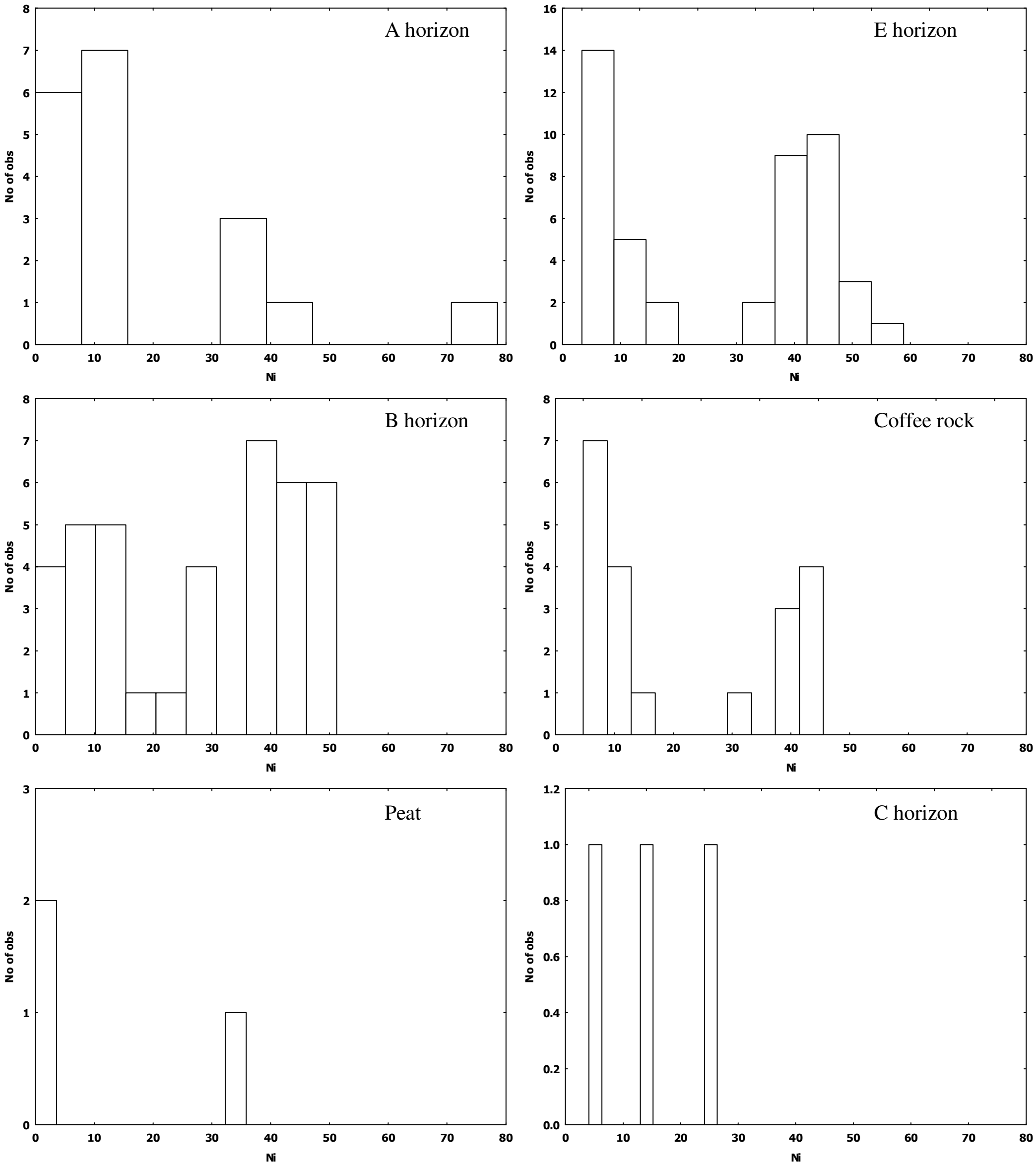
**Appendix Figure 41** Histograms for the concentration of chromium (Cr) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES). * Data are from Kabata-Pendias (2001), Essington (2004); ** Data are from (Alloway, 1995).




| Horizon | Valid N | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 0.69 | nd | 90 | 21 |
| E horizon | 46 | 0.68 | nd | 99 | 15 |
| B horizon | 39 | 1.9 | nd | 46 | 10 |
| Coffee rock | 20 | 4.2 | 0.10 | 15 | 3.6 |
| Peat | 3 | 1.3 | nd | 5.5 | 2.9 |
| C horizon | 3 | 1.1 | 0.62 | 5.1 | 2.5 |
| Mean values for normal surface soils worldwide 22-44 mg $kg^{-1*}$ | | | | | |
| Critical soil concentration 100-400 mg $kg^{-1**}$ | | | | | |

**Appendix Figure 42** Histograms for the concentration of lead (Pb) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES). * Data are from Kabata-Pendias (2001), Essington (2004); ** Data are from (Alloway, 1995).

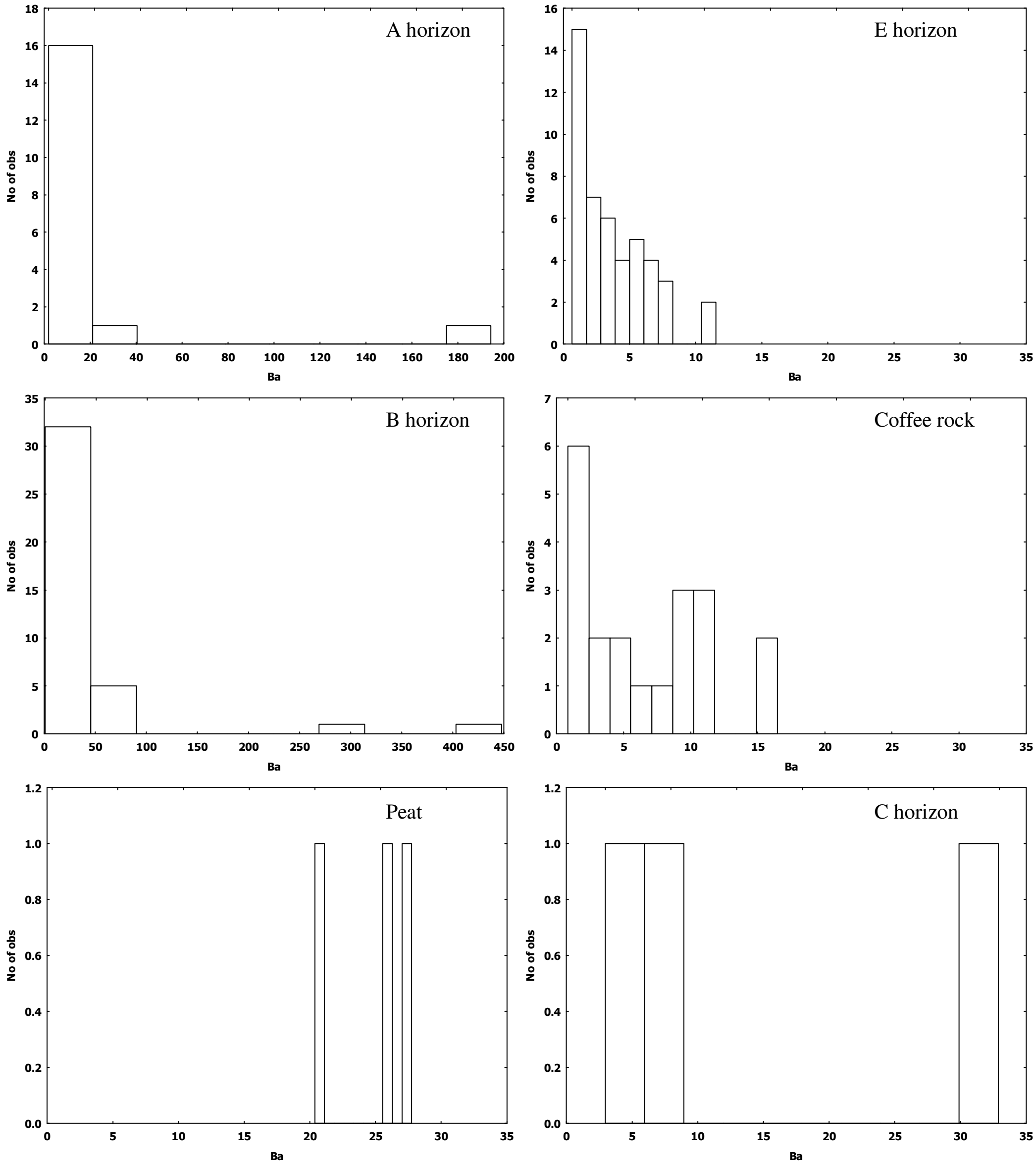
## Ni




| Horizon | Valid N | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 9 | nd | 79 | 20 |
| E horizon | 46 | 36 | 3.3 | 59 | 18 |
| B horizon | 39 | 29 | nd | 51 | 18 |
| Coffee rock | 20 | 12 | 4.7 | 46 | 17 |
| Peat | 3 | nd | nd | 36 | 21 |
| C horizon | 3 | 13 | 4.1 | 26 | 11 |
| Mean values for normal surface soils worldwide 13-34 mg $kg^{-1*}$ | | | | | |
| Critical soil concentration 100 mg $kg^{-1**}$ | | | | | |

**Appendix Figure 43** Histograms for the concentration of nickel (Ni) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (fusion acid digestion method; ICP-OES).* Data are from Kabata-Pendias (2001), Essington (2004); ** Data are from (Alloway, 1995).

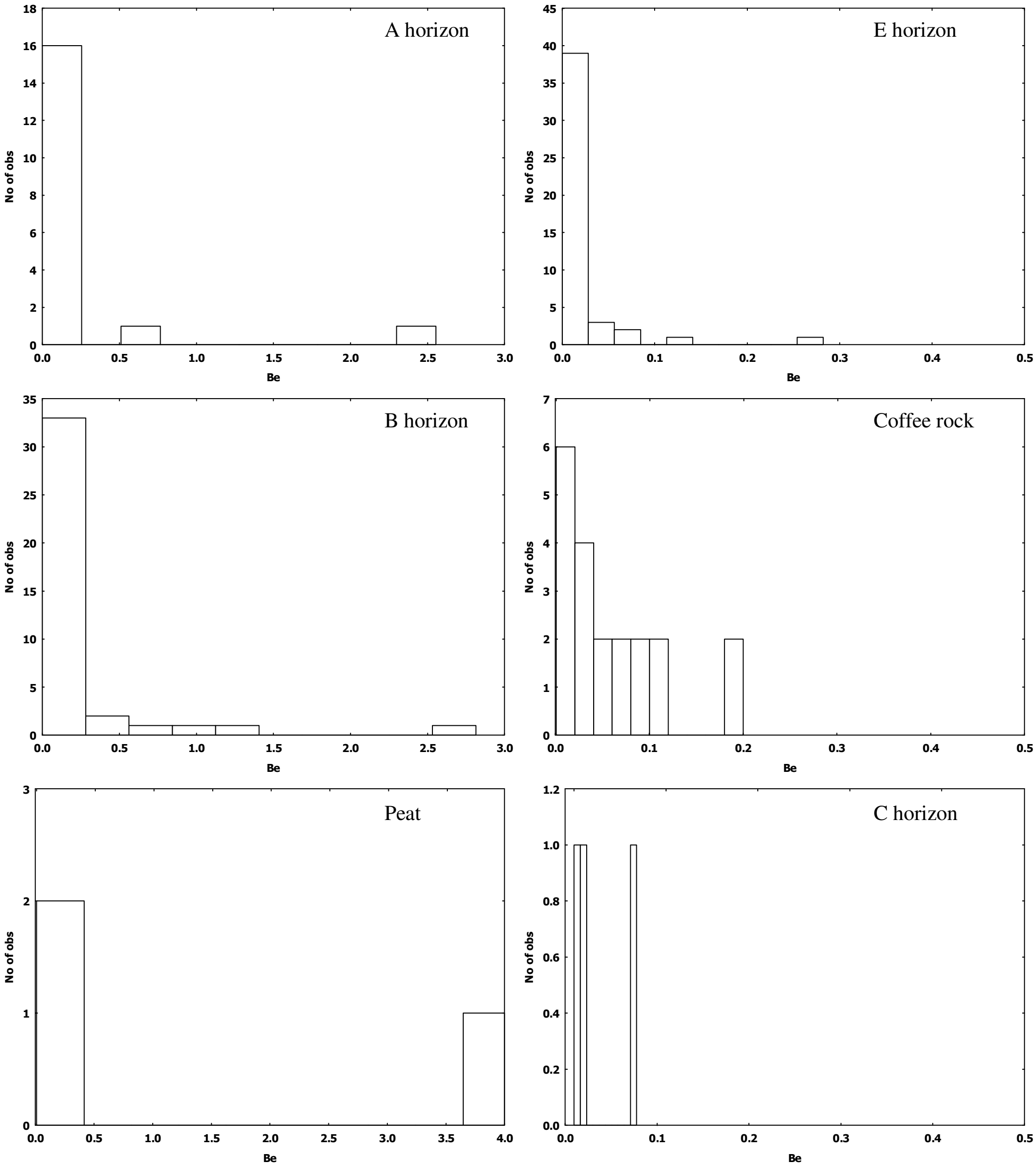
**Ba**




| Horizon | Valid N | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 4.5 | 1.9 | 194 | 45 |
| E horizon | 46 | 3.0 | 0.65 | 12 | 2.8 |
| B horizon | 39 | 8.8 | 0.82 | 448 | 83 |
| Coffee rock | 20 | 5.6 | 0.85 | 16 | 4.8 |
| Peat | 3 | 26 | 20 | 28 | 3.8 |
| C horizon | 3 | 8.2 | 3.0 | 33 | 16 |
| Maximum barium content observed in soils 500-700 mg $kg^{-1*}$ | | | | | |

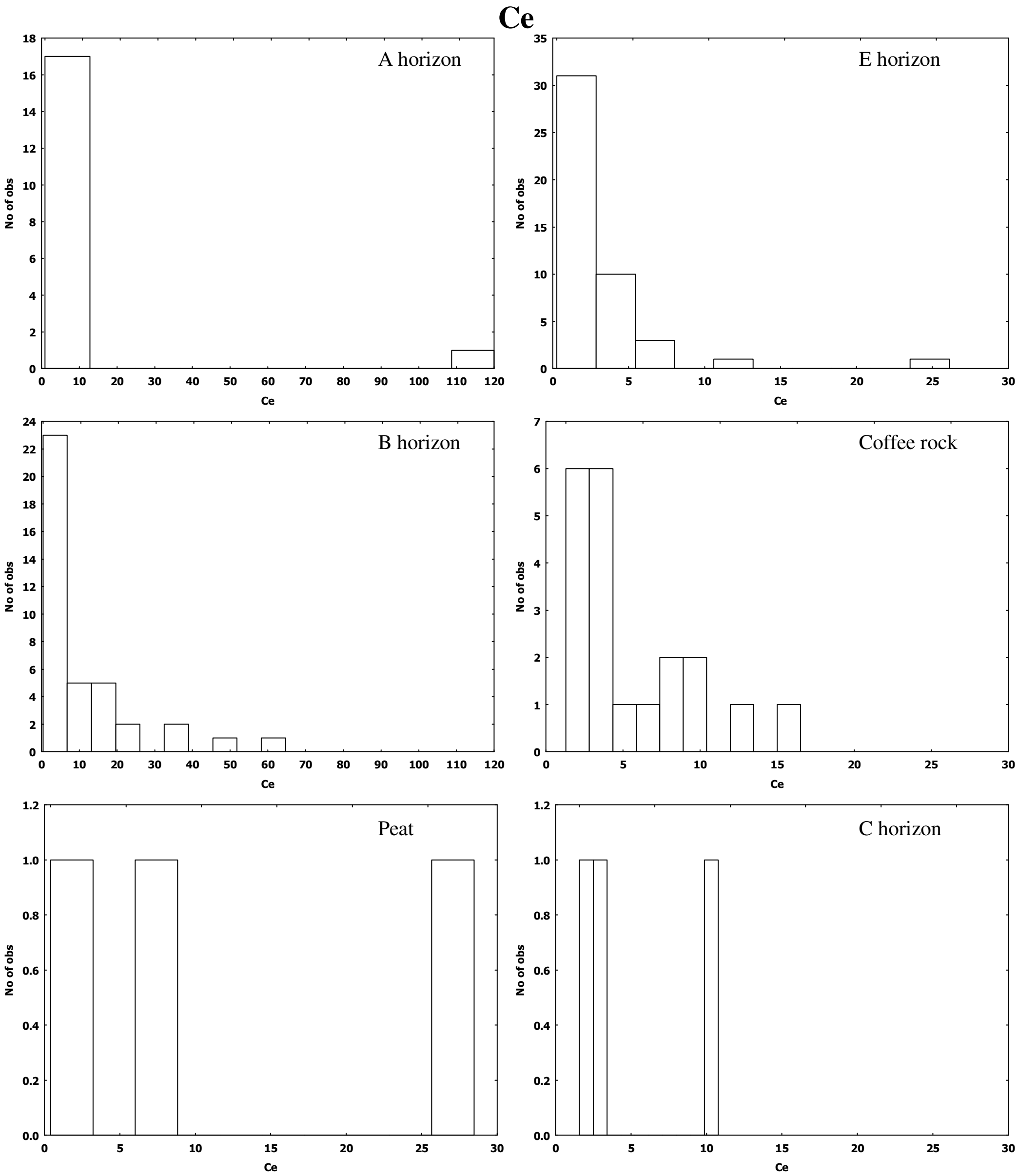
**Appendix Figure 44** Histograms for the concentration of barium (Ba) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES). * Data are from Crompton (2006).

**Be**




| Horizon | Valid N | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 0.0078 | 0.00029 | 2.6 | 0.61 |
| E horizon | 46 | 0.0047 | nd | 0.28 | 0.05 |
| B horizon | 39 | 0.032 | nd | 2.8 | 0.51 |
| Coffee rock | 20 | 0.044 | 0.00087 | 0.20 | 0.06 |
| Peat | 3 | 0.19 | 0.011 | 4.0 | 2.3 |
| C horizon | 3 | 0.017 | 0.010 | 0.078 | 0.04 |
| Mean values for normal surface soils worldwide 0.35-3.52 mg $kg^{-1*}$ | | | | | |

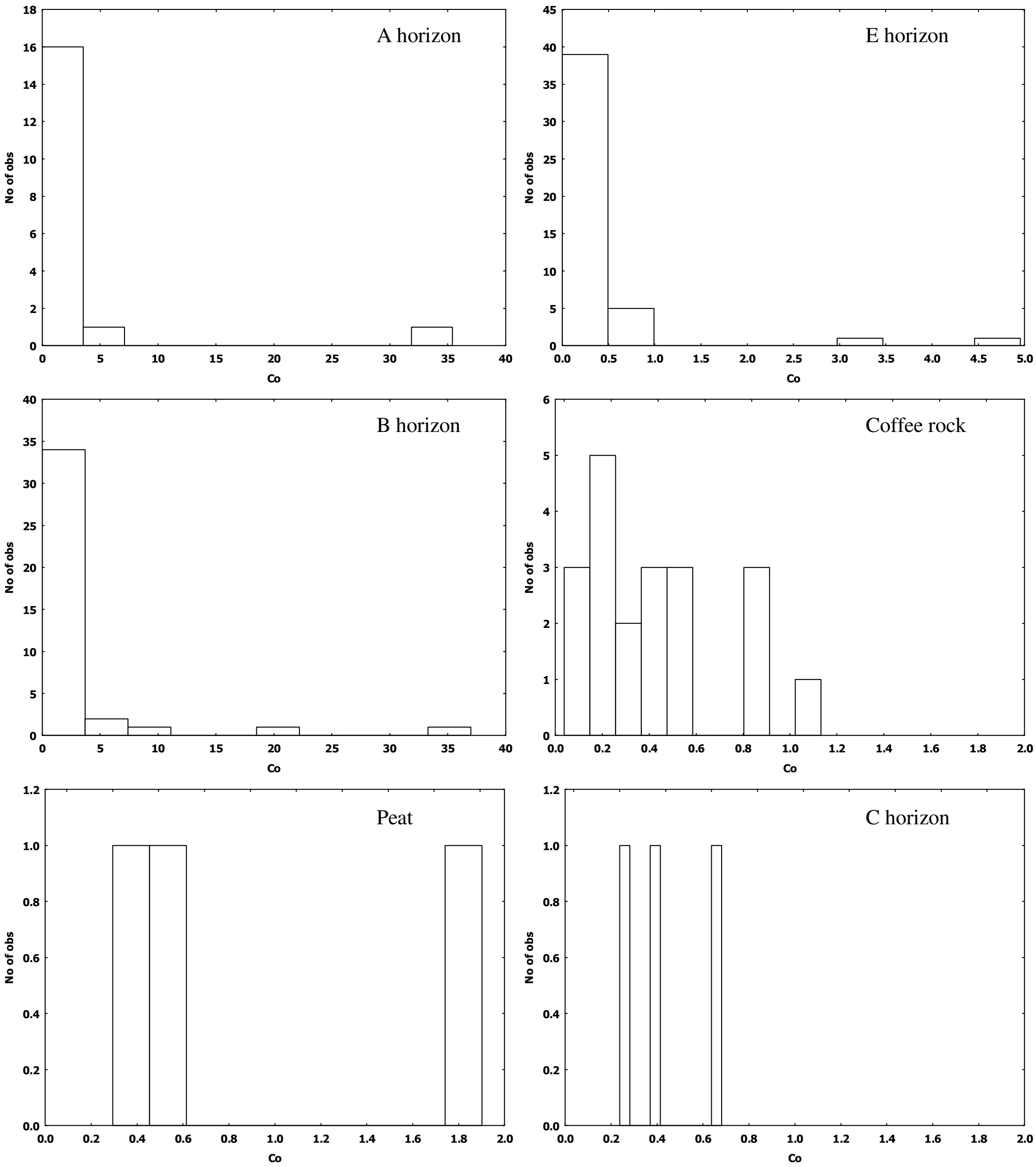
**Appendix Figure 45** Histograms for the concentration of beryllium (Be) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES).* Data are from Kabata-Pendias (2001), Essington (2004).




| Horizon | Valid N | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 1.6 | 0.87 | 121 | 28 |
| E horizon | 46 | 1.8 | 0.27 | 26 | 4 |
| B horizon | 39 | 4.2 | 0.39 | 65 | 14 |
| Coffee rock | 20 | 3.7 | 1.3 | 17 | 4 |
| Peat | 3 | 8.2 | 0.41 | 28 | 14 |
| C horizon | 3 | 3.2 | 1.6 | 11 | 5 |

**Appendix Figure 46** Histograms for the concentration of cerium (Ce) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES).

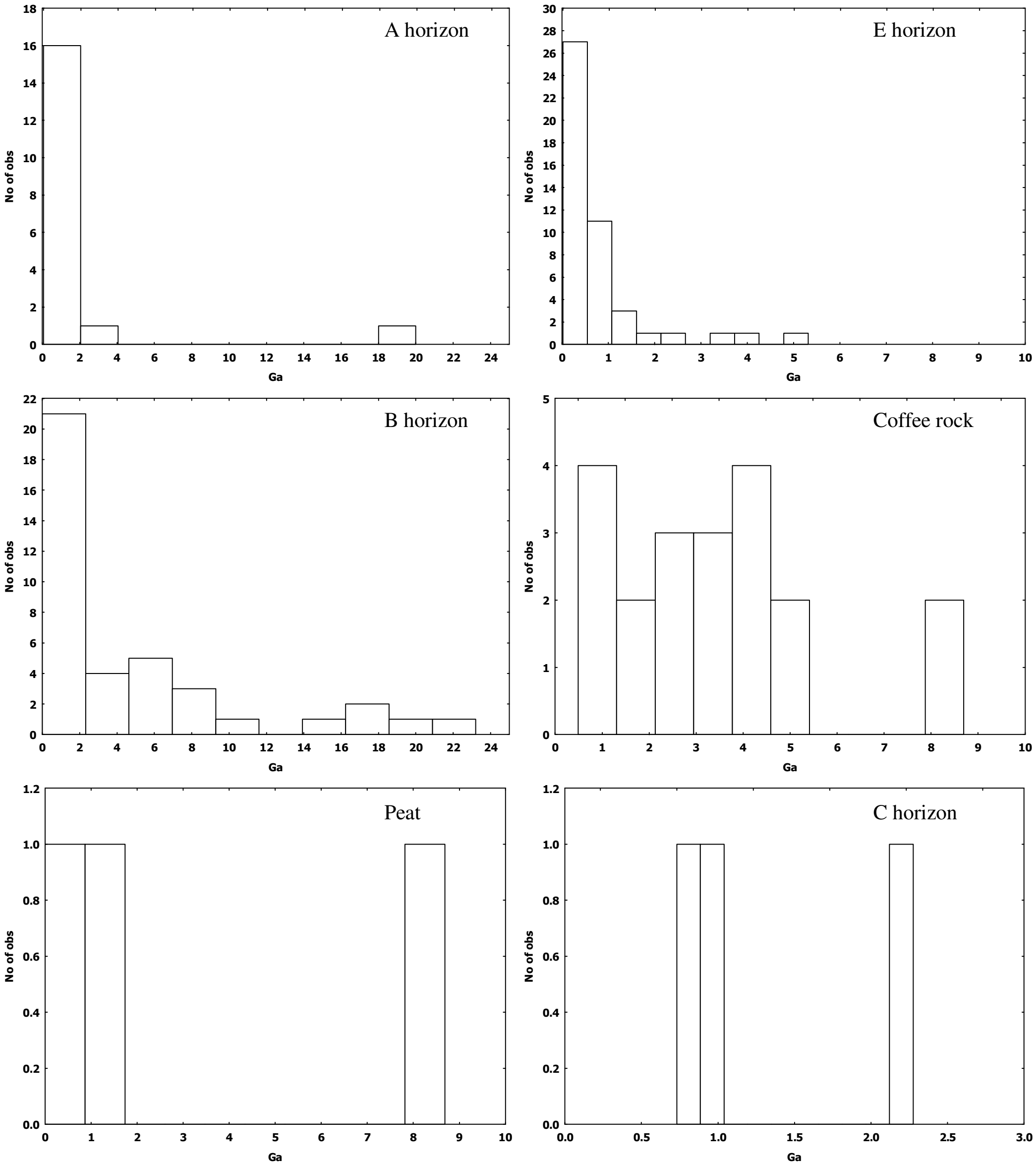
## Co




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 0.19 | 0.0066 | 35 | 8.3 |
| E horizon | 46 | 0.12 | nd | 5.0 | 0.84 |
| B horizon | 39 | 0.34 | nd | 37 | 6.7 |
| Coffee rock | 20 | 0.36 | 0.038 | 1.13 | 0.30 |
| Peat | 3 | 0.56 | 0.29 | 1.90 | 0.86 |
| C horizon | 3 | 0.38 | 0.24 | 0.68 | 0.23 |
| Mean values for normal surface soils worldwide 4.5-12 mg $kg^{-1}$* | | | | | |
| Critical soil concentration 25-50 mg $kg^{-1}$** | | | | | |

**Appendix Figure 47** Histograms for the concentration of cobalt (Co) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES).* Data are from Kabata-Pendias (2001), Essington (2004); ** Data are from (Alloway, 1995).

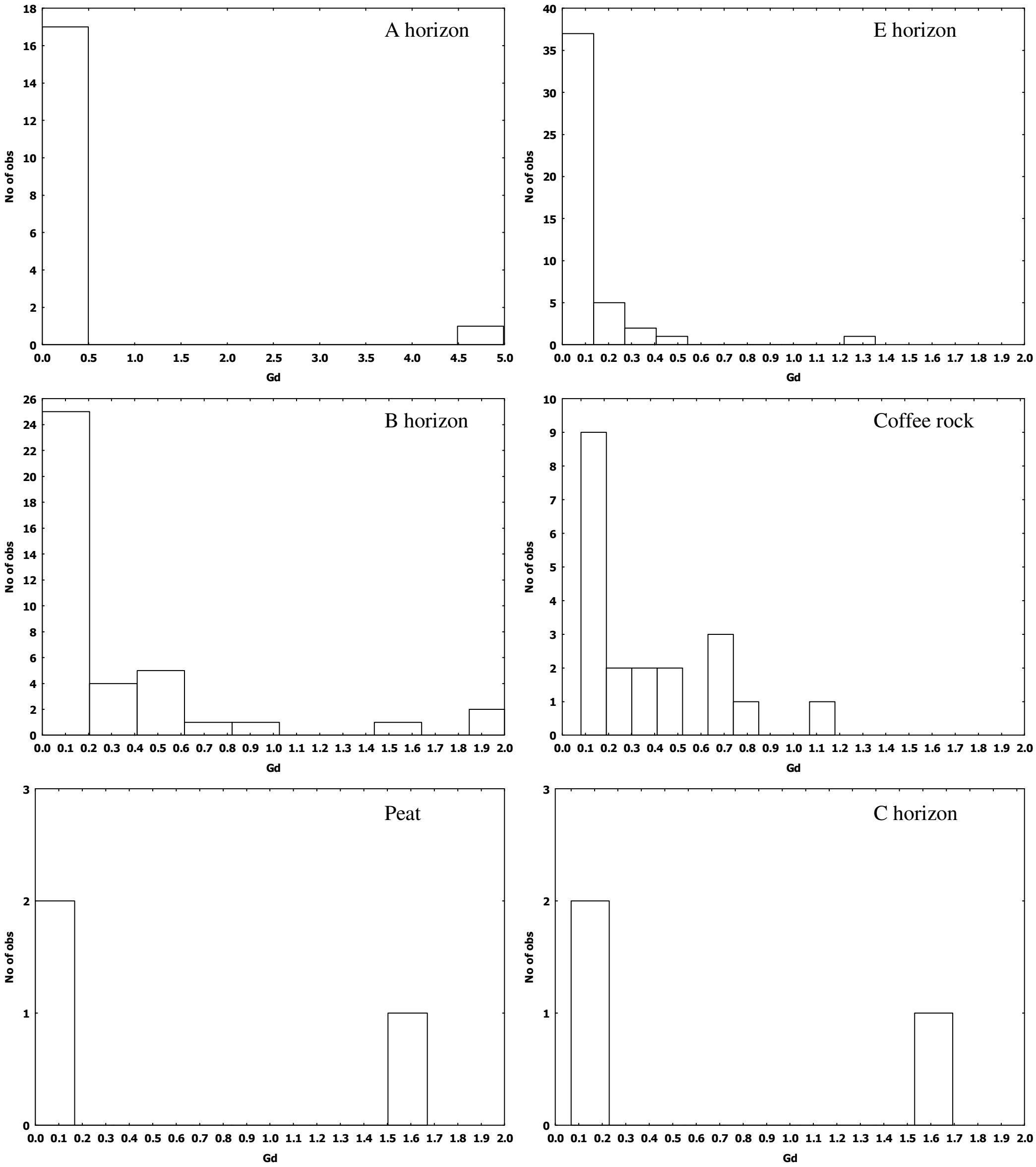
## Ga




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 0.26 | 0.064 | 20 | 4.7 |
| E horizon | 46 | 0.43 | 0.017 | 5.3 | 1.1 |
| B horizon | 39 | 1.5 | nd | 23 | 6.0 |
| Coffee rock | 20 | 3.4 | 0.49 | 8.7 | 2.2 |
| Peat | 3 | 1.49 | nd | 8.7 | 4.6 |
| C horizon | 3 | 1.0 | 0.73 | 2.3 | 0.8 |
| Mean values for normal surface soils worldwide 1-70 mg $kg^{-1}$* | | | | | |

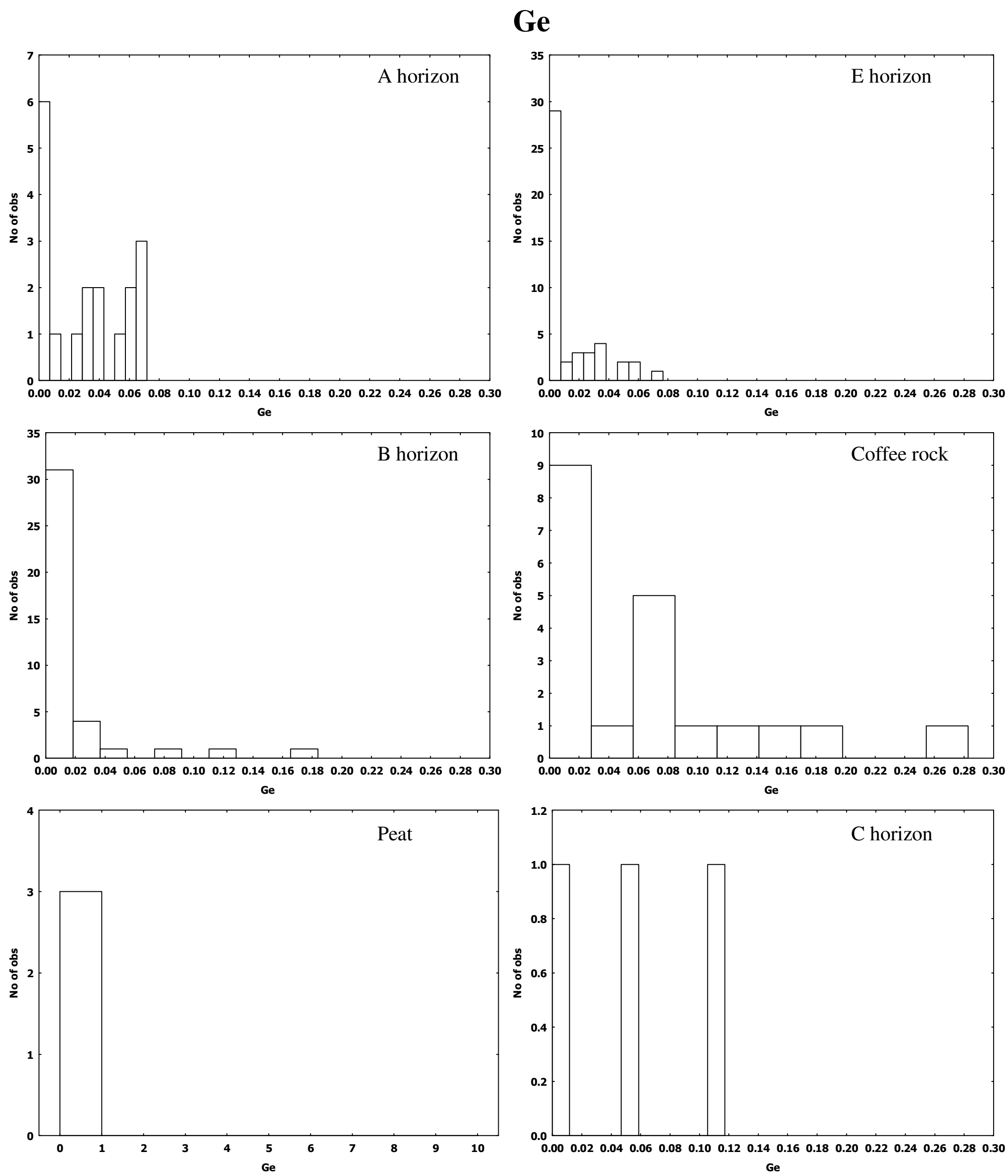
**Appendix Figure 48** Histograms for the concentration of gallium (Ga) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES).* Data are from Kabata-Pendias (2001), Essington (2004).

## Gd




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 0.082 | nd | 5.0 | 1.2 |
| E horizon | 46 | 0.076 | nd | 1.4 | 0.20 |
| B horizon | 39 | 0.089 | nd | 2.1 | 0.52 |
| Coffee rock | 20 | 0.21 | 0.081 | 1.2 | 0.30 |
| Peat | 3 | nd | nd | 1.7 | 0.96 |
| C horizon | 3 | 0.10 | 0.067 | 1.7 | 0.93 |

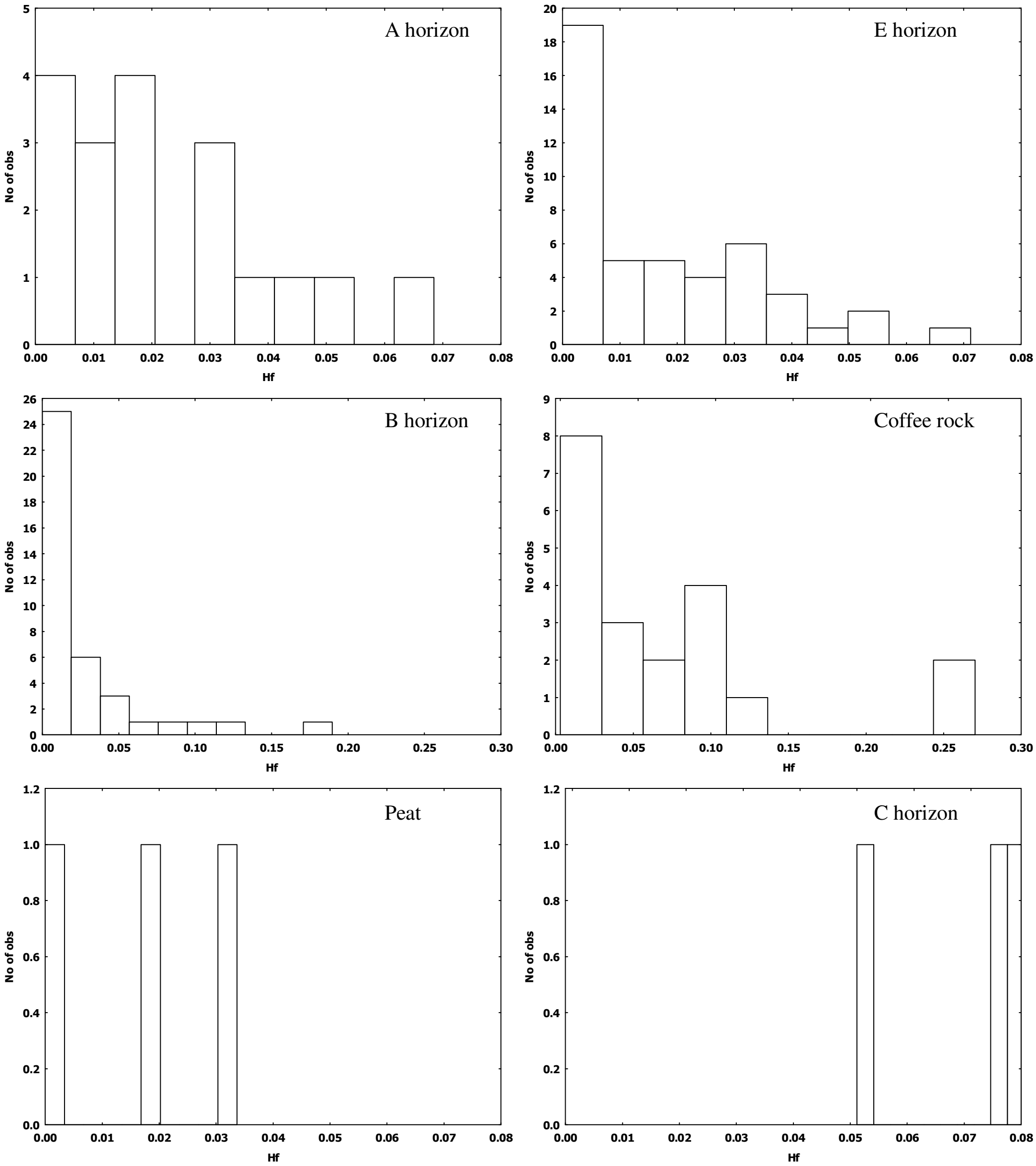
**Appendix Figure 49** Histograms for the concentration of gadolinium (Gd) in A, E, B, coffee rock, peat and C horizon materials (in mg kg$^{-1}$ unit) (aqua regia method; ICP-OES).




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 0.033 | nd | 0.072 | 0.028 |
| E horizon | 46 | 0.000010 | nd | 0.077 | 0.020 |
| B horizon | 39 | nd | nd | 0.18 | 0.037 |
| Coffee rock | 20 | 0.055 | nd | 0.28 | 0.076 |
| Peat | 3 | nd | nd | nd | nd |
| C horizon | 3 | 0.052 | nd | 0.12 | 0.059 |

**Appendix Figure 50** Histograms for the concentration of germanium (Ge) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES).

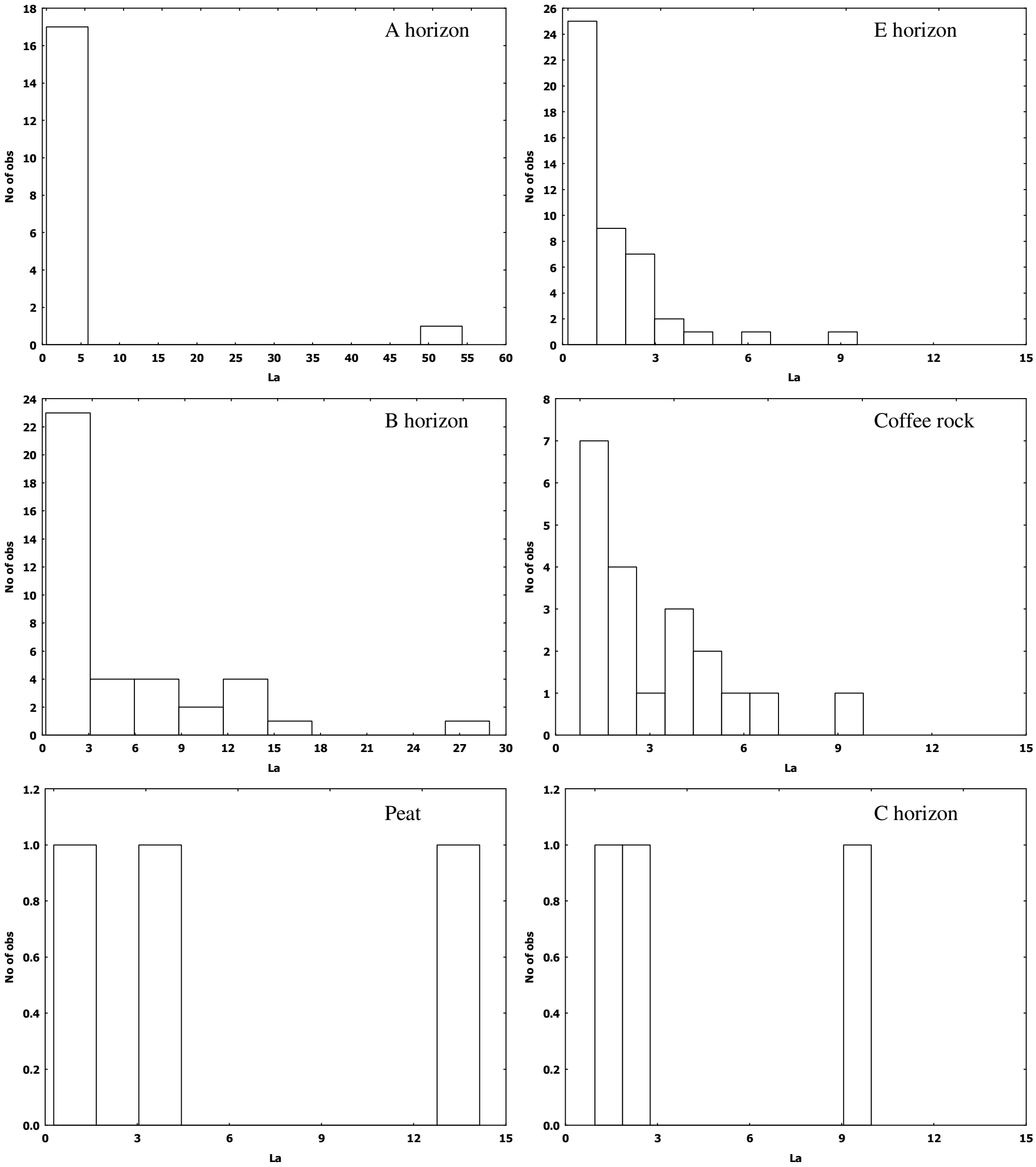
## Hf




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 0.022 | 0.015 | nd | 0.069 |
| E horizon | 46 | 0.017 | 0.011 | nd | 0.071 |
| B horizon | 39 | 0.025 | 0.008 | nd | 0.19 |
| Coffee rock | 20 | 0.072 | 0.045 | 0.0031 | 0.27 |
| Peat | 3 | 0.018 | 0.019 | nd | 0.034 |
| C horizon | 3 | 0.069 | 0.076 | 0.051 | 0.081 |
| Maximum hafnium content observed in soils 0.6-4.1 mg $kg^{-1}$* | | | | | |

**Appendix Figure 51** Histograms for the concentration of hafnium (Hf) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES). * Data are from Crompton (2006).

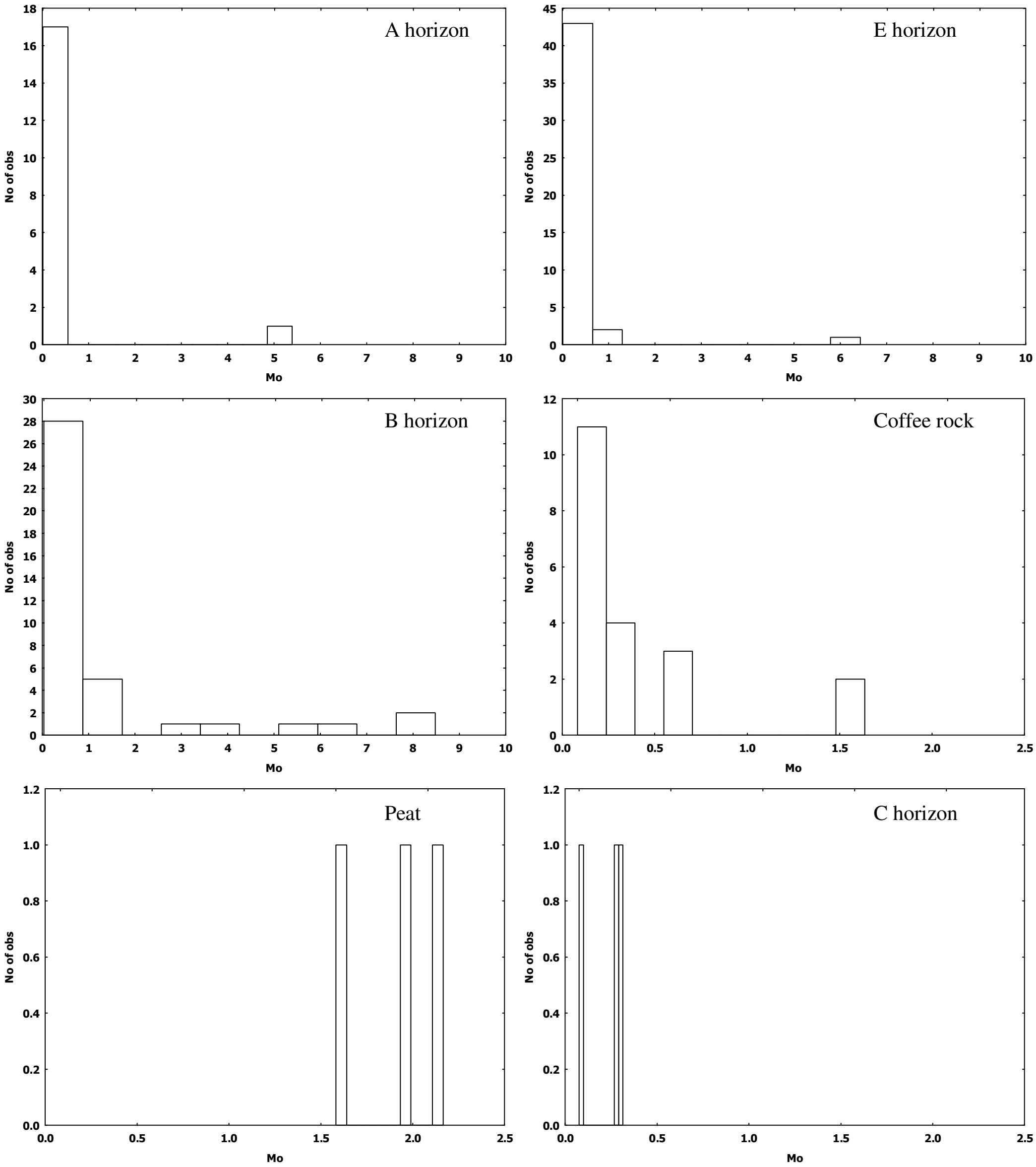
**La**




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 1.03 | 0.52 | 54 | 13 |
| E horizon | 46 | 1.03 | 0.18 | 10 | 1.7 |
| B horizon | 39 | 2.4 | 0.23 | 29 | 5.9 |
| Coffee rock | 20 | 2.3 | 0.77 | 10 | 2.4 |
| Peat | 3 | 4.3 | 0.28 | 14 | 7.1 |
| C horizon | 3 | 2.1 | 0.96 | 10 | 4.9 |
| Maximum hafnium content observed in soils 15-47 mg $kg^{-1*}$ | | | | | |

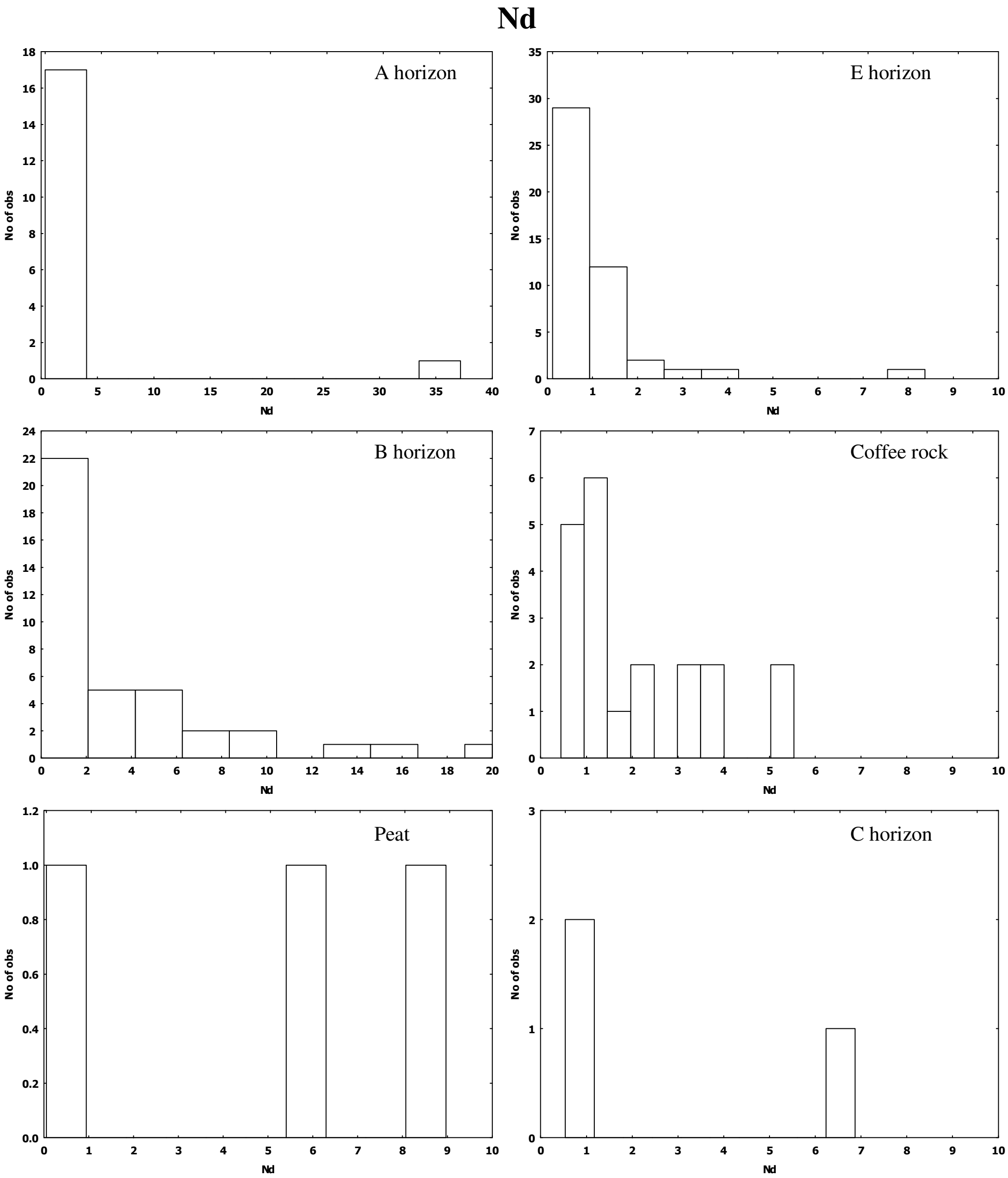
**Appendix Figure 52** Histograms for the concentration of lanthanum (La) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES). * Data are from Crompton (2006).

## Mo




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 0.13 | 0.013 | 5.4 | 1.24 |
| E horizon | 46 | 0.095 | 0.013 | 6.4 | 0.95 |
| B horizon | 39 | 0.34 | 0.034 | 8.5 | 2.18 |
| Coffee rock | 20 | 0.20 | 0.083 | 1.6 | 0.44 |
| Peat | 3 | 1.9 | 1.6 | 2.2 | 0.29 |
| C horizon | 3 | 0.28 | 0.075 | 0.31 | 0.13 |
| Maximum hafnium content observed in soils 0.2-437 mg $kg^{-1*}$ | | | | | |

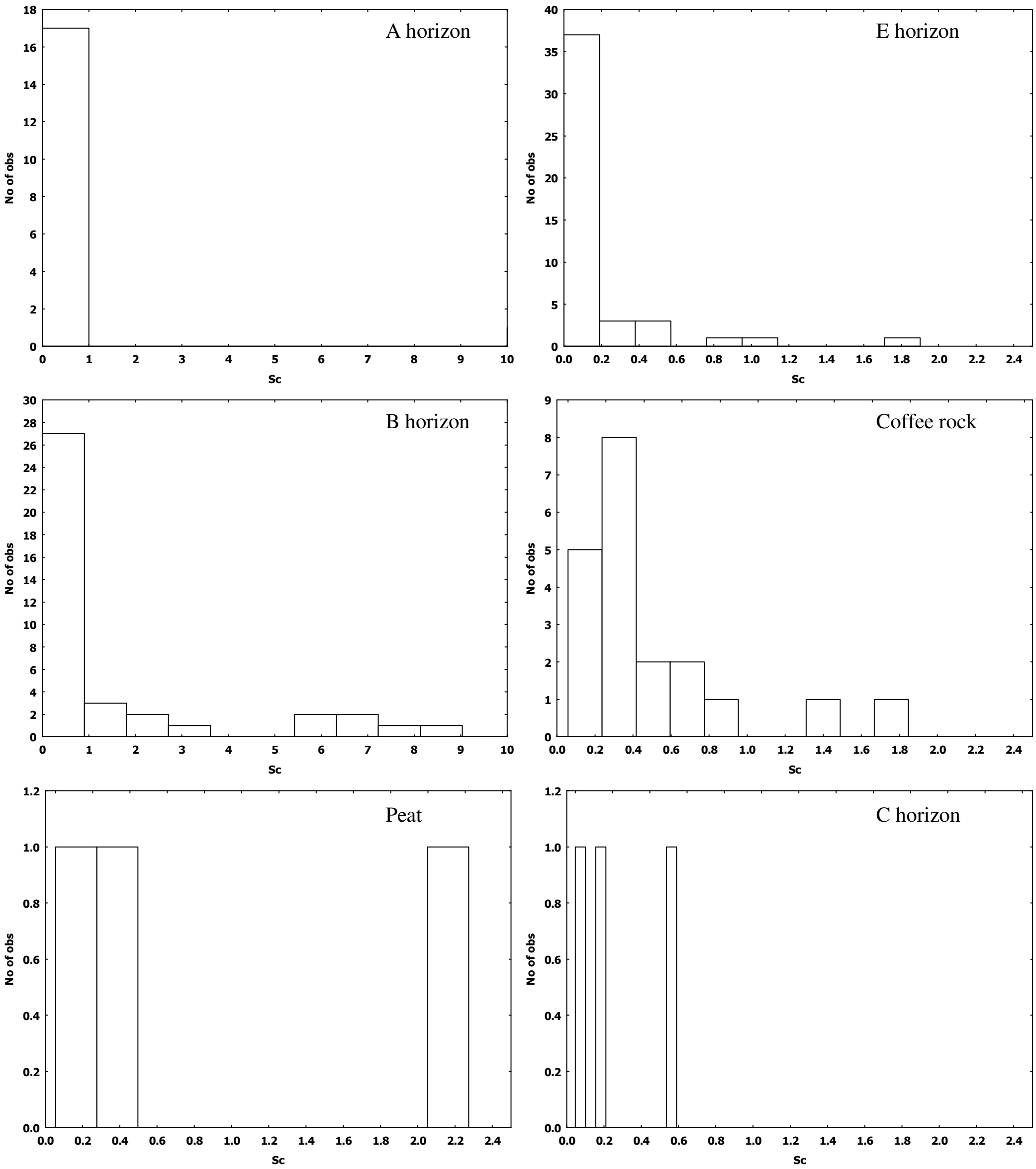
**Appendix Figure 53** Histograms for the concentration of molybdenum (Mo) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES). * Data are from Crompton (2006).




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 0.60 | 0.35 | 37 | 8.6 |
| E horizon | 46 | 0.65 | 0.11 | 8.4 | 1.3 |
| B horizon | 39 | 1.5 | nd | 21 | 4.7 |
| Coffee rock | 20 | 1.4 | 0.44 | 5.5 | 1.6 |
| Peat | 3 | 5.4 | 0.054 | 9.0 | 4.5 |
| C horizon | 3 | 1.0 | 0.54 | 6.9 | 3.5 |

**Appendix Figure 54** Histograms for the concentration of neodymium (Nd) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES).

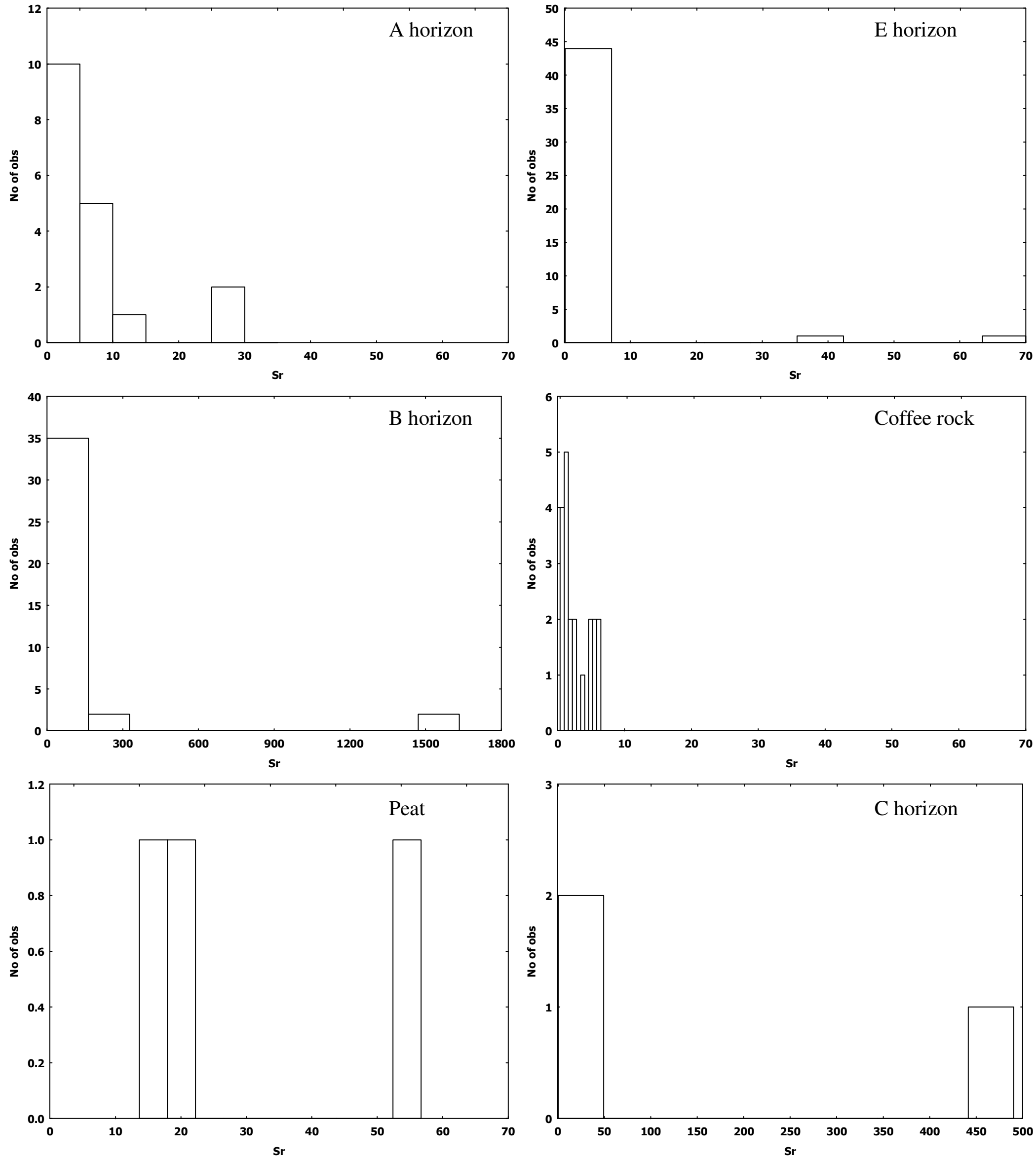
**Sc**




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 0.042 | 0.0030 | 10.1 | 2.4 |
| E horizon | 46 | 0.051 | nd | 1.9 | 0.34 |
| B horizon | 39 | 0.23 | nd | 9.0 | 2.5 |
| Coffee rock | 20 | 0.29 | 0.058 | 1.8 | 0.45 |
| Peat | 3 | 0.38 | 0.054 | 2.3 | 1.2 |
| C horizon | 3 | 0.17 | 0.046 | 0.59 | 0.29 |

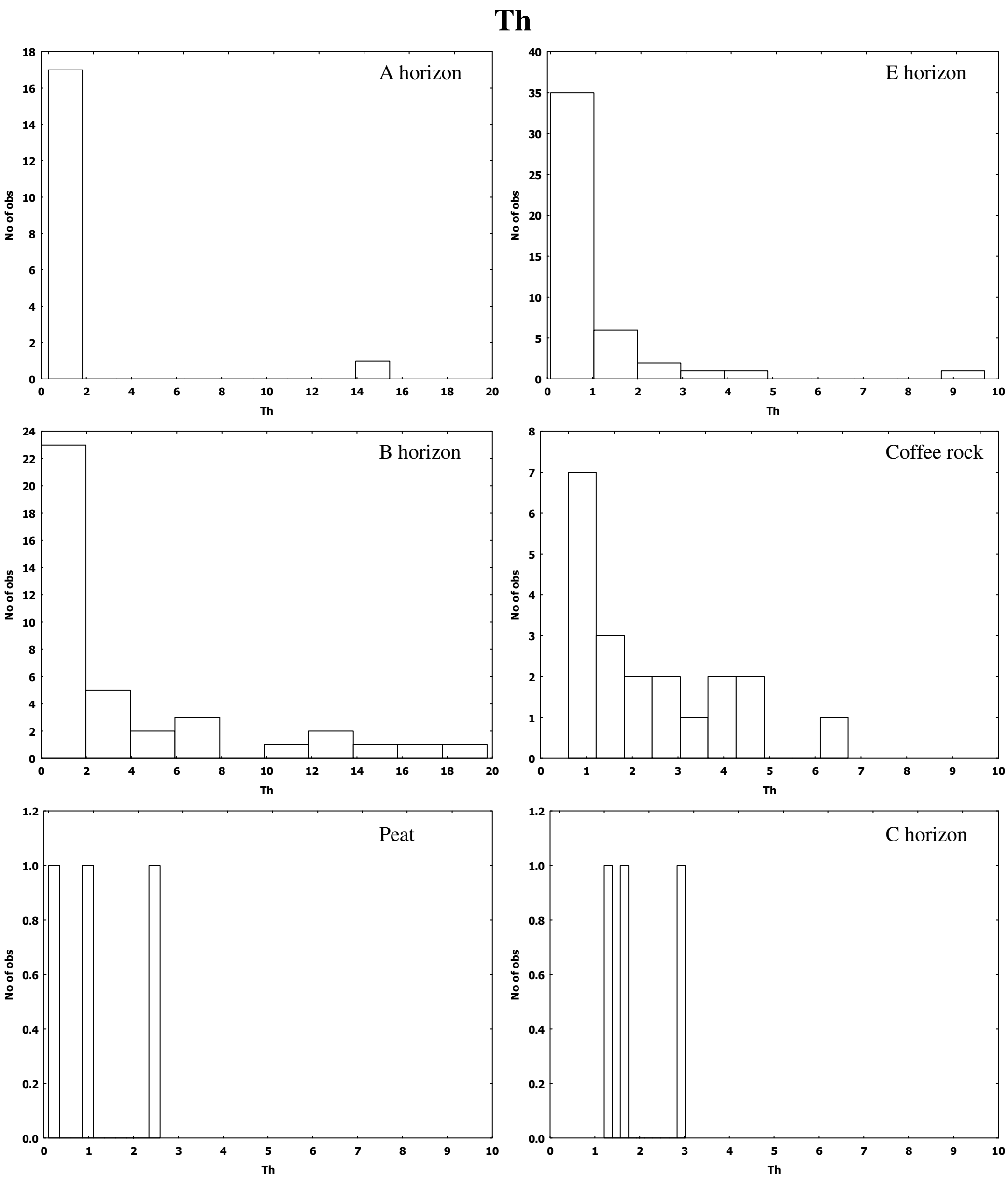
**Appendix Figure 55** Histograms for the concentration of scandium (Sc) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES).

# Sr




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 4.5 | 0.29 | 29 | 8.1 |
| E horizon | 46 | 0.40 | 0.11 | 70 | 12 |
| B horizon | 39 | 1.9 | 0.28 | 1634 | 356 |
| Coffee rock | 20 | 1.8 | 0.38 | 6.5 | 2.09 |
| Peat | 3 | 20 | 14 | 57 | 23 |
| C horizon | 3 | 1.08 | 0.56 | 490 | 283 |
| Mean values for normal surface soils worldwide 87-210 mg $kg^{-1}$* | | | | | |

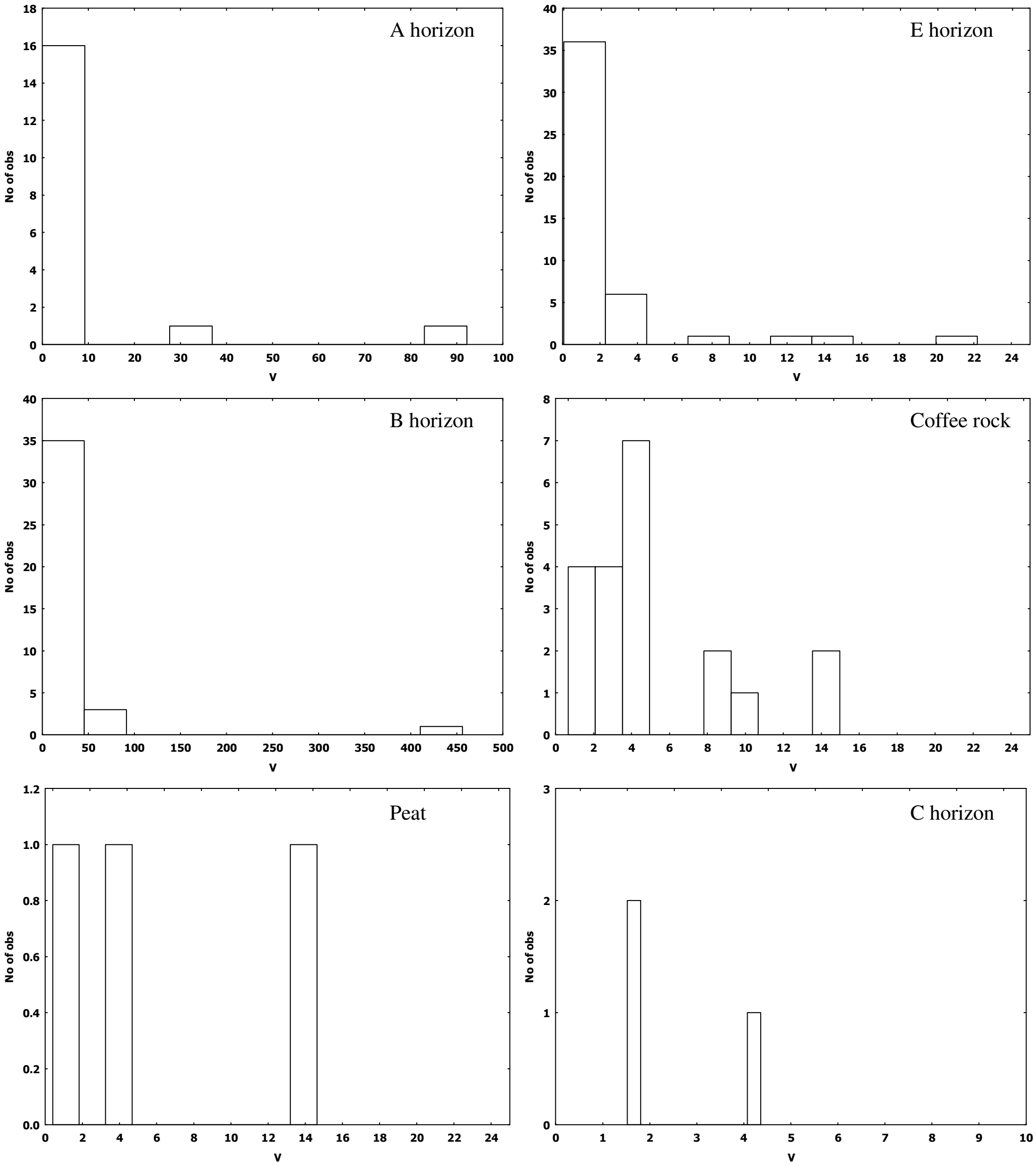
**Appendix Figure 56** Histograms for the concentration of stronium (Sr) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES). * Data are from Kabata-Pendias (2001), Essington (2004).




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 0.48 | 0.32 | 15 | 3.5 |
| E horizon | 46 | 0.58 | 0.074 | 10 | 1.5 |
| B horizon | 39 | 1.3 | 0.011 | 20 | 5.2 |
| Coffee rock | 20 | 1.7 | 0.60 | 6.7 | 1.7 |
| Peat | 3 | 1.1 | 0.10 | 2.6 | 1.3 |
| C horizon | 3 | 1.6 | 1.2 | 3.0 | 0.9 |

**Appendix Figure 57** Histograms for the concentration of thorium (Th) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES).

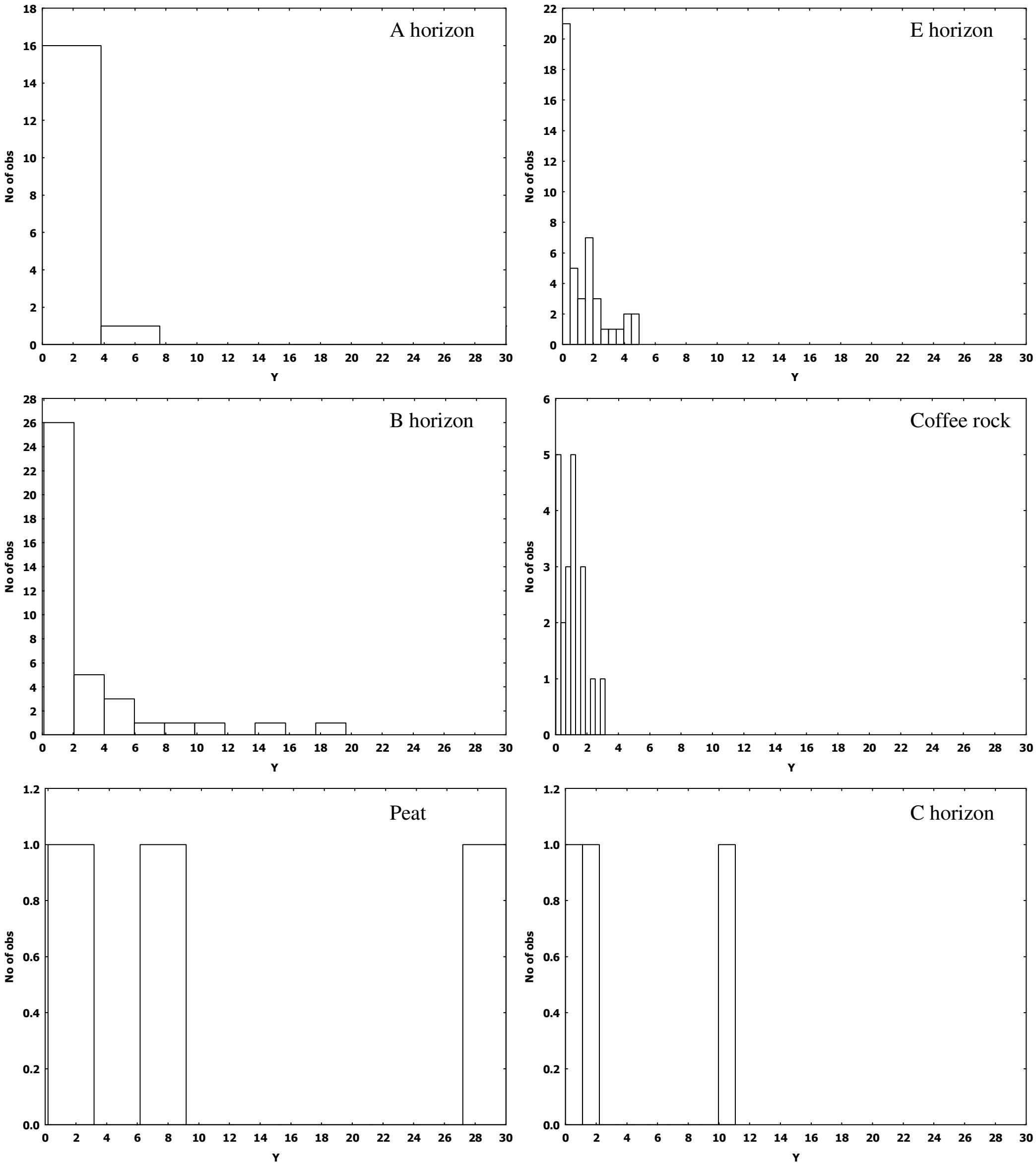
**V**




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 0.90 | 0.015 | 92 | 22 |
| E horizon | 46 | 1.05 | 0.076 | 22 | 4.1 |
| B horizon | 39 | 2.3 | nd | 456 | 74 |
| Coffee rock | 20 | 4.0 | 0.66 | 15 | 4.04 |
| Peat | 3 | 4.2 | 0.41 | 15 | 7.4 |
| C horizon | 3 | 1.8 | 1.5 | 4.4 | 1.6 |
| Mean values for normal surface soils worldwide 18-115 mg $kg^{-1}$* | | | | | |
| Critical soil concentration 50-100 mg $kg^{-1}$** | | | | | |

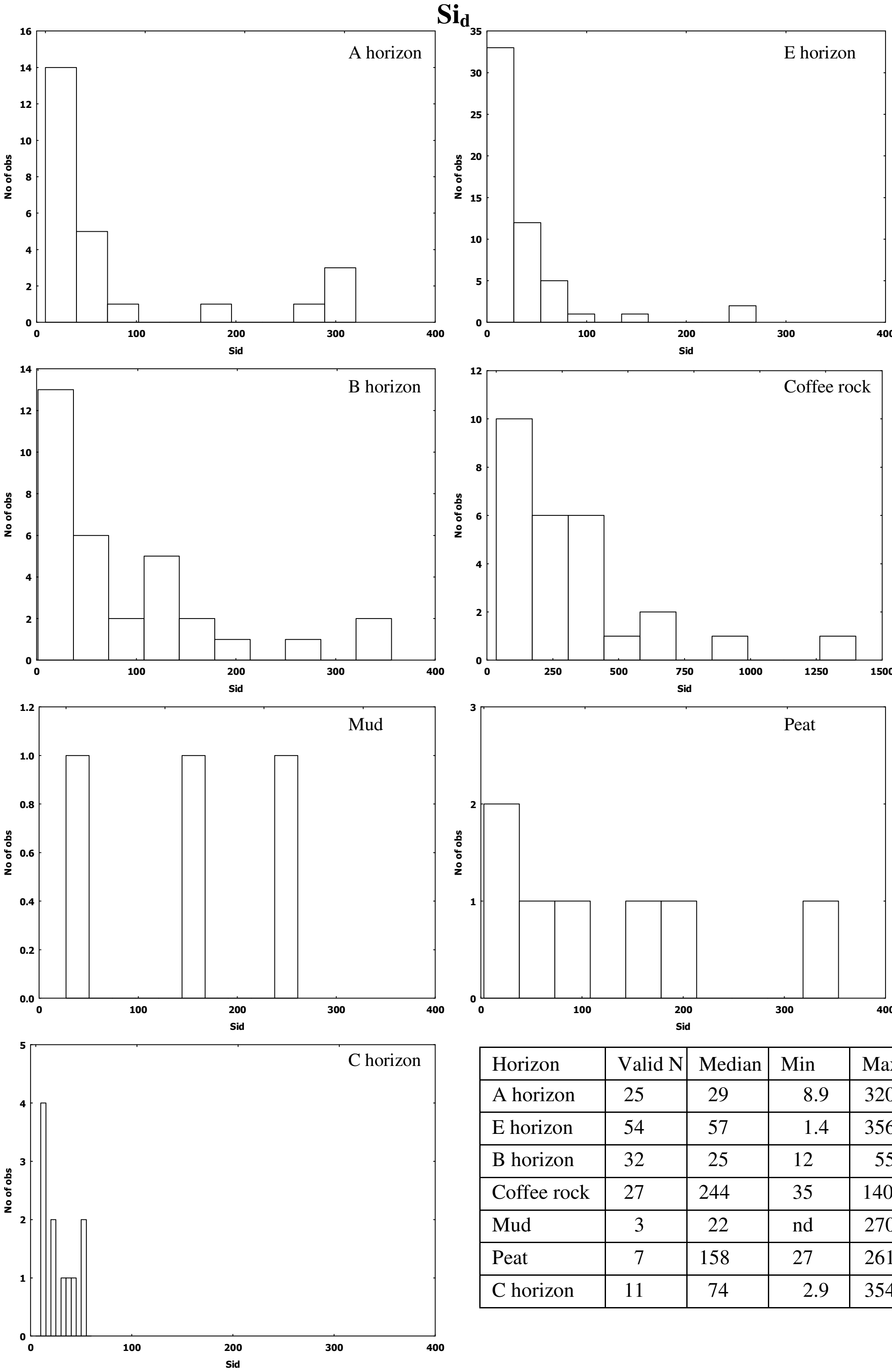
**Appendix Figure 58** Histograms for the concentration of vanadium (V) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES). * Data are from Kabata-Pendias (2001), Essington (2004); ** Data are from (Alloway, 1995).

**Y**




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 18 | 1.5 | nd | 38 | 8.7 |
| E horizon | 46 | 0.59 | nd | 5.0 | 1.4 |
| B horizon | 39 | 1.5 | 0.10 | 20 | 4.4 |
| Coffee rock | 20 | 0.97 | 0.019 | 3.2 | 0.82 |
| Peat | 3 | 6.8 | 0.17 | 30 | 16 |
| C horizon | 3 | 1.7 | nd | 11 | 6.0 |

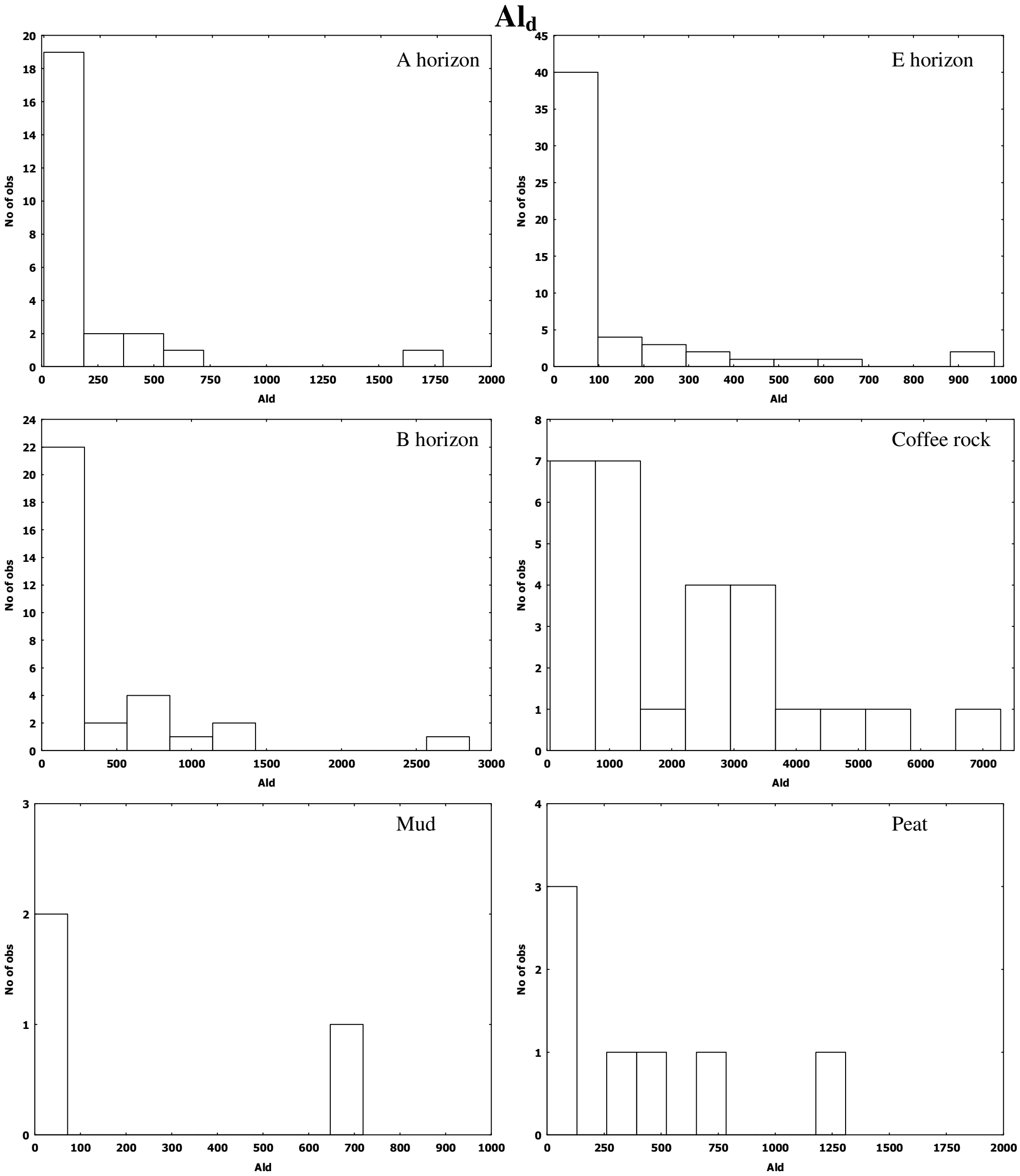
**Appendix Figure 59** Histograms for the concentration of yttrium (Y) in A, E, B, coffee rock, peat and C horizon materials (in mg $kg^{-1}$ unit) (aqua regia method; ICP-OES).

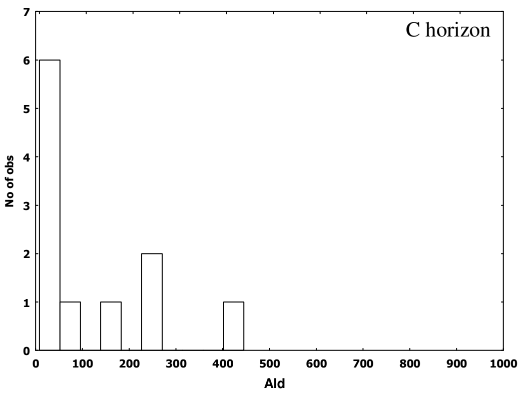



| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 25 | 29 | 8.9 | 320 | 105 |
| E horizon | 54 | 57 | 1.4 | 356 | 92 |
| B horizon | 32 | 25 | 12 | 55 | 17 |
| Coffee rock | 27 | 244 | 35 | 1400 | 300 |
| Mud | 3 | 22 | nd | 270 | 52 |
| Peat | 7 | 158 | 27 | 261 | 117 |
| C horizon | 11 | 74 | 2.9 | 354 | 125 |

**Appendix Figure 60** Histograms for the concentration of silicon extracted by dithionite citrate bicarbonate (Sid) for A, E, B, coffee rock, mud, peat and C horizons (in mg $kg^{-1}$ unit).

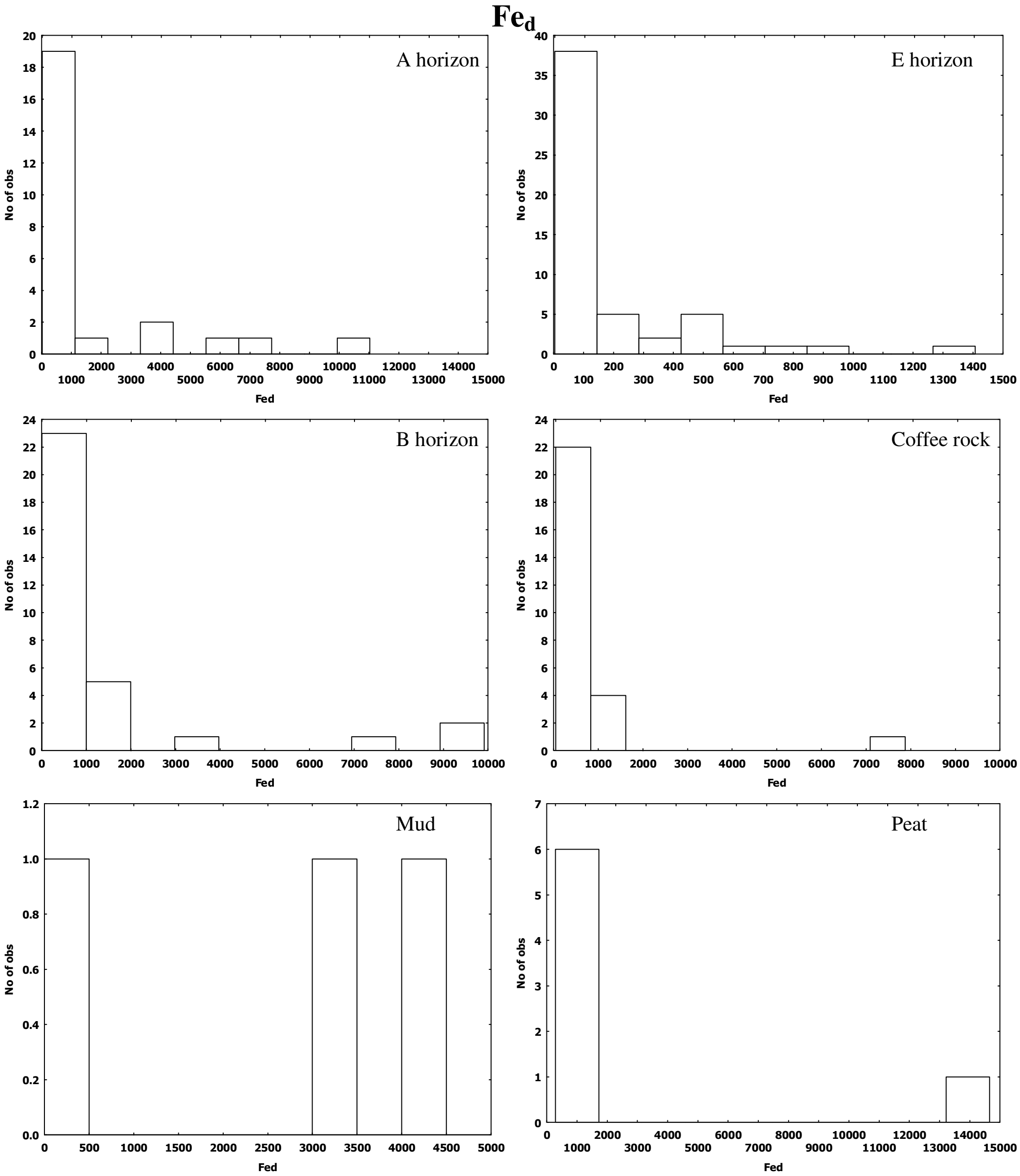
# $Al_d$

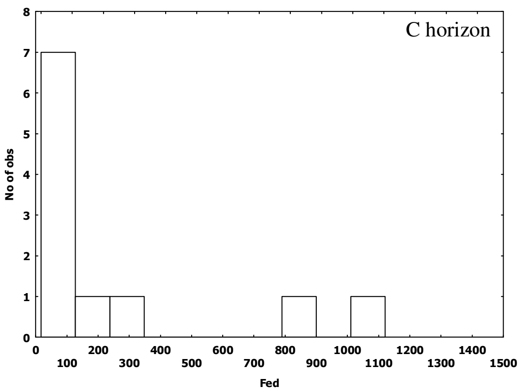



| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 25 | 69 | 10 | 1786 | 371 |
| E horizon | 54 | 179 | nd | 2853 | 567 |
| B horizon | 32 | 39 | 7.8 | 445 | 142 |
| Coffee rock | 27 | 1378 | 51 | 7285 | 1744 |
| Mud | 3 | 26 | nd | 980 | 212 |
| Peat | 7 | 64 | nd | 719 | 398 |
| C horizon | 11 | 303 | nd | 1308 | 470 |

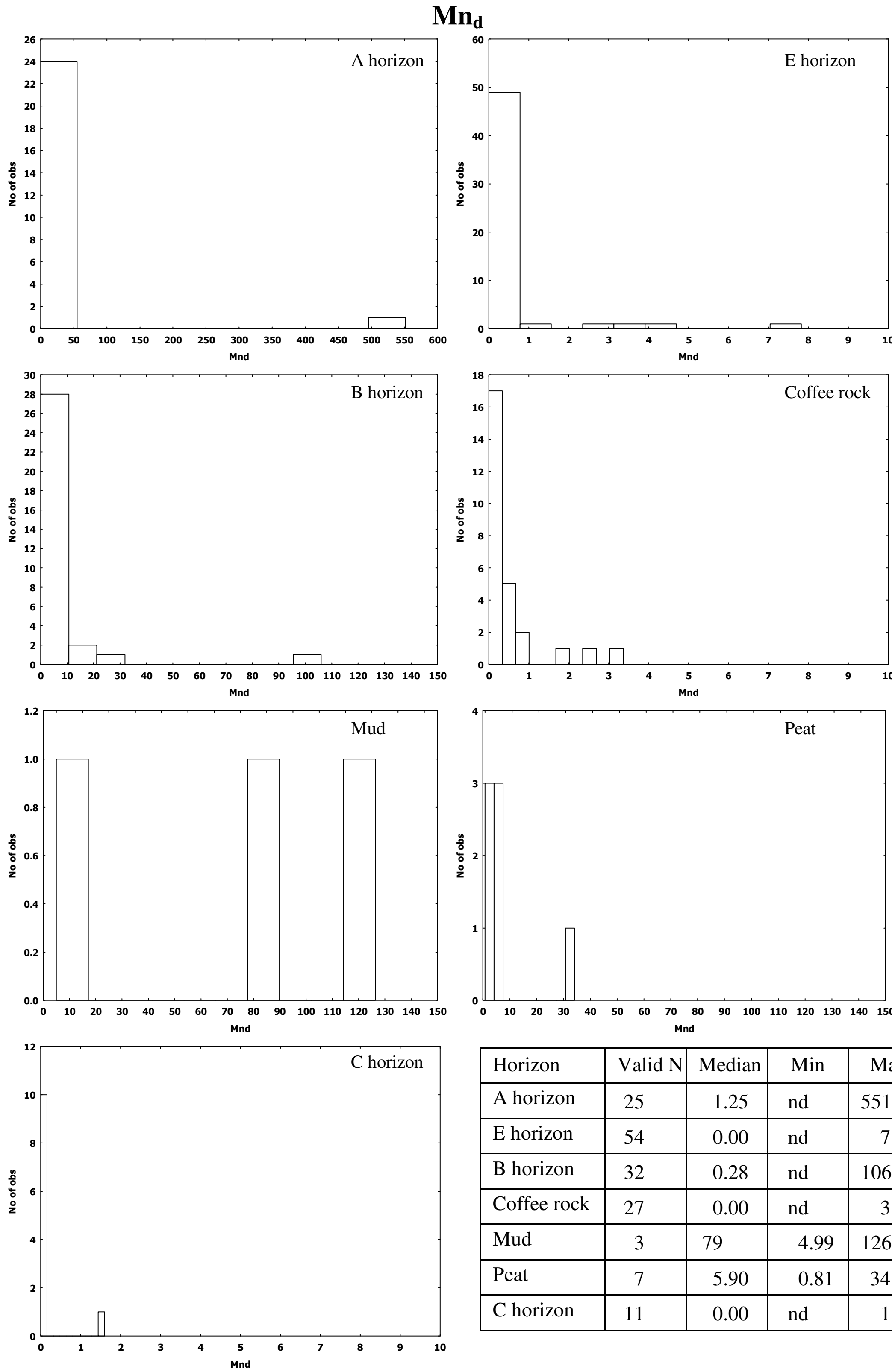
**Appendix Figure 61** Histograms for the concentration of aluminium extracted by dithionite citrate bicarbonate (Ald) for A, E, B, coffee rock, mud, peat and C horizons (in mg $kg^{-1}$ unit).



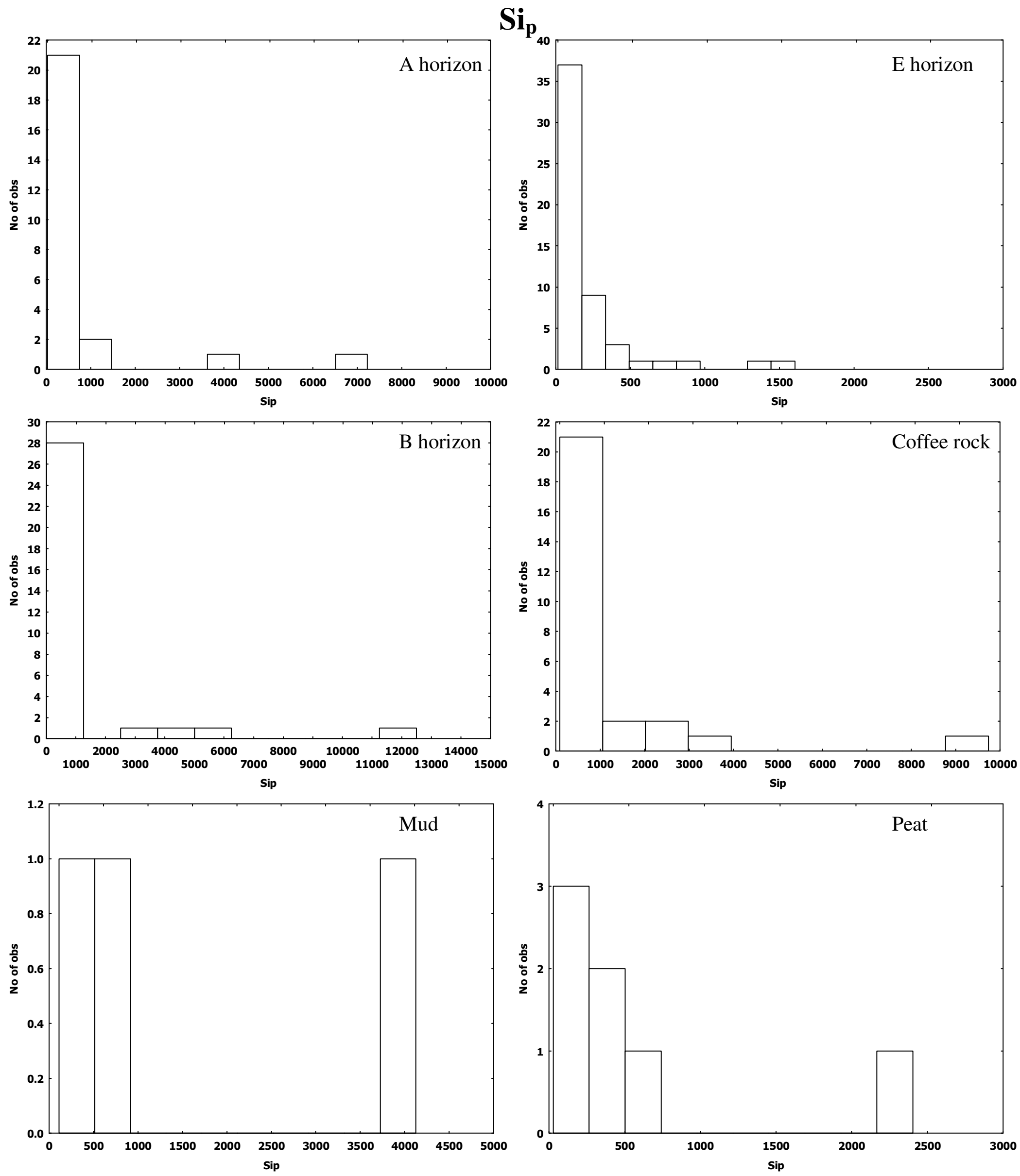

| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 25 | 249 | 21 | 11031 | 2804 |
| E horizon | 54 | 247 | 4.6 | 1407 | 268 |
| B horizon | 32 | 63 | 10 | 9917 | 2604 |
| Coffee rock | 27 | 206 | 50 | 7874 | 1493 |
| Mud | 3 | 71 | 29 | 4268 | 2246 |
| Peat | 7 | 3437 | 281 | 14657 | 5170 |
| C horizon | 11 | 1200 | 17 | 1121 | 378 |

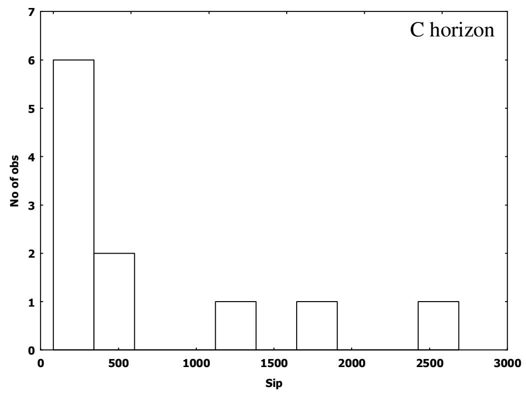
**Appendix Figure 62** Histograms for the concentration of iron extracted by dithionite citrate bicarbonate (Fed) for A, E, B, coffee rock, mud, peat and C horizons (in mg $kg^{-1}$ unit).




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 25 | 1.25 | nd | 551 | 110 |
| E horizon | 54 | 0.00 | nd | 7.8 | 1.33 |
| B horizon | 32 | 0.28 | nd | 106 | 19 |
| Coffee rock | 27 | 0.00 | nd | 3.4 | 0.83 |
| Mud | 3 | 79 | 4.99 | 126 | 61 |
| Peat | 7 | 5.90 | 0.81 | 34 | 12 |
| C horizon | 11 | 0.00 | nd | 1.6 | 0.48 |

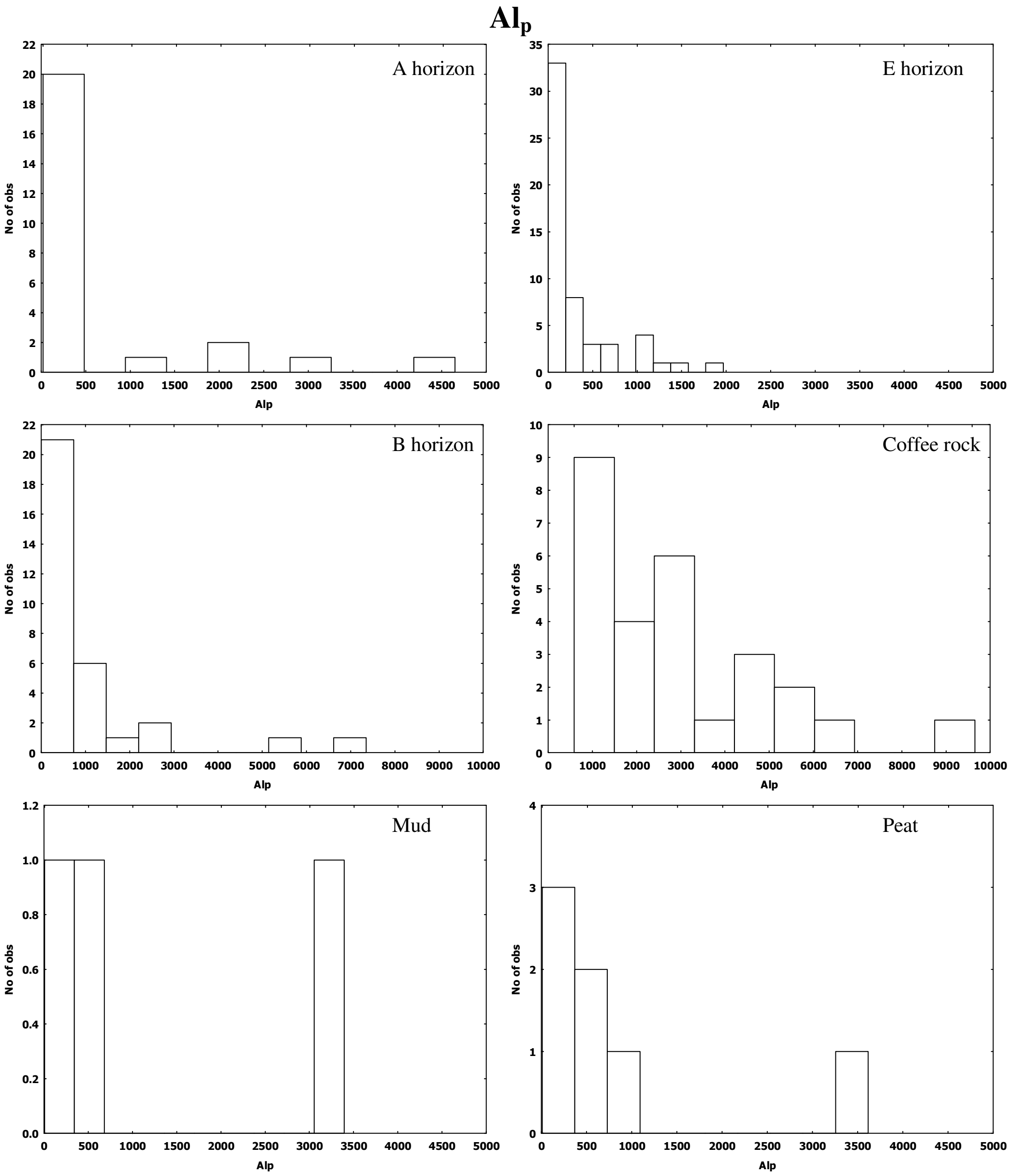
**Appendix Figure 63** Histograms for the concentration of manganese extracted by dithionite citrate bicarbonate (Mnd) for A, E, B, coffee rock, mud, peat and C horizons (in mg $kg^{-1}$ unit).

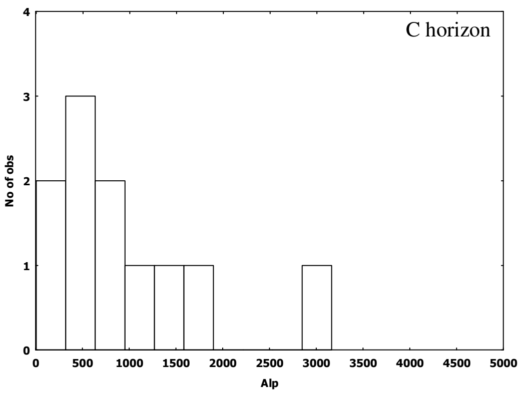



| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 25 | 115 | 31 | 7227 | 1558 |
| E horizon | 54 | 112 | 15 | 1604 | 303 |
| B horizon | 32 | 277 | 14 | 12491 | 2445 |
| Coffee rock | 27 | 321 | 89 | 9739 | 1935 |
| Mud | 3 | 869 | 111 | 4127 | 2134 |
| Peat | 7 | 343 | 27 | 2404 | 835 |
| C horizon | 11 | 329 | 82 | 2688 | 824 |

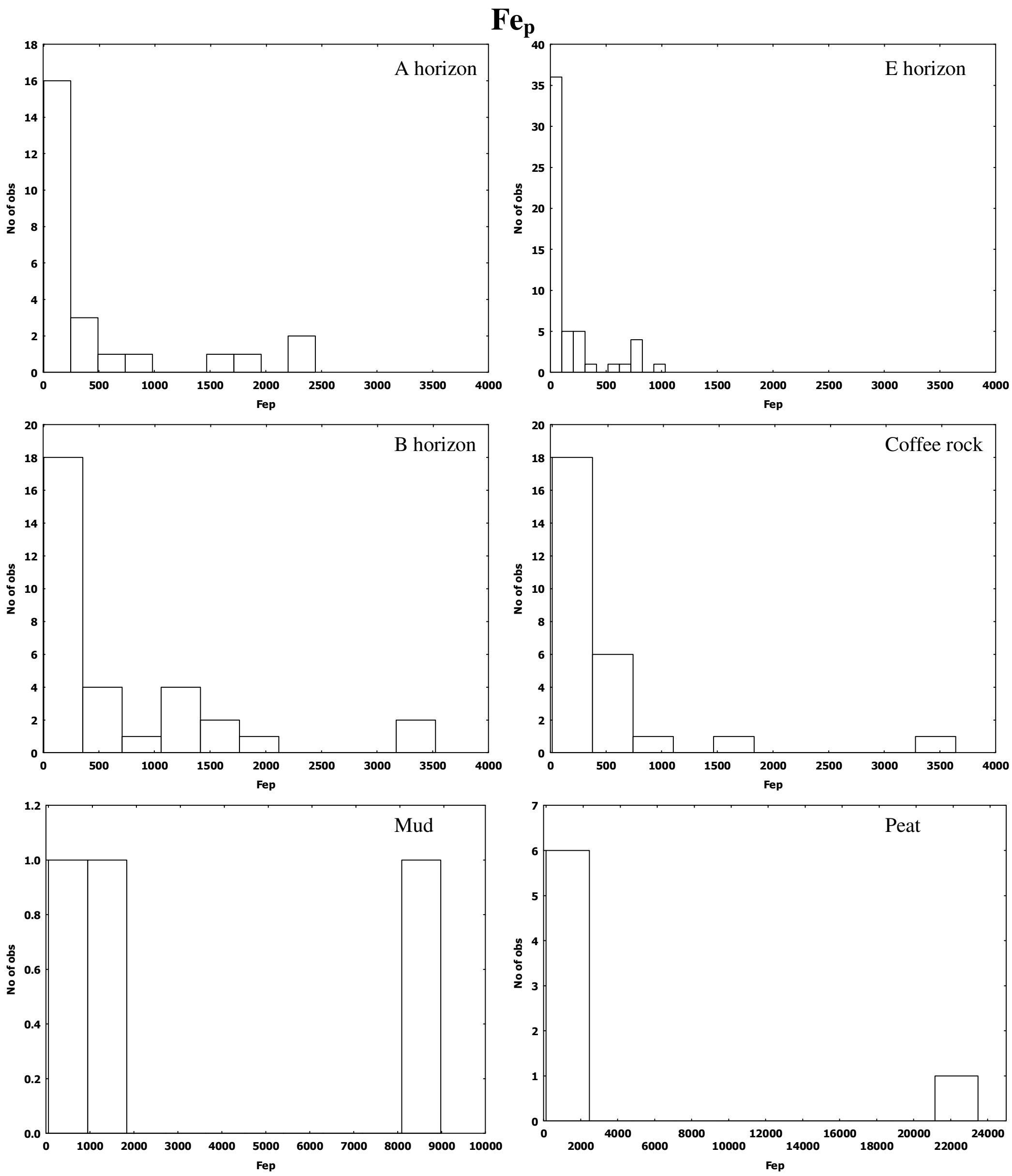
**Appendix Figure 64** Histograms for the concentration of silicon extracted by Na-pyrophosphate (Sip) for A, E, B, coffee rock, mud, peat and C horizons (in mg $kg^{-1}$ unit).

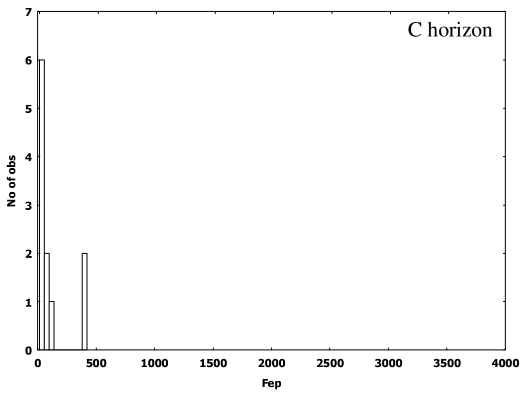



| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 25 | 110 | 19 | 4648 | 1130 |
| E horizon | 54 | 131 | nd | 1968 | 438 |
| B horizon | 32 | 378 | nd | 7351 | 1625 |
| Coffee rock | 27 | 2574 | 591 | 9651 | 2177 |
| Mud | 3 | 487 | 4.6 | 3394 | 1833 |
| Peat | 7 | 538 | 7.7 | 3617 | 1264 |
| C horizon | 11 | 858 | 5.9 | 3164 | 896 |

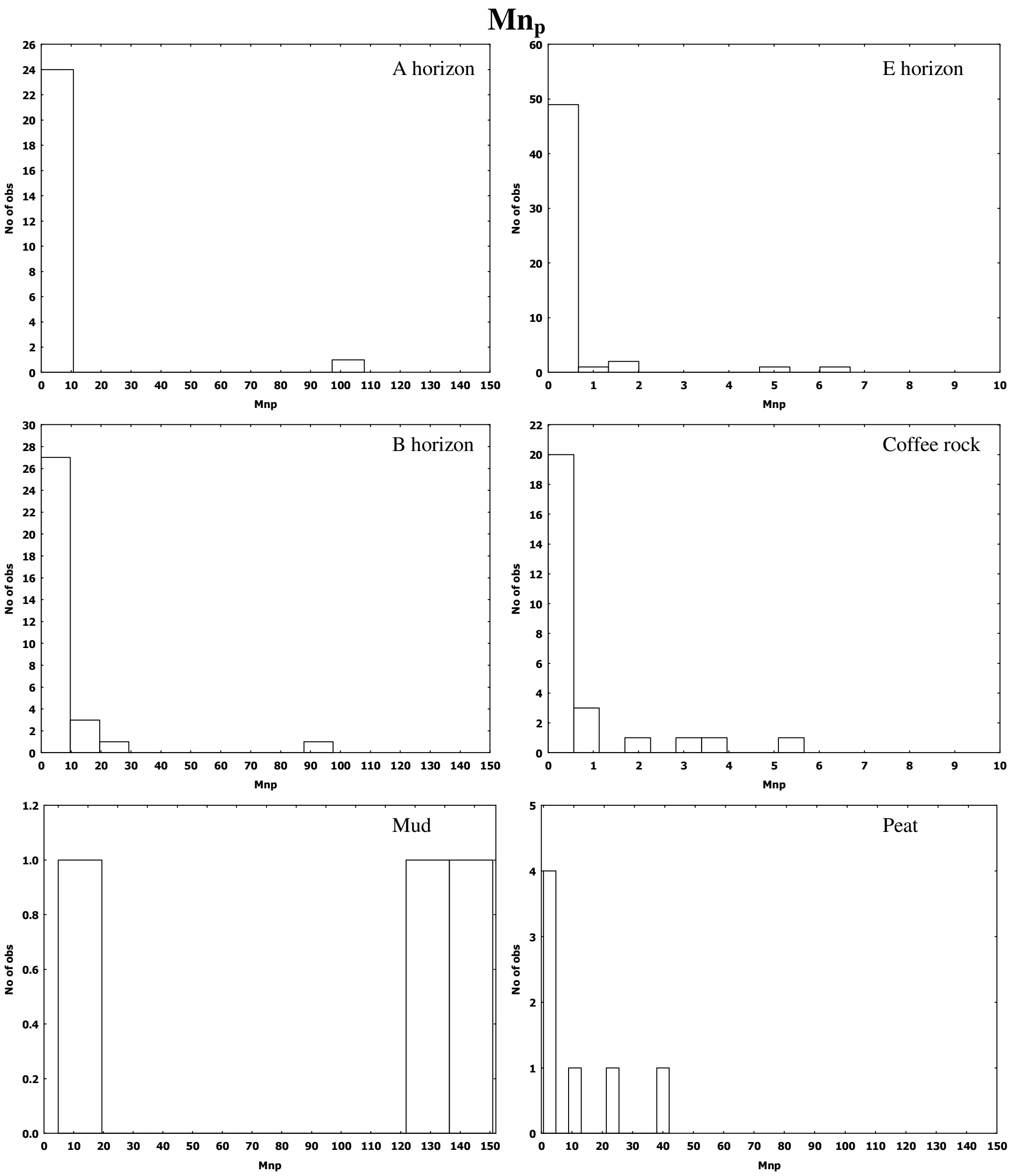
**Appendix Figure 65** Histograms for the concentration of aluminium extracted by Na-pyrophosphate (Alp) for A, E, B, coffee rock, mud, peat and C horizons (in mg $kg^{-1}$ unit).

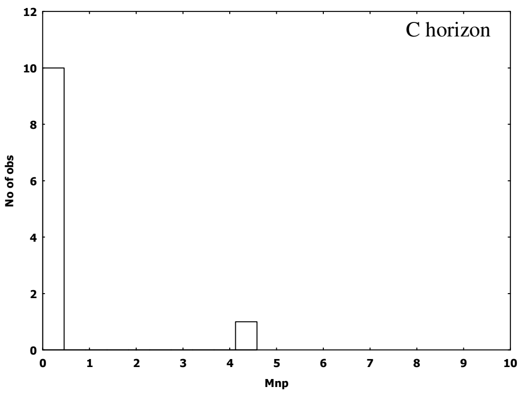



| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 25 | 66 | 4.8 | 2445 | 760 |
| E horizon | 54 | 48 | 0.69 | 1033 | 251 |
| B horizon | 32 | 253 | 4.5 | 3524 | 887 |
| Coffee rock | 27 | 303 | 17 | 3643 | 719 |
| Mud | 3 | 1491 | 54 | 8985 | 4796 |
| Peat | 7 | 929 | 137 | 23486 | 8487 |
| C horizon | 11 | 55 | 16 | 421 | 147 |

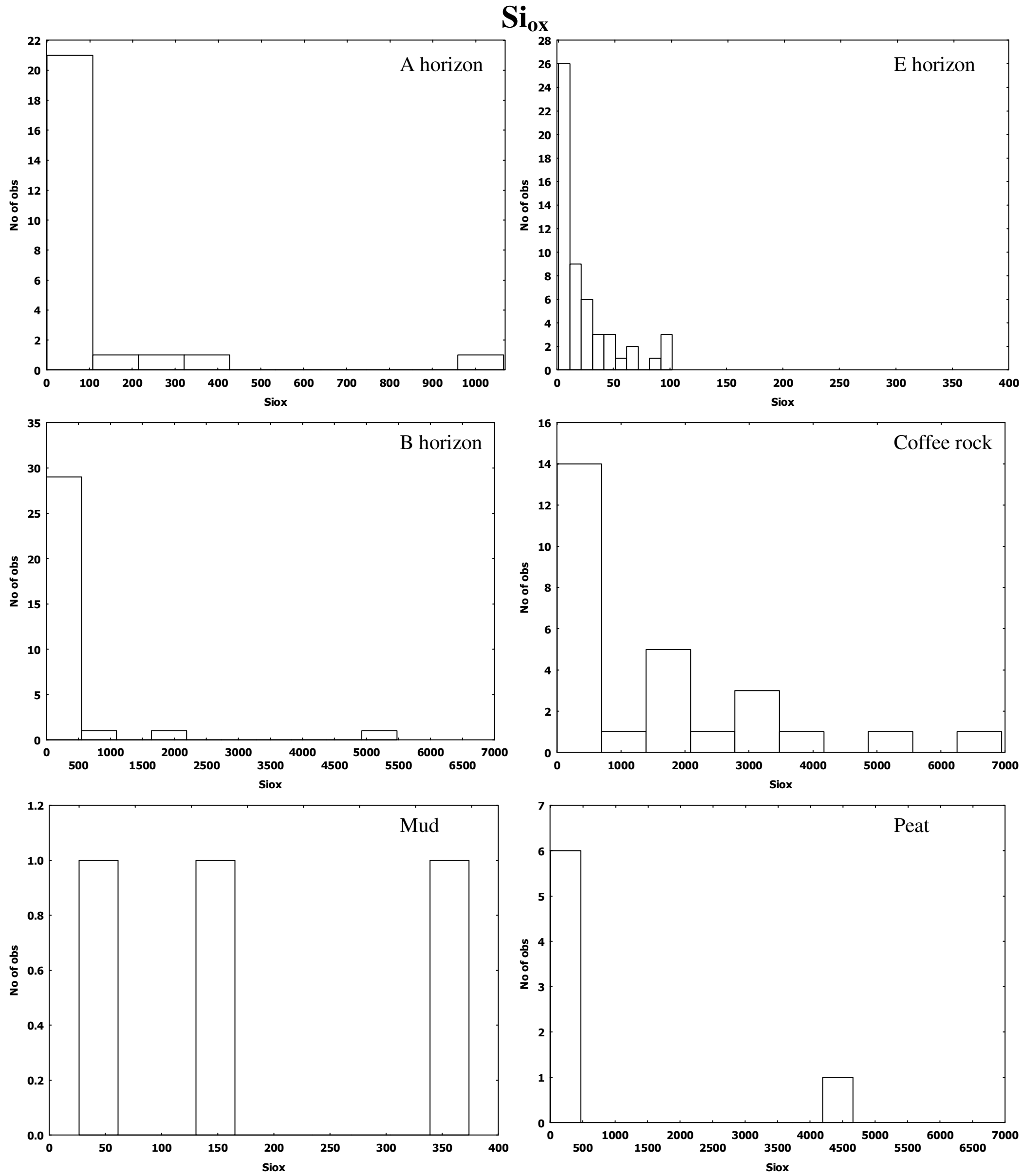
**Appendix Figure 66** Histograms for the concentration of iron extracted by Na-pyrophosphate (Fep) for A, E, B, coffee rock, mud, peat and C horizons (in mg $kg^{-1}$ unit).

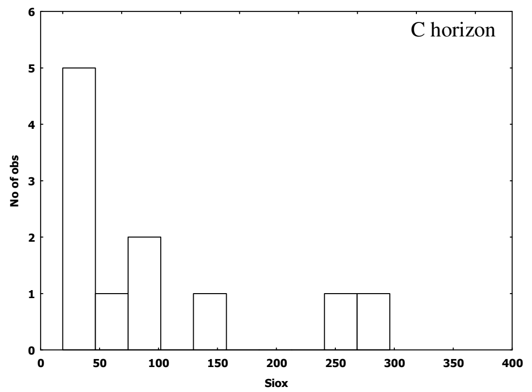



| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 25 | 0.80 | nd | 108 | 21 |
| E horizon | 54 | 0.00 | nd | 6.7 | 1.2 |
| B horizon | 32 | 0.48 | nd | 98 | 18 |
| Coffee rock | 27 | 0.13 | nd | 5.7 | 1.3 |
| Mud | 3 | 126 | 4.80 | 151 | 78 |
| Peat | 7 | 3.67 | 0.64 | 42 | 15 |
| C horizon | 11 | 0.00 | nd | 4.6 | 1.4 |

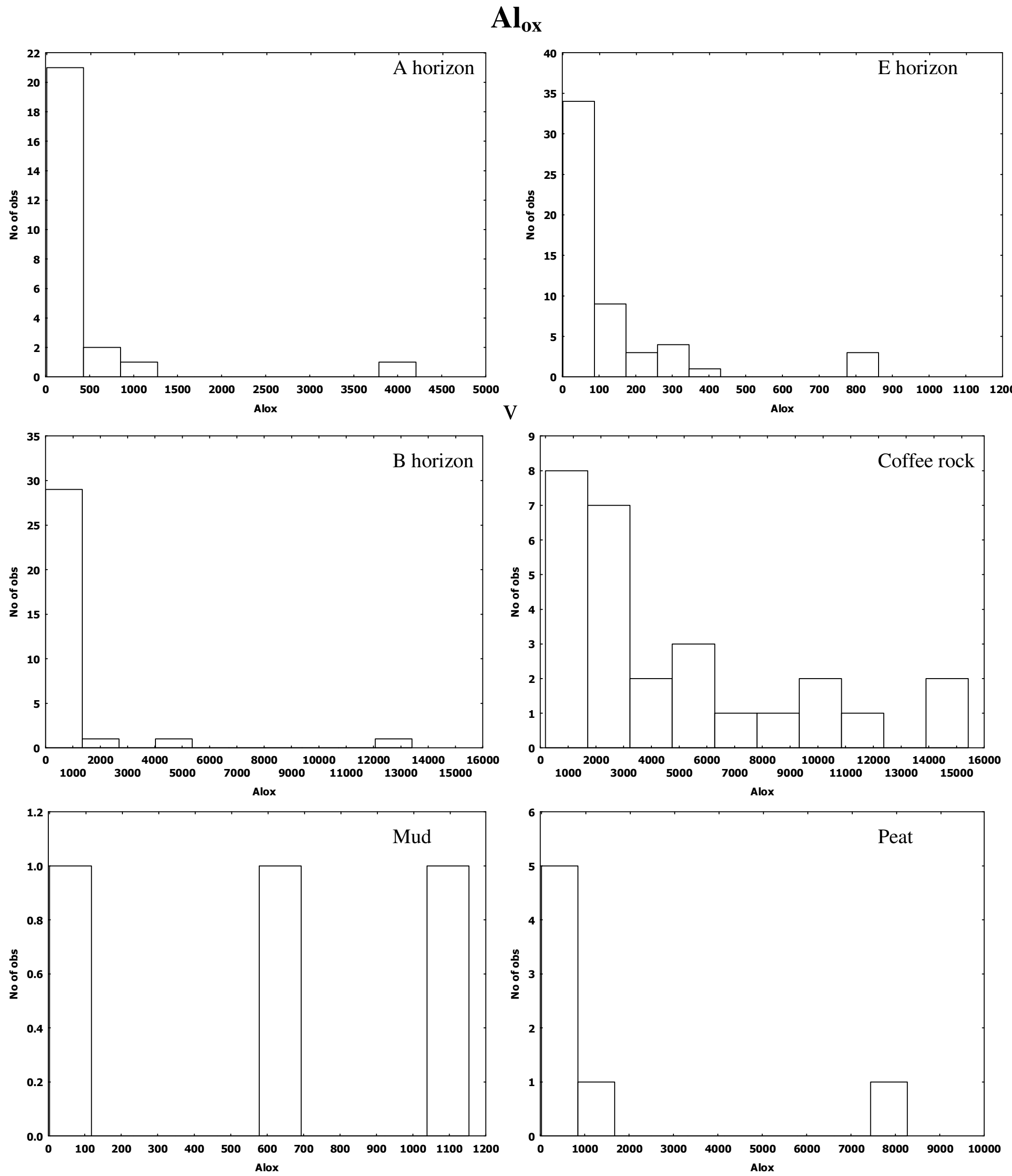
**Appendix Figure 67** Histograms for the concentration of manganese extracted by Na-pyrophosphate (Mnp) for A, E, B, coffee rock, mud, peat and C horizons (in mg $kg^{-1}$ unit).

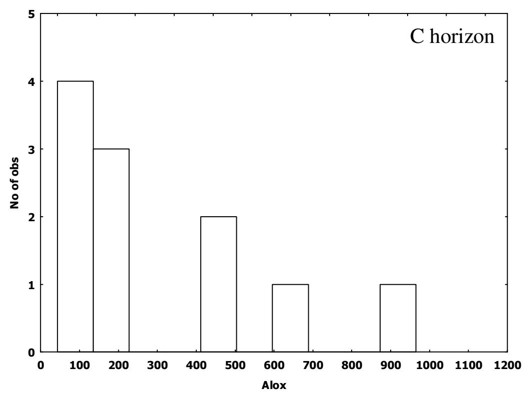



| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 25 | 20 | 1.60 | 1066 | 221 |
| E horizon | 54 | 13 | 1.38 | 102 | 27 |
| B horizon | 32 | 47 | nd | 5476 | 1022 |
| Coffee rock | 27 | 697 | 3.43 | 6947 | 1742 |
| Mud | 3 | 154 | 26 | 374 | 176 |
| Peat | 7 | 74 | 8.1 | 4658 | 1718 |
| C horizon | 11 | 62 | 19 | 296 | 93 |

**Appendix Figure 68** Histograms for the concentration of silicon extracted by oxalic acid (Siox) for A, E, B, coffee rock, mud, peat and C horizons (in mg kg$^{-1}$ unit).

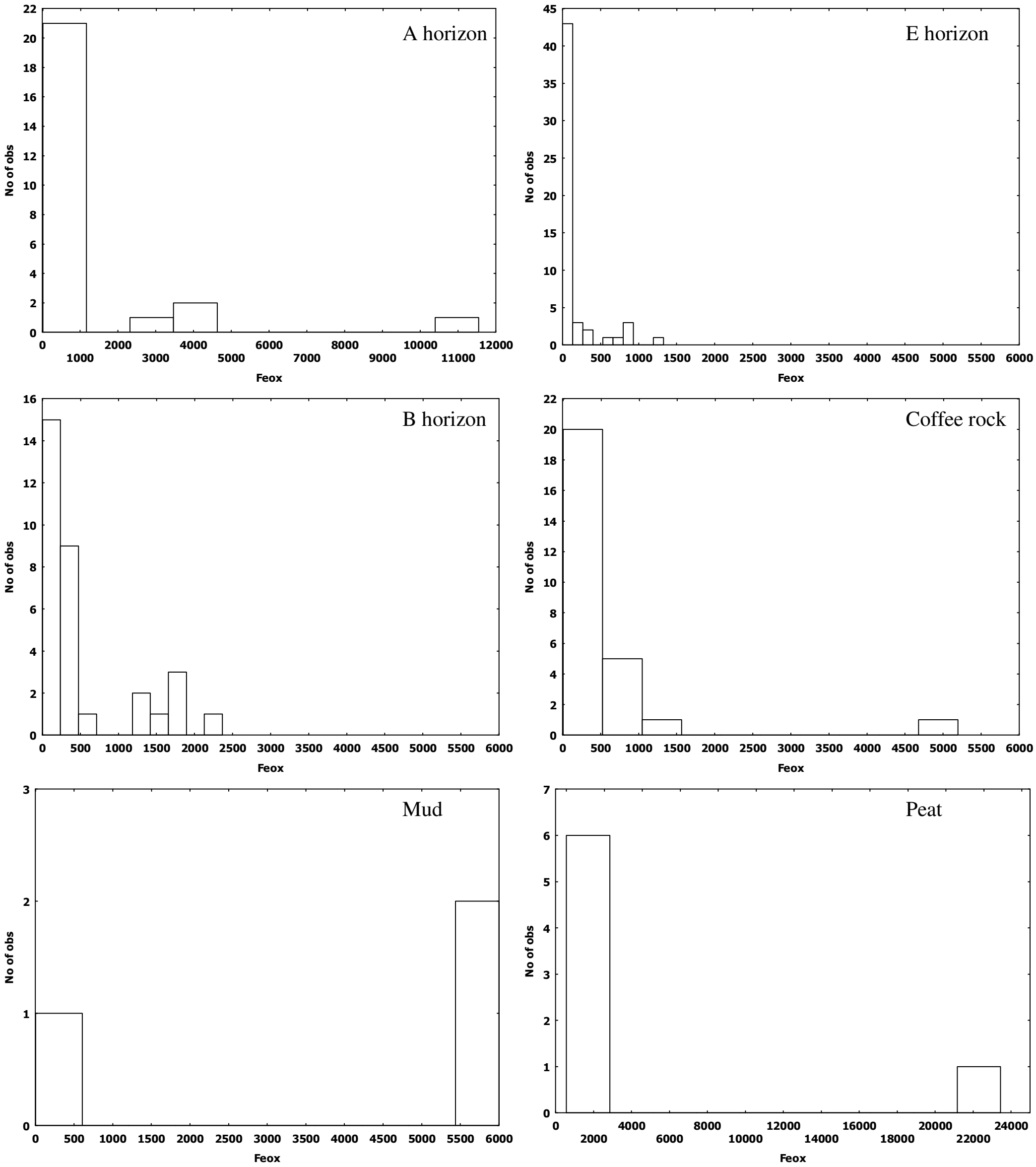


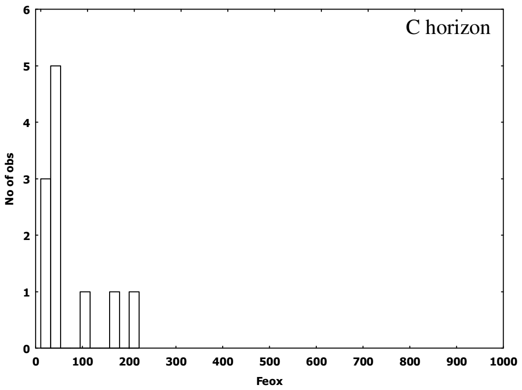




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 25 | 68 | 13 | 4208 | 844 |
| E horizon | 54 | 43 | 1.6 | 862 | 201 |
| B horizon | 32 | 212 | 3.8 | 13406 | 2461 |
| Coffee rock | 27 | 2881 | 186 | 15421 | 4526 |
| Mud | 3 | 618 | 3.0 | 1154 | 576 |
| Peat | 7 | 475 | 22 | 8265 | 2993 |
| C horizon | 11 | 168 | 43 | 965 | 299 |

**Appendix Figure 69** Histograms for the concentration of aluminium extracted by oxalic acid (Alox) for A, E, B, coffee rock, mud, peat and C horizons (in mg kg$^{-1}$ unit).

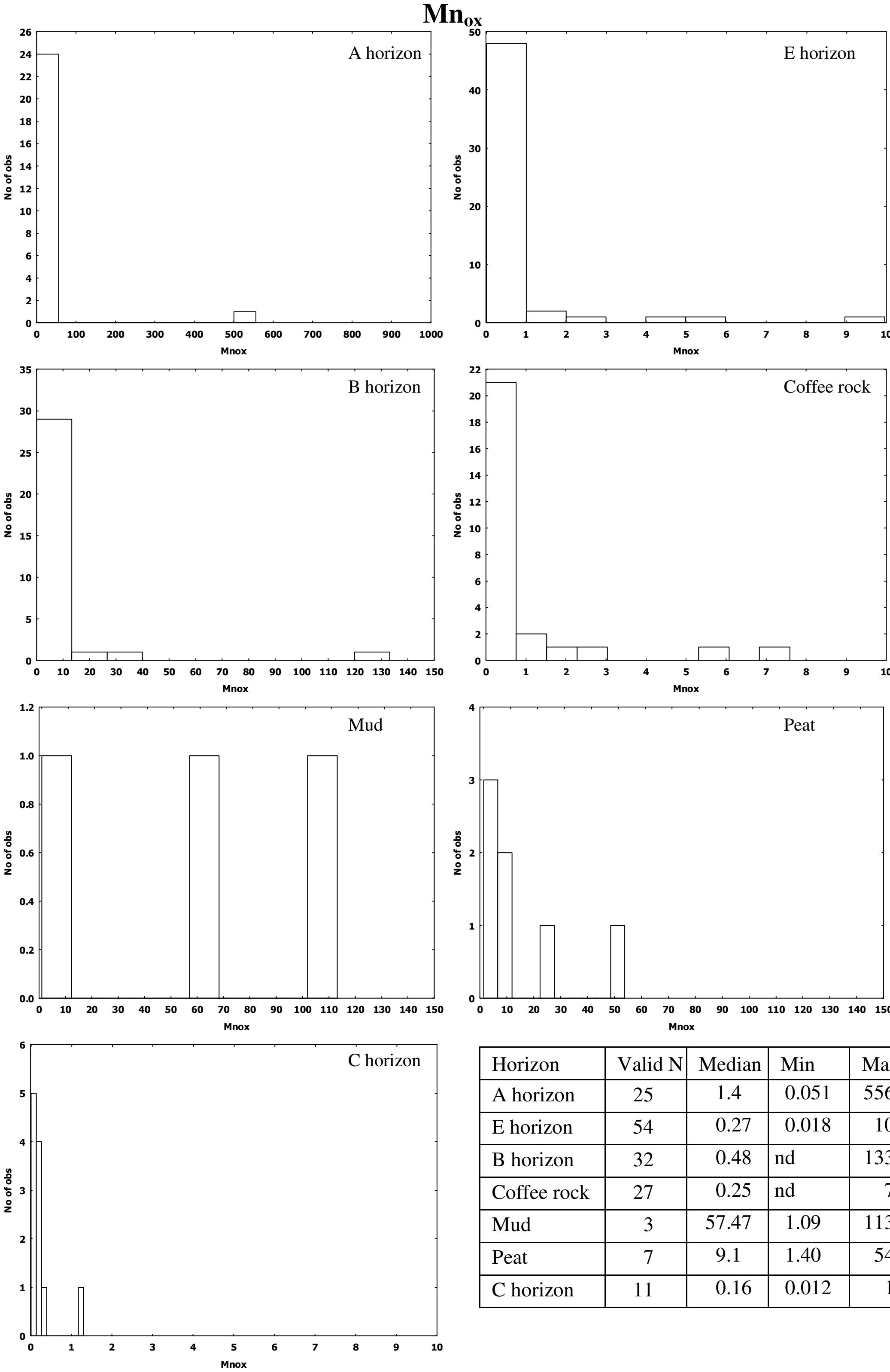
## $Fe_{ox}$




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 25 | 141 | 13 | 11546 | 2491 |
| E horizon | 54 | 45 | 1.7 | 1326 | 282 |
| B horizon | 32 | 251 | 2.6 | 2365 | 672 |
| Coffee rock | 27 | 176 | 7.8 | 5196 | 1007 |
| Mud | 3 | 5441 | 1.6 | 6039 | 3327 |
| Peat | 7 | 1748 | 569 | 23449 | 8260 |
| C horizon | 11 | 43 | 11 | 221 | 67 |

**Appendix Figure 70** Histograms for the concentration of iron extracted by oxalic acid (Feox) for A, E, B, coffee rock, mud, peat and C horizons (in mg $kg^{-1}$ unit).




| Horizon | Valid N | Median | Min | Max | Std.Dev. |
|---|---|---|---|---|---|
| A horizon | 25 | 1.4 | 0.051 | 556 | 111 |
| E horizon | 54 | 0.27 | 0.018 | 10 | 1.6 |
| B horizon | 32 | 0.48 | nd | 133 | 24 |
| Coffee rock | 27 | 0.25 | nd | 7.6 | 1.8 |
| Mud | 3 | 57.47 | 1.09 | 113 | 56 |
| Peat | 7 | 9.1 | 1.40 | 54 | 19 |
| C horizon | 11 | 0.16 | 0.012 | 1.3 | 0.37 |

**Appendix Figure 71** Histograms for the concentration of manganese extracted by oxalic acid (Mnox) for A, E, B, coffee rock, mud, peat and C horizons (in mg $kg^{-1}$ unit).