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Chemical analysis for discriminating between the Pinedale and Bull Lake catenas, Pinedale, Wyoming

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Chemical Analysis for Discriminating Between the Pinedale and Bull Lake Catenas, Pinedale, Wyoming

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Abstract

Determining the age of glacial deposits is crucial to understanding glacial advances and retreats in the Pliestocene and paleoclimatic implications. Relative dating is important in dating glacial deposits because absolute dating is often not possible. An investigation of the Pinedale (14 ka) and the Bull Lake (140 ka) age moraines with the objective of determining the relative age of the soils developed on the moraines based in soil chemical development was conducted. The study area is located adjacent to Fremont Lake in Pinedale, Wyoming, which is located at the western base of the Wind River Mountains. A series of sequential extractions targeting secondary phases produced during weathering of the moraines were used to quantify the difference between the moraines. The extracting agents: DIW, KCl, HCl, CuOAc, and CDB extracted cations Na, Ca, Mg, Mn, Al and Fe, from the soils into solution. These solutions were analyzed on an ICP-AES to determine the cation concentrations. The cation concentrations were then analyzed by Discriminant Function Analyses to determine if the Pinedale and Bull Lake could be differentiated on the basis of soil chemical development. The results indicate that the Pinedale and Bull Lake moraines can be differentiated on the basis of their soil chemical development. In particular with the bulk grain size, elements Ca and Mg, extractions HCl and CDB and soil horizons B (Bull Lake) and AC (Pinedale). In conclusion, soil chemical development can be used to relatively date glacial features, whereas this was not previously known. This new relative dating technique will be particularly useful in areas where absolute dating is not available.

1.0 Introduction

Determining the age of glacial deposits is an important problem in surficial geology. The age of glacial deposits is crucial to the understanding of glacial advances and retreats in the Pleistocene and paleoclimatic implications.

Direct dates for glacial deposits are not easily obtained because most techniques date the formation of a mineral and not the time of deposition of glacial material. Numerous workers have attempted to obtain relative dates for glacial deposits by examining the development of weathering products on the surfaces of boulders located on glacial deposits. Burke and Birkeland (1979) used multiparameter dating techniques, such as the ratio of pitted to nonpitted boulders, pit depth, average rind thickness, and hammer blow weathering ratio, in order to delineate post-Sherwin Pleistocene glaciations. Dorn et al. (1987) determined limiting ages on drifts of Tioga, Tahoe, and Mono Basin age glaciations using rock varnish cation ratio and radiocarbon dating methods. Phillips et al. (1990) attempted to date glacial deposits in Bloody Canyon, California by measuring the accumulation of cosmogenic ^{36}Cl produced by cosmic rays in boulders exposed on moraine crests.

These relative dating techniques are useful, but may contain inherent errors due to boulder spalling. Soils are not affected by spallation, so I conducted an investigation of the Pinedale and Bull Lake moraines in Pinedale, Wyoming with the objective of determining the relative age of the soils developed on the moraines based on the chemical development of the soil profiles. I sequentially extracted secondary phases produced during weathering and quantified the differences between the Pinedale and Bull Lake soil chemical development. If the proposed relative dating technique is shown to be consistent with the absolute ages, it may then be applied to areas where absolute dating is not available.

1.1 Study area

The study area is located on the edge of Fremont Lake (Fig. 1, Fig. 2) north of Pinedale, Wyoming, which is located at the western base of the Wind River Mountains in western Wyoming. The Wind River Range, from which the Pinedale and Bull Lake moraines are derived, consists of a northwest-southeast trending anticlinal uplift. The Central Rocky Mountain Province is formed in part by the Wind River Range. The Wind River Range extends from South Pass to the Gros Ventes Mountains for approximately 190 km and is 60 km wide (Mahaney, 1974).

The anticlinal uplift occurred during the Tertiary and exposed a sequence of Precambrian schist, gneiss and granite. On the eastern flanks of the range, Paleozoic and Mesozoic rocks outcrop, while Tertiary lavas, tuffs, conglomerates and shales occur on the western flanks. Igneous and metamorphic rocks occur with varying textures of fine, medium, coarse, and porphyroblastic. Glacial deposits contain clasts of dioritic gneiss, gabbro-diorite gneiss, quartz-monzonite gneiss, granite gneiss, granite, phibolitic schist, and quartz-syenitic gneiss (Mahaney, 1974).

The location of Fremont Lake was chosen because the parent material of the glacial tills from which the Pinedale and Bull Lake soil catenas are derived is the same. This fact was central to the study because one central assumption was made in comparing the soil profiles: the material from which the soils were derived was the same, so the soil profiles differ only in duration of development. The age of the Pinedale and Bull Lake moraines is constrained by obsidian-hydration, radiocarbon, and K-Ar dates (Porter et al., 1983). The Pinedale age is less than 40 ka and probably closer to 20 ka while the Bull Lake age is less than 140 ka. The age of the Bull Lake glaciation is based on correlation with weathering characteristics and topographic position of Bull Lake moraines in Yellowstone National Park. At Yellowstone, two tills of Bull Lake age are stratigraphically related to ash beds and rhyolitic flows that were dated by the K-Ar method (Mahaney, 1984). The Pinedale moraines are commonly correlated to stage two, and the Bull Lake to stage six, of the marine oxygen isotope record.

1.2 Description of the field area

The type Pinedale moraines border Fremont Lake in Pinedale, Wyoming. Pinedale age deposits are generally hummocky and have many boulders and numerous undrained depressions that are poorly integrated. Weathering ratios indicate that a higher percentage of weathered stones are found in the lower basins than in the alpine and subalpine areas, indicating that the material in the lower basins was deposited before the alpine and subalpine areas and has had a longer period of time to develop weathering features. Mahaney (1978) does believe, however, that there is little difference in the age of early and late stages of the Pinedale glaciation because the different weathering ratios of the basin and alpine moraines is not substantial and therefore does not warrant separate ages for the moraines.

The Bull Lake moraines extend 2-4 km beyond the outer moraines of Pinedale age at Fremont Lake (Figs. 1, 2) and are morphologically quite different from Pinedale moraines. Bull Lake moraines have smooth, rolling morphology and a well-integrated drainage system (Mahaney, 1978). Two stages of Bull Lake glaciation are identified by Richmond (1974, 1976), but little morphological difference between the two deposits can be found. Therefore, for the purpose of this study both Bull Lake moraines are considered to be the same age.

1.3 Climate of the area

I have assumed that the climate of the area has not differed significantly in the last 160,000 years from the modern semi-arid environment. Therefore, a description of the modern climate may represent past climates of this area. Average annual temperature, mean seasonal extremes, and absolute maximum and minimum temperatures calculated using mean winter and summer lapse rates determined in the Colorado Rockies were reported by Mahaney (1974). The area is generally arid to semi-arid climate with the rainfall occurring at a fairly uniform rate throughout the year. During the summer months, thunderstorm activity is common, whereas winters are very cold with high winds.

1.4 Vegetation

Because the climate of the area has probably not significantly varied in the last 160,000 years, the vegetation probably has also remained the same. The modern ground cover is dominated by sagebrush (Artemissa tridentata) in the area surrounding Fremont Lake and the rest of the basin. Groves of pine (Pirus contorta), aspen (Poplus tremuloids) and douglas fir (Psudolotsuga menziesis) occur near water sources such as Fremont Lake, small streams, and irrigation ditches. Part of the field area experienced a severe brush fire in 1987. In the area that was burned, grass has taken over where sagebrush had previously dominated. If grass replacement of sagebrush after brush fires occurs commonly, the vegetation effect on soil development may change from one local microenvironment to the next.

1.5 Soil Development

Soils have often played a major role in the dating of Quaternary deposits in the western United States, primarily because of a lack of material suitable for absolute dating methods. This study focuses on cations in the Pinedale and Bull Lake soil catenas and their relation to the soil profile.

The main factors in the development of a soil profile are parent material, climate, topographic setting, biological activity, and time. The Pinedale and Bull Lake tills are assumed to be derived from the same parent material (i.e., the alpine glaciers that deposited these tills originated in the same mountain valleys, thus eroding the same bedrock that was later deposited in the tills) and to differ only in the time of deposition. Sample locations for this study were at or near the crest of the moraines, so little secondary erosion or deposition occurred that would alter the natural development of the soil profile. The climate of the area was also assumed to have not dramatically changed over the past 160,000 years from a semi-arid regime. A potential weakness of this assumption is that, during the Pinedale Glaciation the study area where the Bull Lake soils were forming was very arid, so a significant amount of aeolian material may have been contributed to the Bull Lake soil profile. Problems associated with aeolian input will be discussed in a later section.

Various soil properties develop and change with time due to the effects of the continuous cycle of percolating water, biomass decomposition, and solar energy imput (Harden, 1982). The soil texture generally becomes finer grained with increasing age as particles break down and clay minerals form. Clay development is also a function of the clay content of the parent material or a source of minerals in the parent material that will weather into clay minerals.

Hue, value, and chroma are color properties that change as the soil develops. If pigments are available in oxidizing environments, color hues will become redder and chromas will become brighter with increasing soil age (Harden, 1982). Melanization, the darkening of soil due to the accumulation of organic matter, also generally increases with increasing soil development.

Soil structure also develops with age toward an aggregate type. In unconsolidated parent material (as the till in this study) structure types in the B horizon develop from a structureless (single-grained or massive) to blocky, to prismatic, and in extreme cases to columnar (Harden, 1982).

1.6 Soil Chemistry

As soil profiles develop, soil chemical and physical conditions change and, in particular, minerals in the clay size fraction accumulate due to the chemical and physical weathering of the parent material. The weathering stages of the parent material resulting in soil development are commonly known as the Jackson-Sherman weathering stages: early, intermediate, and advanced (Sposito, 1989).

The early stage is characterized by the occurance of the minerals gypsum, carbonates, olivene, pyroxene, amphilbole, Fe(II)- bearing micas and feldspars in the clay size fraction. The early stage results from a limited time for weathering, very low water content and organic matter and limited leaching.

The intermediate stage is usually evidanced by quartz, dioctahedral mica, illite, vermiculite, chlorite, and smectites in the clay fraction. The physical and chemical conditions of the soil change slightly in that silicates easily hydrolze, silica is flocculated and transported into the weathering zone, Na, Ca, K, Mg, Fe(II), and leaching is still fairly ineffective.

The advanced stage consists mostly of kaolinite, gibbsite, iron oxides, and titanium oxides. The chemical and physical conditions of the soil change greatly in that Na, K, Mg, Ca, Fe(II), and silica are now removed, effective leaching occurs, Fe(II) is oxidized, low pH, acidic compounds occur, silica is dispersed and Al-hydroxy polymers form (Sposito, 1989).

1.7 Previous Soil Chemistry Studies

Workers have been examining soil chemical development for many years to determine relative ages of glacial deposits where absolute dating criteria are absent. Birkeland et al. (1980) examined soil properties including pH, particle-size distribution, and fractions of Fe, Al, and P in order to distinguish Sherwin and pre-Sherwin tills from those of Tahoe age and also to subdivide and correlate pre-Tahoe age deposits along the eastern side of the Sierra Nevadas.

Karlstrom (1988) tested the hypothesis that the relative degree of soil development can be useful in recognizing different age surface till in Waterton-Glacier Parks and in determining which previously defined glacial chronologies were best supported by the pedological data. Karlstrom's (1988) investigation of soil thickness, Harden and clay accumulation development indices, particle size composition, pH, organic matter composition, percentage of dolomite and calcite, and clay mineralogy, showed that the soil profiles suggested, but did not prove, four different ages of mountain tills and two ages of continental tills in the Waterton-Glacier Park area.

Other workers have primarily examined the soil chemical development of glacial deposits in order to answer questions simular to those asked by Birkeland <u>et al</u>. (1980) and Karlstrom (1988). Berry (1987), Swanson (1985), and Mahaney (1978) examined the soil catenas developed on Pinedale and Bull Lake moraines located in the western United States. Berry (1987) concentrated on soil development on moraine slopes with similar curvature and steepness on the Bull Lake and Pinedale moraines in Bear Valley, Idaho and found a greater amount of dithionite- citrate-extractable iron in the Bull Lake than in the Pinedale soils.

Swanson (1985) examined the Pinedale and Bull Lake moraines that surround Willow Lake in the Green River Basin, west of the Wind River Mountains in western Wyoming slightly north of my study area. Swanson found the percent dithionite-extractable iron and aluminum was greater in the Bull Lake than in the Pinedale soils. The sulfuric acid extractable phosphorous concentration was higher in the Bull Lake except in the C horizon where the phosphorous concentration was higher in the Pinedale soils.

Mahaney (1978) examined the Bull Lake and Pinedale moraines at Fremont Lake, which is also my study area. Mahaney looked at the free iron oxide, extractable hydrogen, and extractable bases. Mahaney found, in general, the extractable cations Na, K, Ca, and Mg, and percent extractable iron were generally higher in all horizons of the Bull Lake than in the Pinedale soils.

Berry (1987), Swanson (1985) and Mahaney (1978) examined the soil chemical development of the Bull Lake and Pinedale moraines in conjunction with other soil properties but not for the purpose of determing if the soil chemical development differ between the two moraines. My project expands upon the previous work in that the soil chemical development of the Bull Lake and the Pinedale soil profiles is analyzed statistically by discriminant function analysis to determine if distinct populations exist for each moraine that could be used to differentiate between them. This objective was achieved by examining the soluble salts, adsorbed cations, and Fe and Mn oxide coatings that were present in the soil by a series of sequential extractions where deionized water targeted soluble salts, potassium chloride and cupric acetate targeted adsorbed cations, and hydrochloric acid and citrate-dithionate bicarbonate (Mephra and Jackson, 1960) targeted sesquioxide phases, whether residual or secondary. This project also expanded on previous studies in that the factors governing sample collection and analysis (grain size, elements, extraction agents and horizon position) were studied in order to determine which resulted in developing distinct Pinedale and Bull Lake populations.

2.0 Objectives

The main objective of this research project was to determine whether soil chemical development of the Bull Lake and Pinedale catenas can be used to differentiate between moraines of different ages that are derived from the same parent material. This objective was accomplished by examining cation concentrations in the soil profiles. Secondary objectives were to determine how grain size, extraction agents, and horizon position affected cation concentrations within the individual soil catenas.

3.0 Methods and Materials

The field sampling area was located in the center lobe of the three lobes of glacial deposits that surround Fremont Lake (Figs. 1, 2). Three sampling sites were located on each moraine: east (PD3, BL3), center (PD1, BL1), and west (PD2, BL2). All of the sample locations were either road or stream ditch cuts. The surface of the cut face was removed to a depth of approximately 20 in. to ensure that the sample was not weathered from the surface of the cut. A sample was taken every 6 in. for the first 4 ft. of the soil column and then every 12 in. for the remainder of the soil column.

A pilot study was done on PD1 and BL1 in order to determine which factors (i.e., grain size, extracting agents, and elements to be analyzed) would be used in the remainder of the study in order to determine if the Pinedale and the Bull

Lake soil profiles could be differentiated on the basis of their soil chemical development. Three samples in Pinedale 1 soil column located at depths of 0-6 in., 12-18 in., and 24-30 in. were compared to four Bull Lake 1 samples at depths of 12-18 in., 18-24 in., 30-36 in., and 84 in. Each soil sample was dried for 24 hours at 110 C and separated into four grain sizes: >62.5 um, 62.5-4 um, 4-2 um, and 2-0 um by using the sieve and pipette method (Day, 1965). A bulk sample containing all size fractions was also prepared for sequential extraction.

The extracting agents were deionized water (DIW), 0.5 M potassium chloride (KCL), 0.5 M cupric acetate (CuOAc), citrate-dithionite-bicarbonate (CDB), and 0.01 M hydrochloric acid (HCl). Citrate-dithionite-bicarbonate extracting agent was prepared from sodium dithionite, sodium citrate and sodium carbonate (Mephra and Jackson, 1960).

Each size fraction and bulk sample was washed with one of the three extracting solutions (CuOAc, CDB, and HCl) by shaking each sample for 30 minutes with a volume of each extraction solution in a 50 ml polyethylene centrifuge tube mounted on a wrist shaker. The solution was then separated from the solid sample by vacuum filtration through a 0.45 um membrane.

Following the pilot study, samples for the remaining four sample sites (PD2, PD3, BL2, BL3) were prepared in an analogous fashion, except that only the bulk and clay grain size fraction (< 2um) were extracted. For Bull Lake 2 and Bull Lake 3, I sampled from all horizons and sampled twice in the BC horizon because it is fairly thick, for a total of six samples. For Pinedale 2 and Pinedale 3, I sampled all three horizons and two samples from the AC horizon because it is also fairly thick, for a total of four samples from Pinedale 2 and Pinedale 3.

3.1 Instrumental Analysis Procedures

The solutions from the extractions in the pilot study as well as the remaining four sample sites were analyzed by inductive coupled plasma atomic emission spectrophotometry (ICP-AES) to determine the concentrations of Na, Ca, Mn, Mg, Fe, Al, and K. K was eliminated from the analysis after the pilot study due to undetectable concentrations. The samples were diluted and calibrated to the detection range of the ICP-AES. The samples were analyzed over a period of two days in which two control runs were conducted in order to determine whether any significant variation of greater than 3% of measured cation concentrations existed in the ICP-AES from day to day. No significant variation was found. Also, several individual samples representing each extraction were analyzed in replicate in order to determine the standard deviation for each element and extraction used in the statistical evaluations of the data. A test for matrix effects found that cation concentrations did vary by more than 5% in the different extracting solutions. Therefore, separate standards for each extracting agent were used to calibrate the ICP-AES.

3.2 Data Analysis Procedures

The data for the pilot study were normalized to

$$a = b * c/d$$

a = final data concentrations
b = cation concentration
c = ml of extracting agent
d = 400 g sample

and the other four sample sites were normalized to

$$e = f * (g/h) * i$$

e = final data 2 concentrations
f = cation concentration
g = g Fraction
h = g Sample
i = ml extraction

In the pilot study, an analysis of variance was performed to determine if grain size, extracting agents, and horizon location significantly affected the concentrations of the cations and to determine which elements merited further investigation.

In the analysis of the four remaining sample sites (PD2, PD3, BL2, and BL3) I was asking the main question of this study (can the Pinedale and the Bull Lake moraines be differentiated on the basis of their soil chemical development) rather than the secondary question addressed in the pilot study: which factors influenced cation concentrations? Accordingly, the data from the remaining sites were analyzed in a different manner than those used on the pilot study. In the analysis of Pinedale 2 and 3 and Bull Lake 2 and 3, only one concentration value per element, extraction, and horizon was determined. For example, one value of Na concentration, extracted with DIW, at a depth of 10 in. in Pinedale 2 was determined. Ideally, 6-8 measurements of each element in each extraction on each sample would have been obtained for the statistical tests to follow, but the resulting experimental and analytical task would have been overwhelming. The measured values from the four remaining sites were assumed to represent a mean value and eight normally distributed values were generated for each location according to the standard deviation obtained in the pilot study. A Monte Carlo simulation procedure implemented in SAS software (SAS Institute Inc., 1986) was used to perform the simulation and generate populations of concentrations representing cation concentrations defined Pinedale 2 and 3 and Bull Lake 2 and 3.

Discriminant function analysis also performed with SAS was used to compare Pinedale 2 to Bull Lake 2 and Pinedale 3 to Bull Lake 3. I did not combine the data from Pinedale 2 and 3 and Bull Lake 2 and 3 to avoid obscuring variation within the Pinedale and Bull Lake moraines. The first set of comparisons defined populations for a Pinedale site and the corresponding Bull Lake site based on cation concentrations found by specific extraction, at all depths in the soil profile, for a given grain size. Thus, the ability to differentiate between horizons was obscured. If a particular soil depth was significantly different in the Pinedale and Bull Lake this type of discriminant function analysis could not detect the horizon effect. The horizon effect on cation concentration and discriminant function analysis was important information because soil development could be discerned and future sampling programs may be governed by this information. Therefore, a second set of discriminant function analyses were performed on populations constrained by similar horizons (A-A, Bt-AC, etc.), specific element, extraction and grain size.

4.0 Results

4.1 Field Data

A general description of the Pinedale and Bull Lake soil profiles is presented in Table 1. The Pinedale soil profile is approximately 4 ft in depth and consists of an A/AC/C profile. The Pinedale soil is generally a gravelly, sandy loam with a weak granular structure. The Bull Lake soil profile is approximately 7 ft. in depth and consists of a A/Bk/C profile. The Bull Lake soil is generally a gravelly, sandy loam with columnar structure.

4.2 Pilot Study Results

The results of the pilot study on PD1 and BL1 showed that greater than 70% of the exchangeable cations are in the clay size fraction (<2 um) (Table 2). The bulk sample did indicate distinct populations for the Pinedale and Bull Lake soils (Appendix 1), but because most of the cations were associated with the clay particles and the bulk sample contained only a very small percentage of clay particles, I examined both the bulk sample and clay fraction in the remainder of the study.

All extractions showed a difference between the Bull Lake and the Pinedale cation concentrations in the bulk sample, with the Bull Lake being generally higher in cation concentrations than the Pinedale. Therefore, all extracting agents were used in the remainder of the analysis. In the case of the <2 um size fraction, I retained CuOAc, HCl, and CDB, but I added KCl. I did not use KCl in the pilot study because a dispersing agent, sodium metasulfate, was used in the pipet analysis of the fines and exchange sites would have been saturated with Na. The dispersant was not used in the remainder if the study because the percentage of fines is very small and they were adequately separated in DIW.

All of the cations analyzed had detectable levels of cation concentrations except potassium. Potassium was below detection limits except in the KCl extracting solution. Therefore, only Na, Ca, Mn, Mg, Fe, and Al were analyzed in the remainder of the study.

4.3 Cation Profiles

Fe-CDB (Figs. 3, 4) is lower in BL2 and BL3 in the bulk grain size, but is generally higher in the PD2 and PD3 in the clay size fraction. Fe bulk is similar in BL2 and BL3 with Fe concentration peaking at the surface and decreasing with depth, while the Fe clay generally increases with depth and peaks at 20 in. in BL3 and 40 in. in BL2.

Al-CDB (Figs. 3, 4) is lower in the BL2 and BL3 in the bulk grain size, but is generally higher in the PD2 and PD3 in the clay fraction. Al mimics Fe in the bulk fraction of BL2 and BL3, in that Al peaks at the surface and declines with depth. Al-CDB in PD2 clay peaks at 35 in. and Al-CDB in PD3 clay peaks at 10 in. and 40 in. AL-CDB in BL3 clay which peaks at 30 and 48 in., is higher than PD3. AL-CDB in BL2 clay peaks at the surface of the soil column and is lower than the maximum Al concentration in PD2, which is at a depth of 36 in.

Mn-CDB (Figs. 5, 6) is below detection limits in PD2, PD3, BL2 and BL3 in the clay fraction. Mn is generally in higher concentrations in the bulk grain size in BL2 and BL3, but peaks at very different depths. BL2 peaks at 0 in., and BL3 peaks at 45 in.

Na-DIW bulk (Figs. 7, 8) is lower in PD2 than BL2 and lower in BL3 than PD3. Na in PD2 remains constant at near 0 at all depths, while BL2 increases with depth to a maximum at 48 in. BL3 also remains fairly constant with depth, while PD3 increases with depth to a maximum at 36 in.

Na-KCl in both grain sizes (Figs. 7, 8) is lower in BL3 than PD3, but higher in grain size in BL2 than PD2. BL2 in both grain sizes increases with depth to a maximum at 48 in., while PD2 in both grain sizes remains fairly constant of near 0 concentrations at all depths. BL3, Na concentrations, in both grain sizes increases with depth, peaks at 30 in., and then decreases with depth. PD3 bulk Na concentrations increases with depth and peaks at 36 in. and PD3 clay also increases with depth, peaks at 25 in. and then decreases with depth.

Na-HCl (Figs. 9, 10) is generally lower in concentration in BL2 bulk, PD2 clay and BL3 bulk and clay. PD2 and PD3 bulk behave similarily in that Na concentrations increase with depth, peak at 25 in. and then decrease with depth. PD2 clay remains near 0 at all depths, while PD3 clay increases with depth to a maximum at 36 in. BL2 bulk and clay increases with depth and peaks at 42 in. BL3 in both fractions also increases with depth and peaks at 30 in. (bulk) and 42 in. (clay).

Ca-DIW (Figs. 11, 14) is generally higher in the Bull Lake. BL2 and BL3 are very similar profiles with peaks in Ca concentration at the surface of the profiles with peaks at 30 in.

Ca-KCl (Figs. 11, 14) is higher in the Bull Lake for both locations and grain sizes. In BL2 and BL3 bulk Ca concentrations remain fairly constant with depth, while BL2 clay increases with depth to 42 in. and Ca concentrations in

BL3 clay increases with depth to 18 in. and then decreases with depth. PD2 Ca concentrations remain fairly constant with depth in both grain size fractions, whereas PD3 bulk and clay vary greatly with depth.

Ca-HCL bulk and clay (Figs. 12, 15) is higher in the Bull Lake for both locations. BL2 bulk increases with depth to 29 in. and then decreases with increasing depth. BL2 clay also increases with depth to 30 in. and then decreases. PD2 bulk and clay remain fairly constant with depth. BL3 bulk remains constant with depth, while BL3 clay increases with depth to 42 in. and then decreases. PD3 bulk varies with depth, while PD3 clay remains constant with depth.

Ca-CuOAc bulk and clay (Figs. 12, 15) is higher in the Bull Lake horizons for both locations. PD3 bulk and clay remains fairly constant with depth, while BL2 bulk increases with depth to 30 in. and then decreases with depth. BL2 clay generally increases with depth to 48 in. PD3 bulk decreases with depth and PD3 clay increases with depth to 10 in. and then decreases. Ca in BL3 bulk and clay generally increases with depth and peaks at 30 in. and 48 in. respectively.

Ca-CDB bulk and clay (Figs. 13, 16) is higher in the Bull Lake horizon in both locations. Ca in the Bull Lake profiles generally increases with depth to a maximum and then decreases at greater depths. PD2 and PD3 Ca concentrations in the bulk decrease with depth to a minimum at 25 in. and then slightly increases. PD2 clay remains fairly constant with Ca concentrations near 0 at all depths. PD3 clay increases slightly with depth to a maximum at 36 in.

Mg-DIW (Figs. 17, 20) is higher in BL2 bulk and PD3 bulk. BL2 and PD2 generally increase with depth to peak at 42 in. and 36 in. respectively. BL3 bulk remains fairly constant with depth, while PD3 increases with depth to 36 in.

Mg-KCl (Figs. 17, 20) is higher in BL3, bulk and clay fractions, BL2 bulk, and PD2 clay. PD3 and BL3 bulk increase with depth to 36 in. and 48 in. respectively. PD3 and BL3 clay, increase to a depth of 25 in. and 6 in. and then decrease with depth. PD2 and BL2 bulk, increase with depth to 36 in. and 42 in. respectively. PD2 clay increases to a depth of 18 in. and then decreases. Mg concentrations in BL2 clay is below detection limits.

Mg-HCl (Figs. 18, 21) is higher in PD3 bulk and clay, and BL2 bulk and clay. PD3 bulk remains constant with depth, while BL3 varies with depth. Mg concentrations in PD3 clay increases to a depth of 25 in. and then decreases, while BL3 clay remains constant with depth. PD2 and BL2 bulk remains fairly constant with depth, with BL2 increasing from 30 to 48 in. PD2 clay remains constant in Mg concentrations of near 0 at all depths. BL2 clay also remains constant with depth except for a slight increase in Mg concentration between 42 and 48 in.

Mg-CuOAc (Figs. 18, 21) is higher in BL2 bulk and clay, BL3 bulk, and PD3 clay. PD2 bulk and clay remains fairly constant with depth, while BL2 bulk and clay increases with depth with a maximum Mg concentration at 25 in. BL3 bulk and clay also vary with depth with maximum concentrations at 36 and 42 in., respectively.

Mg-CDB (Figs. 19, 22) is higher in the Bull Lake samples in both locations and grain sizes. Mg concentrations in PD2 bulk remains constant with depth, while BL2 bulk increases with depth to a maximum Mg concentration at 48 in. PD2 clay is below detection limits and BL2 clay increases with depth to a maximum at 48 in. PD3 bulk and clay increases with depth to a maximum at 36 and 25 in., respectively. BL3 bulk and clay vary with depth with maximum Mg concentrations at 30 and 32 in., respectively.

4.4 Discriminant function analysis

4.41 Discrimination on the Basis of Horizon, Location, & Grain Size

Discriminant function analyses were used to characterize various subsets of the complete data base generated by the Monte Carlo simulation. The four populations PD2, PD3, BL2, and BL3 in this section were examined on the basis of horizon, location, and grain size, while keeping elements and extracting agents constant.

Discriminant function analysis performed on simulated populations for the same element and extraction at a specific location yielded higher probabilities of samples correctly categorized as a Pinedale or Bull Lake sample when the data for individual soil horizons were tested rather then when the data from all horizons were combined and then tested (Appendix 3). Discriminant functions for individual horizons resulted in probabilities generally greater than 80% with most probabilities between 90-100%. Discriminant functions performed on populations containing data from all soil depths resulted in probabilities ranging from 50-80% (appendix 3).

Comparison of discriminant functions analysis performed on populations PD2 vs BL2 and PD3 vs BL3 when holding element and extraction constant, yielded nearly the same probabilities for samples being correctly categorized in that the probabilities of PD2 vs BL2 did not differ from the probabilities of PD3 vs BL3 by more than 5 points. BL3 yielded very similar probabilities of samples being correctly categorized.

Populations were also differentiated on the basis of grain size, bulk and clay. In general discriminant function analysis performed on the same element and extraction yielded higher probabilities for the bulk size fraction than the clay size fractions. However, there were exceptions where the bulk grain size did not yield higher probabilities than the clay. Such a case occurred for Mn in extractions HCl and CDB where both grain sizes yielded similar results of probabilities at or near 100% (Appendix 3).

4.42 Discrimination on the Basis of Element and Extracting Agent

In order to determine which elements and extractions resulted in populations that produced high (70-100%) probabilities of samples being correctly categorized, discriminant function analysis performed on specific combinations of element and extracting agent while keeping grain size, horizon and location constant. Discriminant function analyses where performed were detectable amounts of cations were present (Appendix 2).

In this second series of discriminant function analyses populations were again separated by grain size (bulk and clay) and soil depth. The elements in Table 3 were analyzed.

Al and Fe produced detectable cation concentrations in only the CDB extraction. The probability of Fe being correctly categorized ranged from 37.5 to 100% in the clay fraction for both PD and BL and near or at 100% in the bulk fraction for both PD and BL. Al is correctly categorized in the CDB extraction for the bulk fraction 100% of the time for both the Pinedale and Bull Lake samples. However, the clay fraction has much lower probabilities ranging from 12.5 to 87.5 % with most probabilities between 50 and 60%.

Generally, Na was extracted by KCl, HCl and CuOAc but was more likely to be correctly catagorized than in extractions HCl and CuOAc. In KCl, Na in the clay size was unlikely to be correctly catagorized for both Pinedale and Bull Lake samples with PD2 *vs* BL2 being more likely of the two to be correctly catagorized than PD3 *vs* BL3. Bulk samples in extraction KCl were more likley to be correctly catagorized than the clay fraction, but generally the probabilities were still low (25-100%). Extraction HCL yielded higher probabilities (67.5-100%) in the Bull Lake samples in comparison to Pinedale samples (50.0-75%). Also, samples in extraction HCl were more likely to be correctly catagorized in the bulk size fraction and the deeper soil depths. Samples in CuOAc were more likely correctly catagorized as a Pinedale or a Bull Lake of the three extracting agents where Na was present, but CuOAc did not extract Na at all locations. In general, CuOAc produced high probabilities of samples being correctly catagorized as a Pinedale or Bull Lake for both soil catenas and grain sizes except in the Bull Lake clay grain fraction (37.5-87.0%)(Appendix 3).

Mn extracted by CDB and HCl yielded higher probabilities of samples being correctly categorized in both Pinedale and Bull Lake soil catenas and both grain size fractions with HCl extracting agent (Appendix 3). HCl resulted in probabilities of 100% for all comparisons, while CDB ranged from 50-100% (BL) and 62.5-100% (PD). Extracted Mg yielded measurable amounts of cation concentrations in all 5 extractions: DIW, KCl, HCl, CuOAc, and CDB, used in the analysis. All 5 extractions yielded similar results, in that no single or group of extractions produced significantly higher or lower probabilities of samples being correctly catagorized as a Pinedale or Bull Lake than any other extraction.

Ca also yielded measurable amounts of cation concentration in all 5 extractions. In this instance DIW, HCl, CuOAc and CDB yielded similar probabilities of near or 100%, of samples being correctly catagorized as a Pinedale or Bull Lake, where as KCl produced much lower probabilities, PD (75-25%) and BL (100-12.5%) in the clay size fraction. The bulk fraction in the KCl extraction was more likely to be correctly catagorized than the clay fraction, but still substantially less likely than the remaining extracting agents.

5.0 Discussion

5.1 Soil Development

The soil chemical development of the Pinedale and Bull Lake catenas is apparently a complicated story as revealed by this research. Figure 3 through Figure 22 show that soil depth vs concentrations curves for specific elements, grain size and extracting agent are very different for locations PD2 vs BL2 and PD3 vs BL3. This observation may imply that a significant intramoraine variation in cation concentration exists. PD3 produces unusually high cation concentrations in comparison to BL3 in all elements except Ca. The location of PD3 in proximity to Fremont Lake may contribute to high levels of cation concentrations. Perhaps the water level of Fremont Lake was higher in the past, allowing groundwater to influence cation concentration development in the soils adjacent to the lake. A second possibility is that sediments in the bottom of the lake were incorporated in the glacial ice that later deposited the moraines directly surrounding the lake. Either of these mechanisms or another unknown process could have increased the cation concentration found in Pinedale 3.

Nevertheless, generalizable trends are evident in all soil depth vs cation concentration curves. The greatest difference between the Pinedale and Bull Lake cation concentrations occur between the AC horizon in the Pinedale and the B horizon in the Bull Lake (the Pinedale Ac and the Bull Lake B horizon are soil developmentaly simular). Extractions CDB and HCl and the elements Ca show the greatest difference in cation concentration.

Because PD3 shows abnormally high cation concentrations and may not depict a typical Pinedale profile, I will focus attention on the interesting points of PD2 and BL2. Fe and Al have nearly identical soil curves (Fig. 3) implying that Al and Fe are closely associated in the sesquioxide phases attacked by CDB. Mn is present in very low concentrations in the HCl extraction possibly because the extracting agent was not strong enough or because there is very little Mn present in these soils. A combination of these two reasons is likely because Mn was detectable in the CDB extraction but only in small amounts (Fig. 5).

Na produced results in PD2 vs BL2 in the bulk and clay grain sizes (Figs. 7, 9) that clearly demonstrates that the Bull Lake is a distinctly different moraine with higher cation concentrations than the Pinedale. However, Na was highest in concentrations in the BC-C horizon, rather than the expected B horizon. This behavior is due apparently to extensive leaching that has transported Na to deeper horizons.

Ca concentrations were always higher in BL2 than in PD2 for both grain sizes. Extractions CuOAc, HCl and CDB produced the greatest differences in Ca concentrations of the five extractions (Figs. 11, 12, 13). Ca concentrations were also higher in BL3 than in PD3 (Figs. 14, 15, 16). Ca is present apparently in very high concentrations in both locations of the Bull Lake because a well developed caliche zone is in the B horizon. The caliche is present due to the high evaporation rate and low precipitation rate in the area and the older age of the Bull Lake. Given sufficient time the Pinedale catena will probably also develop a caliche zone.

PD3 had cation concentrations that were unusually high due to the proximity of Fremont Lake, but how do cation concentrations in BL2 compare to BL3? Fe and Al curves in the bulk grain size in extraction CDB (Figs. 3, 5) are similar for BL2 and BL3, but not in the clay fraction. Ca curves in the CDB extraction for both grain sizes are also similar for BL2 and BL3 (Figs. 13, 16). Mg concentrations curves are also similar for extractions HCl and CuOAc, whereas the CDB extraction produces curves that are slightly different (Figs. 19, 21). All other depth vs cation concentration curves for BL2 and BL3 differ in shape or magnitude. These patterns imply that intramoraine soil chemical development is occurring possibly due to the effect Fremont Lake on adjacent moraines, because a consistent pattern of soil chemical development can not be discerned, but this hypothesis should be formally tested.

Other factors that may have contributed to the development of the Bull Lake and Pinedale soils should be considered given the results of this research. During the Pinedale glacial episode the climate was very arid due to a large amount of water retained in the glaciers, and the aeolian content of the atmosphere was greatly elevated. Thus, the Bull Lake soils developing in this arid climate may have received a significant aeolian input. The Pinedale soils have not experienced a post-depositional glacial episode and therefore have not acquired additional aeolian input. This fact may contribute to observation made in this study that the cation concentrations are not always higher in the Bull Lake than the Pinedale.

5.2 Discussion of Discriminant Function Analysis

It is apparent from the results of the discriminant function analysis on the Monte Carlo-simulated data that the Bull Lake and the Pinedale soil catenas can be differentiated into two distinct populations based on the soil chemical development. This approach of examining soil chemical development by sequential extraction apparently produces significantly statistical populations when the discriminant functions are performed on data specified by element, extracting agent, grain size and horizon position, rather than combining data into one population generated by all of the analytical factors (Appendix 3).

All elements analyzed in this study produced measurable cation concentrations in all or some of the extracting agents, in both grain sizes, all soil horizons and both locations (PD2, PD3, etc.) (Table 3). Only Ca and Mg yielded concentrations in all five extractions chosen in this study whereas the remaining elements were present in detectable concentrations in only a few of the extracting agents. Therefore in future research, Ca and Mg are the obvious elements for investigation if circumstances require a limited number of elements to be analyzed. It does however, appear that any of the six elements in this study discriminate between the Bull Lake and the Pinedale catenas.

All five extractions yielded measurable amounts of cation concentrations (Table 3), but only CDB produced measurable cation concentrations in all 6 elements and HCl produced measurable cation concentrations in 4 elements. However, all extractions used in the discriminant function analysis produced probabilities of samples being correctly categorized as Pinedale or Bull Lake moraines greater that 80% in most cases (Appendix 3). Therefore, any of the five extractions can be used to discriminate between the Pinedale and Bull Lake soil catenas, but CDB and HCl will yield the most information that may be useful in studying soil profiles.

The bulk and clay size fractions worked equally well in discriminating between the Pinedale and Bull Lake soils (Appendix 3). Therefore, the time consuming process of separating the clay size particles from the soil samples can be avoided by using bulk samples in future studies.

Also, it is apparent from the results of the discriminant function analysis that all horizons produced cation concentrations that can be differentiated into two distinct morainal populations. In future studies if limits exist for field sampling, any soil depth could be sampled and most likely produce results that would distinguish between the Bull Lake and Pinedale soils. However, the B horizon in the Bull Lake and the AC horizon in the Pinedale exhibit the greatest difference in cation concentration and are probably the most likely locations to yield significantly distinct populations.

6.0 Conclusions

The results of the discriminant function analysis demonstrate that the Pinedale and Bull Lake soil catenas can be differentiated on the basis of soil chemical development. Bulk or clay grain size, extractions HCl and CDB, elements Ca and Mg, and horizons B (Bull Lake) and AC (Pinedale) produce the distinct Bull Lake and Pinedale soil chemical populations. The remaining elements, extractions, and horizon positions did discriminate between the Pinedale and Bull Lake soils, but did not produce cation concentrations that were as distinguishable as the previous parameters.

It is also apparent from the soil depth vs cation concentration curves that the soil profiles at PD2, PD3, and BL2, BL3 are developing differently in regards to cation concentration. Because of this observation, various soil properties such as soil texture, hue, rubification, melanization, and pH should be studied in conjunction with soil chemical development when attempting to determine the relative age of glacial moraines. Further investigation of soil chemical development on glacial moraines is required before this process of analysis can independently determine the relative ages of the Quaternary deposits. Intramoraine variation should be further investigated to determine the effect of Fremont Lake on cation concentrations by increasing the number of sample locations in the moraines and multiple analysis of given elements rather than analysis of simulated data as was done in this study. In conclusion, I believe soil chemical development can be a useful process of determing relative ages of glacial deposits.

	Pinedale Moraine	Bull Lake Moraine
O Horizon	2-4 cm dark brown to black	absent
A Horizon	28-30 cm 10 yr 2/1 gravely, silty, sandy, loam granular structure	22-25cm dark brown-dull yellowish brown gravely, sandy loam granular structure
B Horizon	absent	43-80 cm brown, dull yellowish brown, gray - yellow brown gravely, sandy loam columnar structure stage 3 carbonate
BC Horizon	absent	60 - 65 cm 5y 5/3 gravely sandy loam columnar stage 1 carbonate
AC Horizon	15-20 cm 10 yr 3/4 gravely sandy loam weak granular-single grain	absent
BC Horizon	absent	65-68 cm 5y 5/3 gravely sandy loam columnar structure
Cox Horizon	60-65 cm 5y 4/2 gravely sandy loam massive structure	absent

Table 1: Soil profile description for the Pinedale and Bull Lake Moraines

C Horizon	60^{+} cm 2.5y 4/4 gravely sandy loam single grain structure	60^{+} cm 5y 5/3 gravely, sandy, clay loam massive structure
Other features	sand deposits 30 -100 cm thick from the Bull Lake outwash are found at the	Larger percentage of stones weathered to grus than the
Pinedale		
	base of soil profile	moraine

Table 1: Soil profile description for the Pinedale and Bull Lake Moraines

Source	Sum of Squares	Degrees Freedom	Mean Squares	F Value
PD Na	19990130	29	689314	15.52
Extraction	192494	3	64164	1.44
Grain Size	10305646	4	2576409	58.01**
Horizon	1554691	2	777345	17.01**
Extrac./Horz.	1317000	6	21950	0.49
Grain Size/Horz.	3122448	8	390306	8.79**
Extrac./Grain Size	594406	6	99067	2.23
Error	444130	10	44413	
Total	20434261	39		
PD Ca	164629	36	4573	7.29
Extraction	30924	4	7731	16.14**
Grain Size	55820	4	13955	22.08**
Horizon	1493	3	746	0.92
Extrac./Horz.	3253	8	406	0.72
Grain Size/Horz.	4394	8	549	0.92
Extrac./Grain Size	59399	10	5939	9.47**
Error	175921	18		
Total	175921	54		

Table 2: Anova Table for Pilot Study Data

Source	Sum of Squares	Degrees Freedom	Mean Squares	F Value
PD Mg	1658	36	46	5.99**
Extraction	294	4	73	9.57**
Grain Size	554	4	138	18.03**
Horizon	21	2	10	1.42
Extrac./Horz.	41	8	5	0.68
Grain Size/Horz.	59	8	7	0.97
Extrac./Grain Size	609	10	60	7.93**
Error	138	18		
Total	1796	54		
PD Mn	153	36	4	4.57**
Extraction	27	4	8	7.28**
Grain Size	61	4	14	16.43**
Horizon	6	2	2	3.65*
Extrac./Horz.	6	8	1	0.9
Grain Size/Horz.	14	8	2	1.94
Extrac./Grain Size	34	10	3	3.65**
Error	16	18	1	
Total	170	54		

Table 2: Anova Table for Pilot Study Data

Source	Sum of Squares	Degrees Freedom	Mean Squares	F Value
BL Na	439786	36	11938	7.05**
Extraction	14025	3	4675	2.76*
Grain Size	230752	4	57688	34.06**
Horizon	18667	3	6222	3.67*
Extrac./Horz.	9420	9	1046	0.62
Grain Size/Horz.	35835	11	3257	1.92
Extrac./Grain Size	19720	6	3286	1.94
Error	27097	16		
Total	456883	52		

BL Ca	31164	45	692	1.6*
Extraction	11315	4	2838	6.52**
Grain Size	3004	4	751	1.73
Horizon	1554	3	518	1.2
Extrac./Horz.	3165	12	263	0.61
Grain Size/Horz.	7519	12	626	1.45
Extrac./Grain Size	3809	10	380	0.88
Error	12131	28		
Total	43296	73		

Table 2: Anova Table for Pilot Study Data

Source	Sum of Squares	Degrees Freedom	Mean Squares	F Value
BL Mg	594	45	13	2.68**
Extraction	224	4	56	11.39**
Grain Size	44	4	11	2.29*
Horizon	3	3	1	0.22
Extrac./Horz.	128	12	10	2.18*
Grain Size/Horz.	114	12	9	1.94*
Extrac./Grain Size	45	10	4	0.93
Error	137	28	28	
Total	732	73	73	

Source	Sum of Squares	Degrees Freedom	Mean Squares	F Value
BL Mn	25	45	0.57	6.30**
Extraction	7	4	1.83	21.01*
Grain Size	3	4	0.71	7.82*
Horizon	1	3	0.33	3.67*
Extrac./Horz.	2	12	0.15	1.73
Grain Size/Horz.	2	12	0.16	1.79*
Extrac./Grain Size	9	10	0.93	10.20**
Error	2	28		
Total	28	73		

* Significant at the 95% confidence level

** Significant at the 99% confidence level

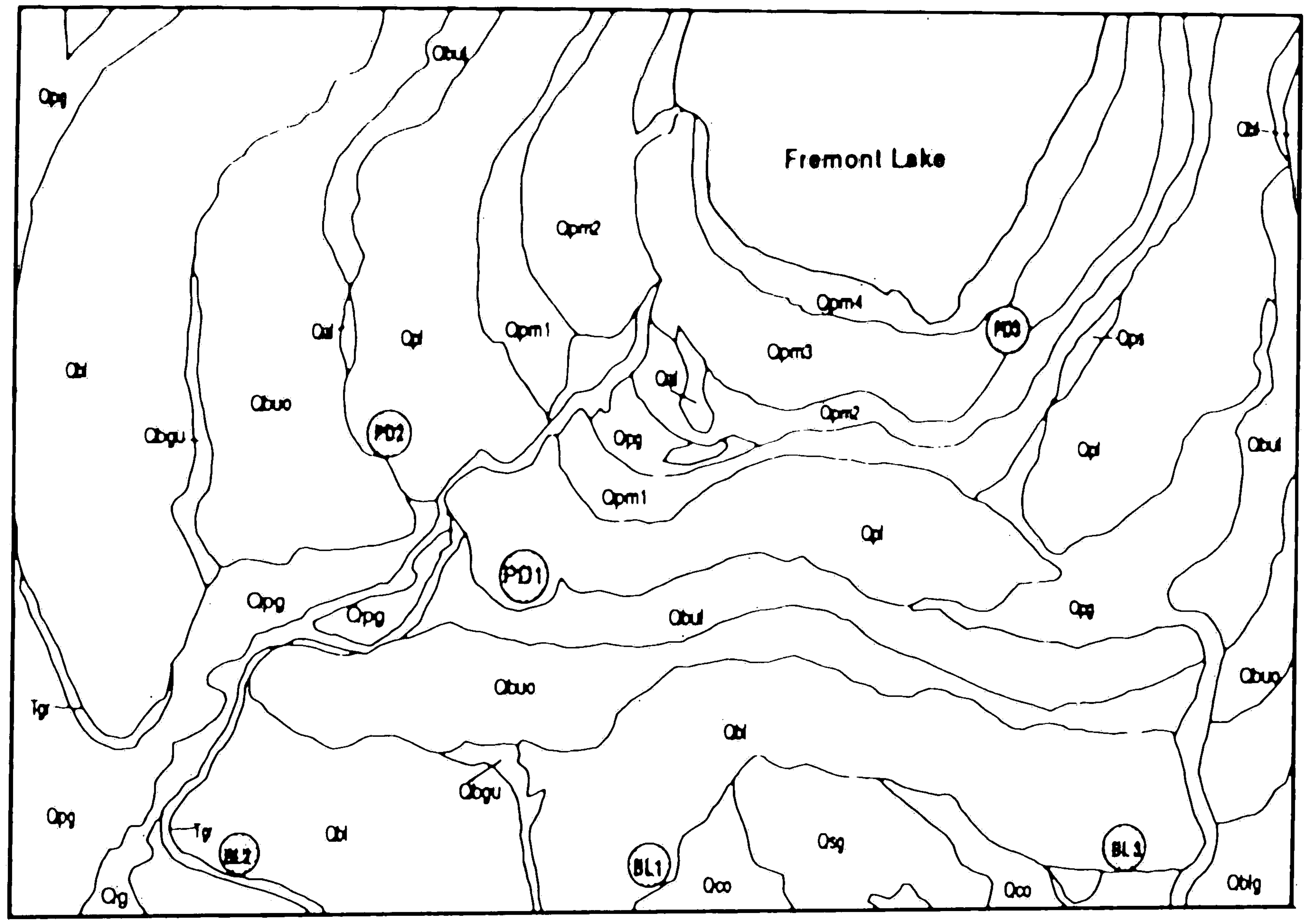
Table 2: Anova Table for Pilot Study Data

Clay, Bulk PD2, PD3 BL2, BL3	DIW	KCl	CuOAc	HCl	CDB
Na			X	X	X
Ca	X	X	X	X	X
Mg	X	X	X	X	X
Al					X
Fe					X
Mn				X	X

Table 3: Soil chemical analysis for sample sites PD2, PD3, BL2 and BL3

Clay, Bulk PD2, PD3 BL2, BL3	DIW	KCl	CuOAc	HCl	CDB
Na			X	X	X
Ca	X	X	X	X	X
Mg	X	X	X	X	X
Al					X
Fe					X
Mn				X	X

Table 3: Soil chemical analysis for sample sites PD2, PD3, BL2 and BL3



42 52' 30"

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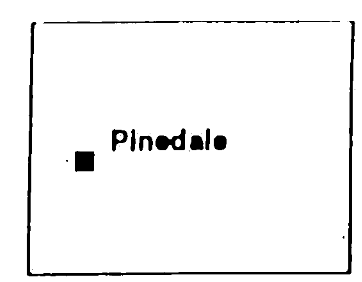


Wyoming

Legend

PD 1 Pinedale sample site 1

PD 2 Pinedale sample site 2

PD 3 Pinedale sample site 3

BL 1 Bull Lake sample site 1

BL 2 Bull Lake sample site 2

BL 3 Bull Lake sample site 3

Figure 1 Glacial deposits at the Pinedale type locality (modified from Richmond 1974) and sample locations of this study.

Figure 1 - Legend

Glacial Deposits Pinedale Type Locality

(Modified from Richmond, 1973)

Qco - Colluvium (Holocene and Pleistocene)

Qpm4 - Till of 4th recessional readvance of ice

Qpm3 - Till of 3rd recessional readvance of ice

Qpm2 - Till of 2nd recessional readvance of ice

Qpm1 - Till of outermost advance of ice of middle stage

Qpl - Lower till (Pleistocene, Pinedale Glaciation)

Qpg - Gravel (Pleistocene, Pinedale Glaciation)

Qal - Fine-grained alluvium (Holocene)

Qg - Stream gravel (Holocene)

Qbui - Inner moraine of upper till (Pleistocene, Bull Lake Glaciation)

Qbuo - Outer moraine of upper till (Pleistocene, Bull Lake Glaciation)

Qbl - Lower Till (Pleistocene, Bull Lake Glaciation)

Qbgu - Upper Gravel

Qsg - Gravel (Pleistocene, Sacagawea Ridge Glaciation)

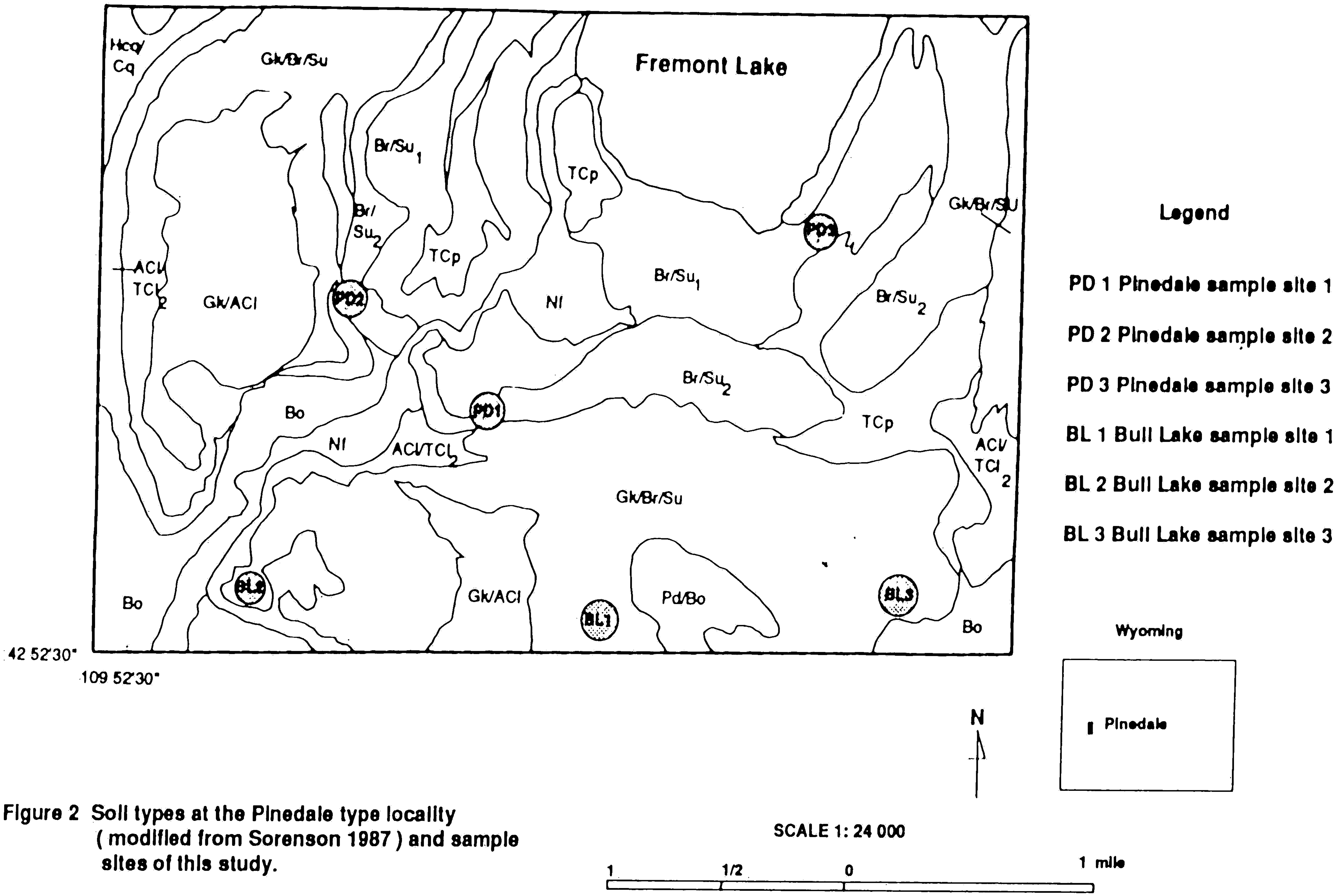


Figure 2 Soil types at the Pinedale type locality (modified from Sorenson 1987) and sample sites of this study.

Figure 2 - Legend

Soils Deposits, Pinedale Type Locality

(Modified from Sorenson ,1987)

ACl/TCl_1	Argic Cryoboroll-Typic Cryoboroll complex (0-20 percent slopes)
ACl/TCl_2	Argic Cryoboroll-Typic Cryoboroll complex (20-60 percent slopes)
Bo	Boulder gravelly sandy loam (Argiudic Ctyoboroll) (0-20 percent slopes)
Br/Su_1	Burnt Lake-Sublette complex (Typic Cryoboroll-Argic Pachic Cryoboroll) (0-20 percent slopes)
Br/Su_2	Burnt Lake-Sublette complex (Typic Cryoboroll-Argic Pachic Cryoboroll) (20-60 percent slopes)
Gk/ACl	Gelkie (Argic Cryoboroll)-Argic Cryoboroll complex (0-20 percent slopes)
Gk/Br/Su	Gelkie-Burnt Lake-Sublette complex (Argic Cryoboroll-Typic Cryoboroll, Argic Pachic Cryoboroll)(0-20 percent slopes)
Hcq/Cq	Histic Cryaquoll complex (0-5 percent slopes)
Nf	New Fork gravelly loam (Typic Cryaquoll)(0-5 percent slopes)
Pd/Bo	Pinedale-Boulder complex (Argiudic Cryoboroll-Argiudic Cryoboroll) (0-5 percent slopes)
TCp	Typic Cryochrept (0-20 percent slopes)

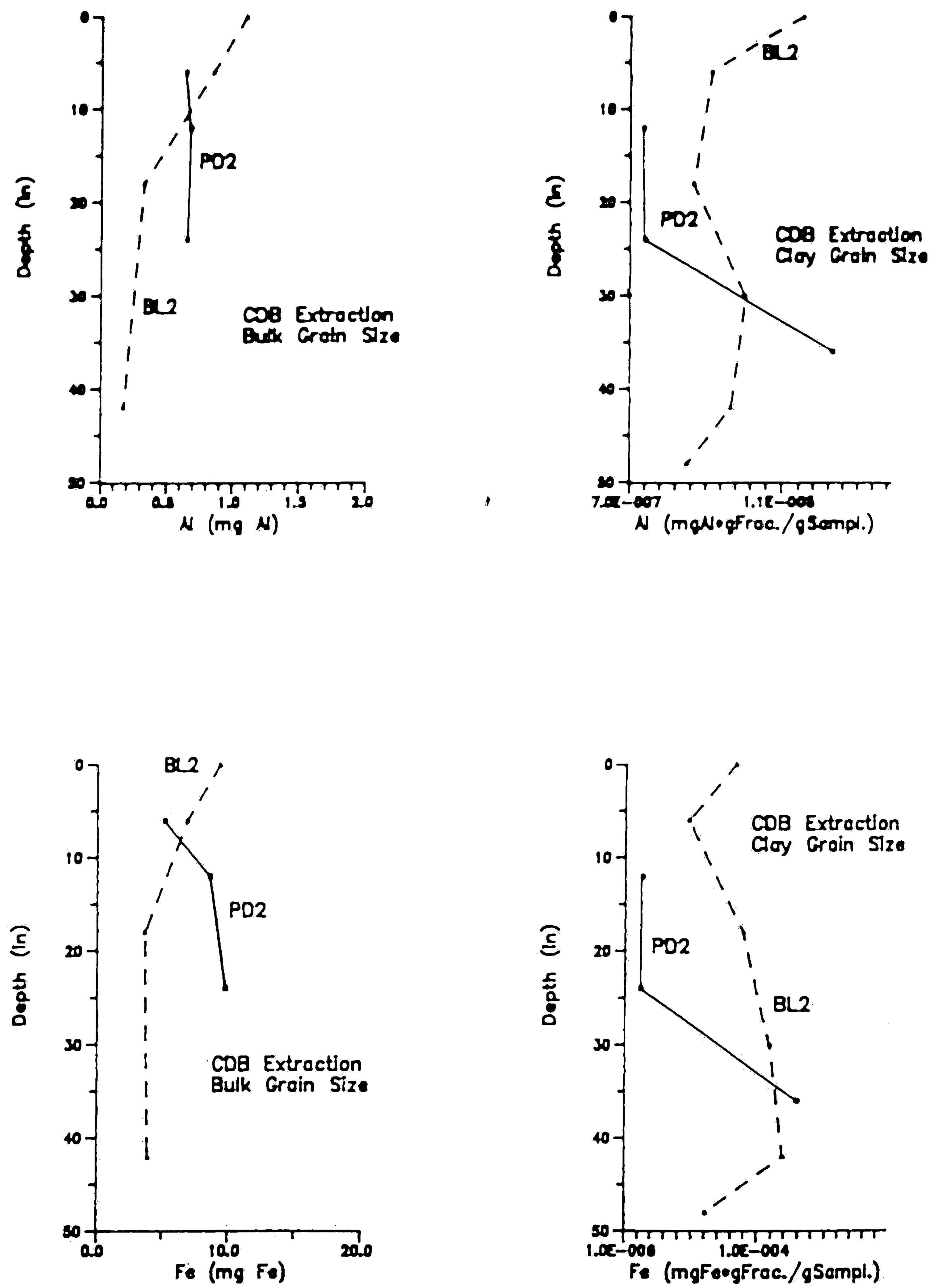


Figure 3 : Depth vs Concentration for PD2 and BL2 , for Elements Fe and Al in Extraction CDB, in Bulk and Clay size fractions

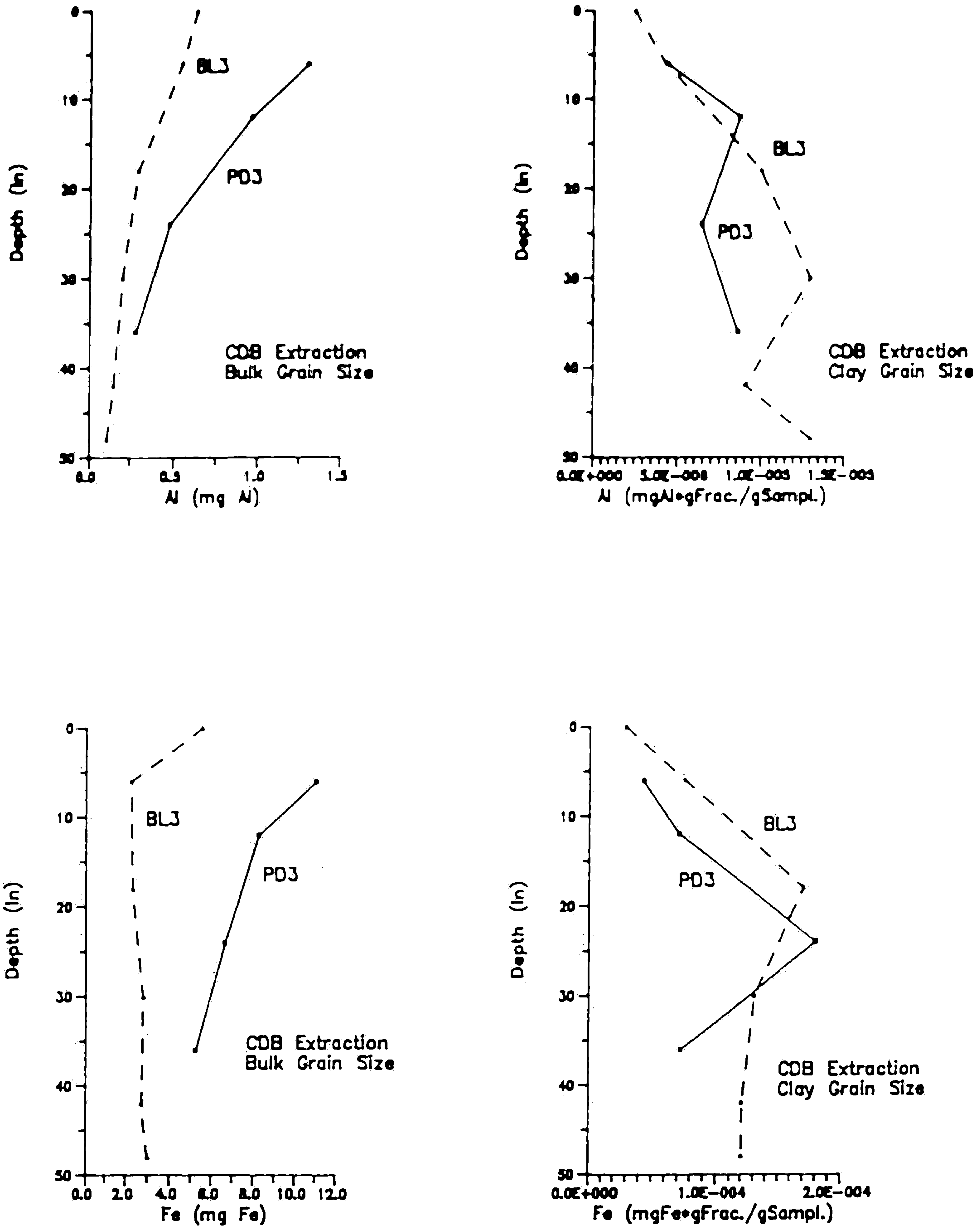
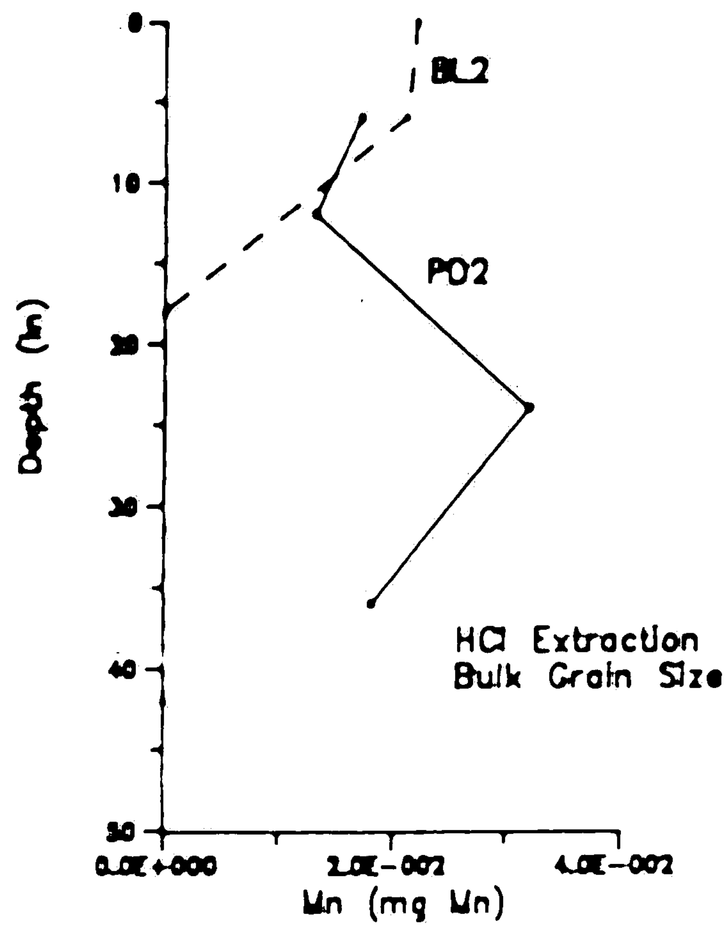
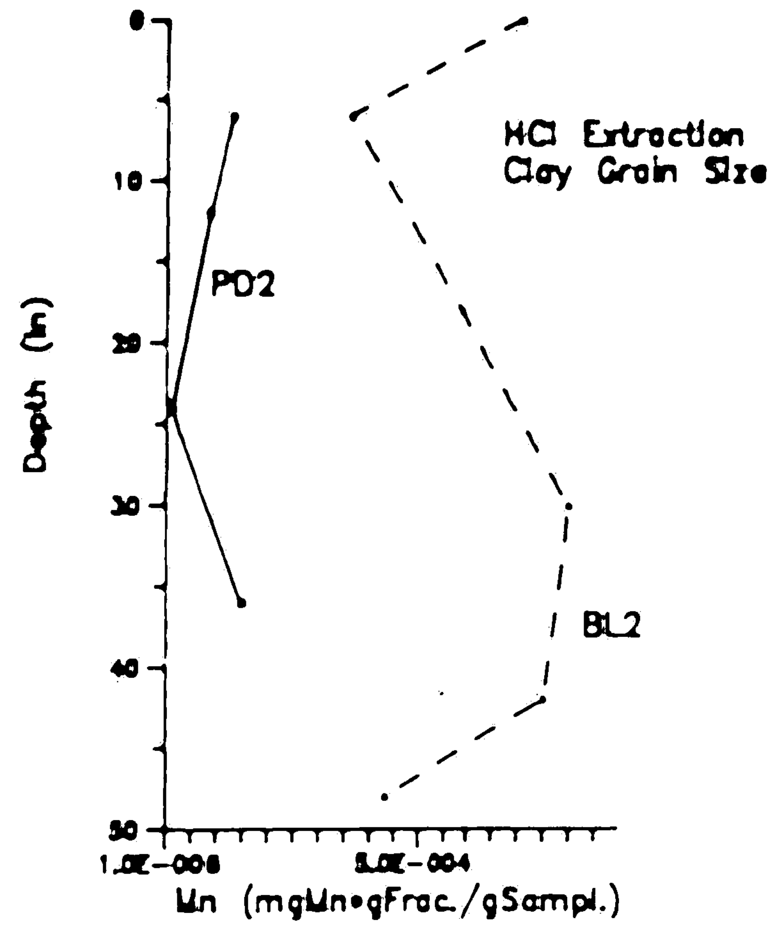
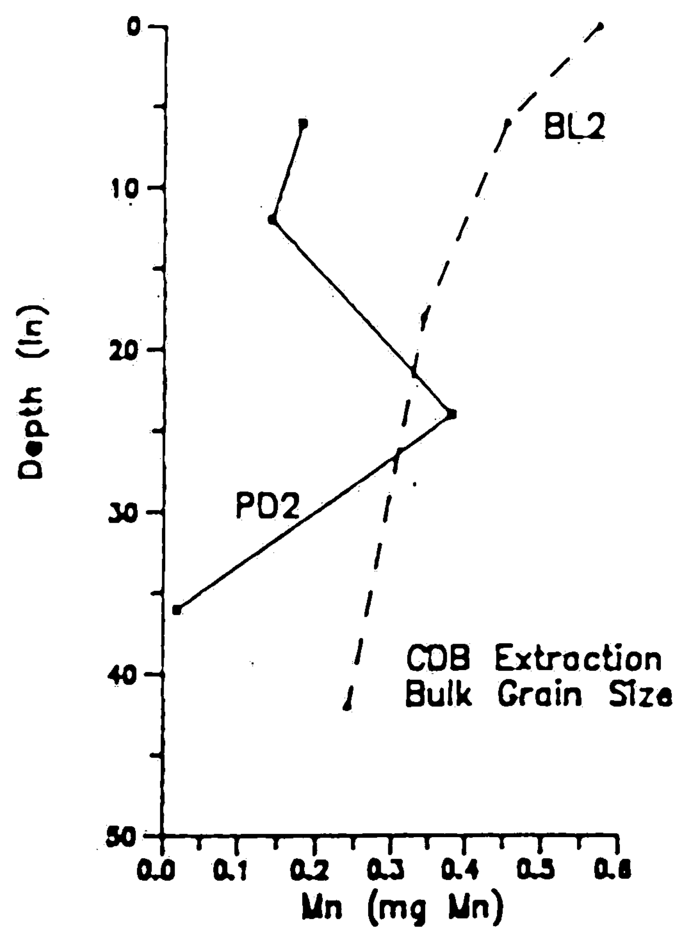


Figure 4 : Depth vs Concentration for PD3 and BL3, for Elements Fe and Al in Extraction CDB, in Bulk and Clay size fractions.







PD2 and BL2 below detection limits

Figure 5 : Depth vs Concentation for PD2 and BL2, for Element Mn in Extractions HCl and CDB, in Bulk and Clay size fractions.

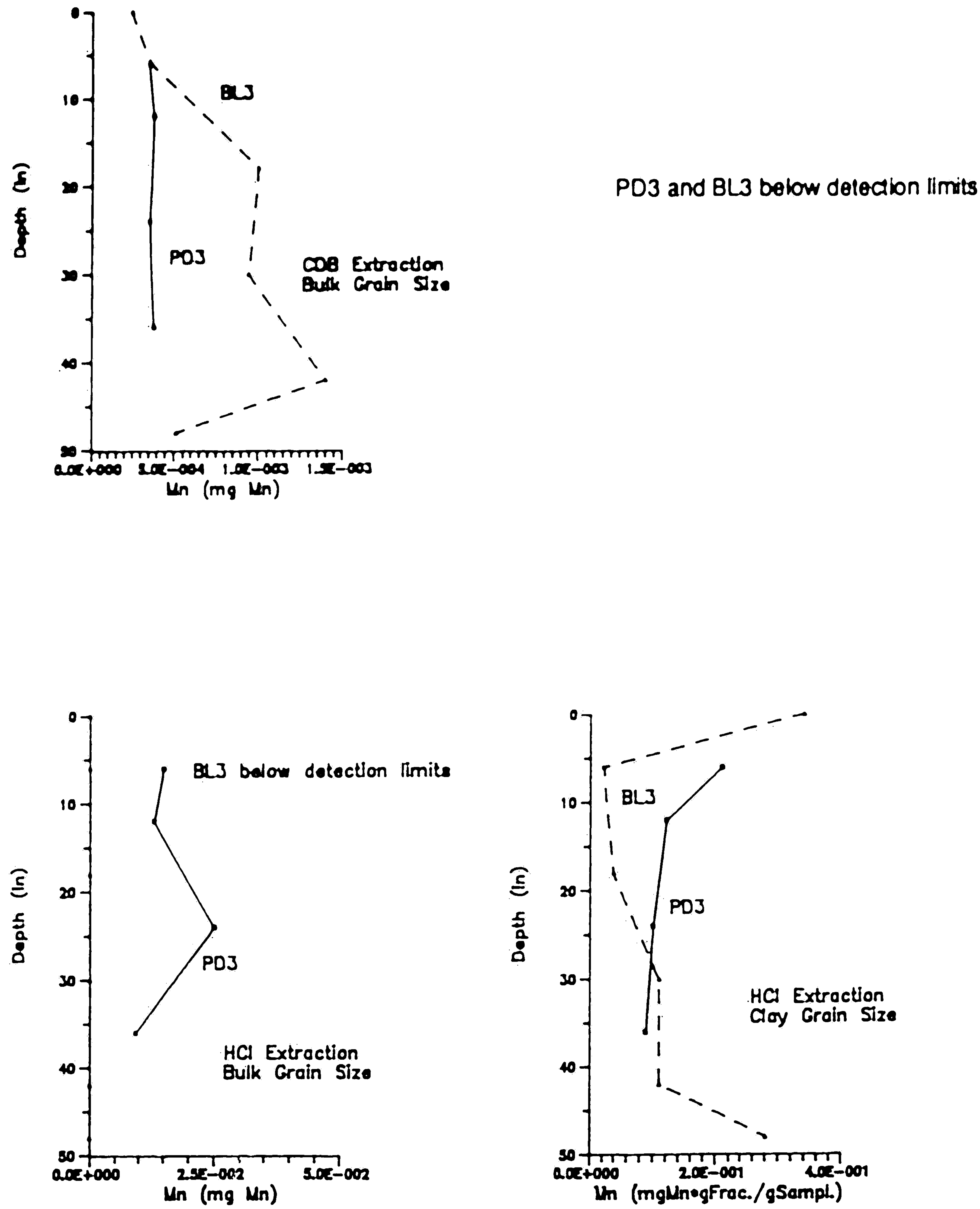
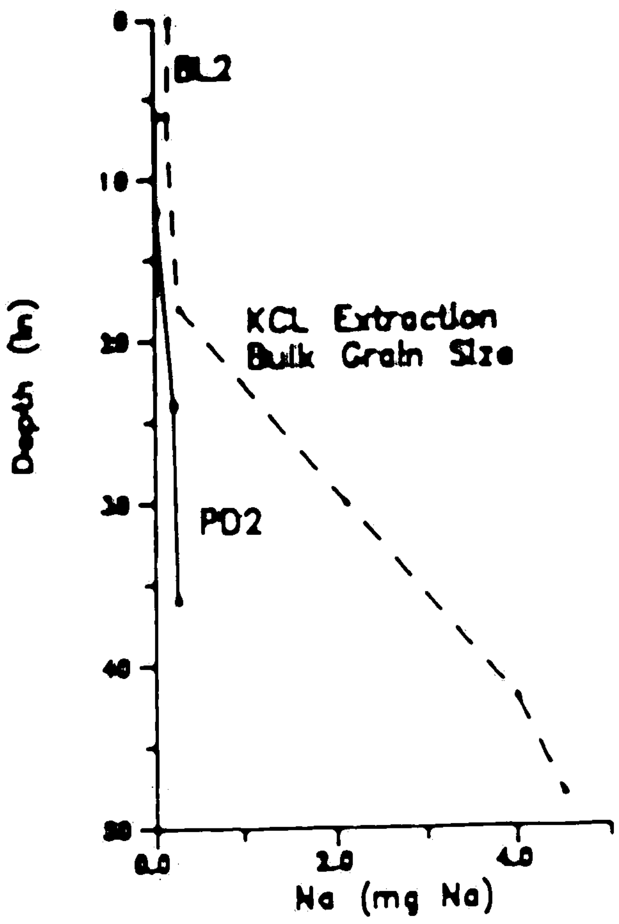
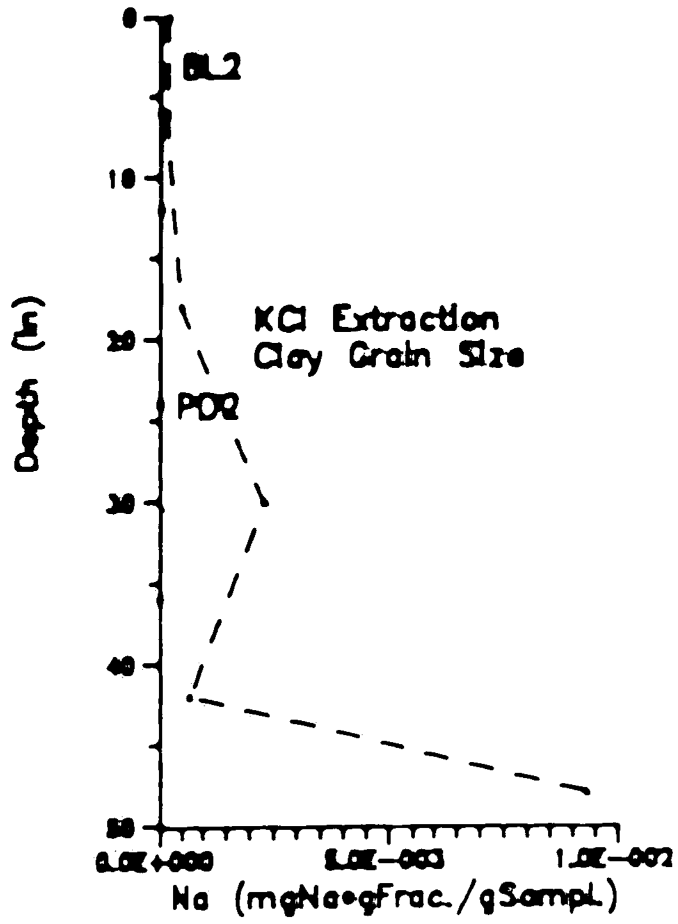


Figure 6 : Depth vs Concentration for PD3 and BL3, for Element Mn in Extractions HCl and CDB, in BUlk and Clay size fractions.





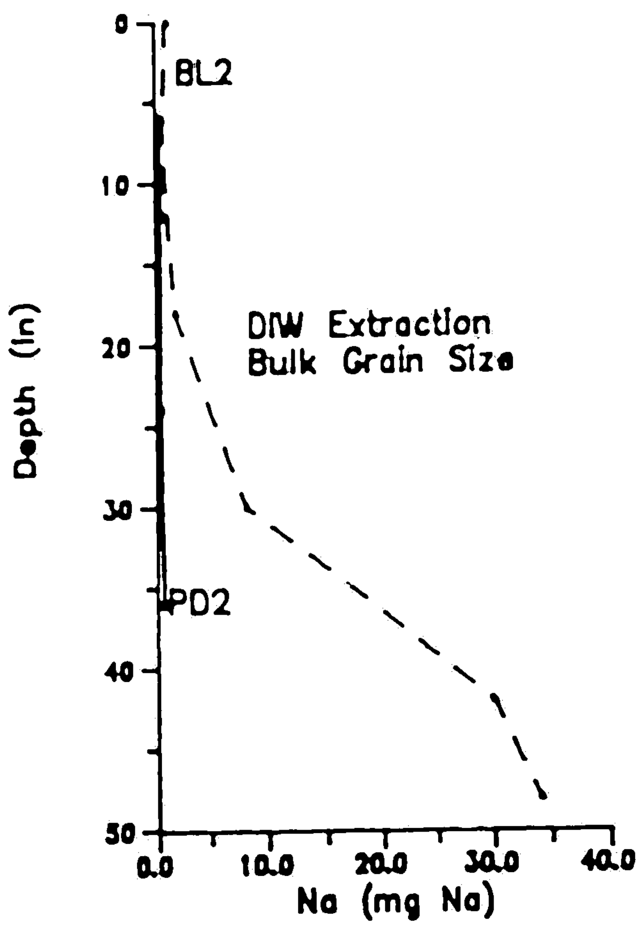


Figure 7 : Depth vs Concentration for PD2 and BL2 , for Element Na in Extractions DIW and KCl, in Bulk and Clay size fractions.

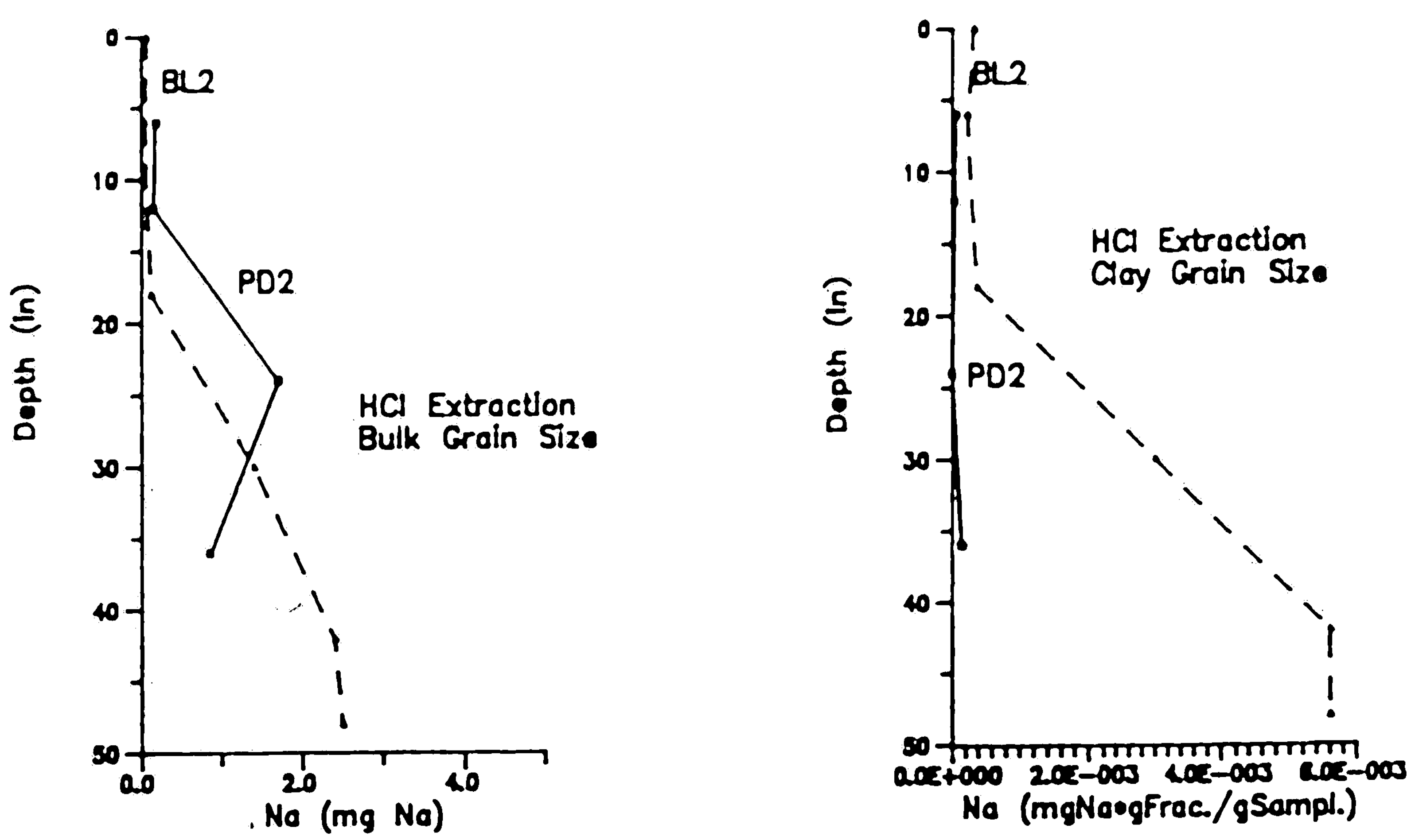


Figure 8 : Depth vs Concentration for PD2 and BL2, for Element Na in Extraction HCl, in Bulk and Clay size fractions.

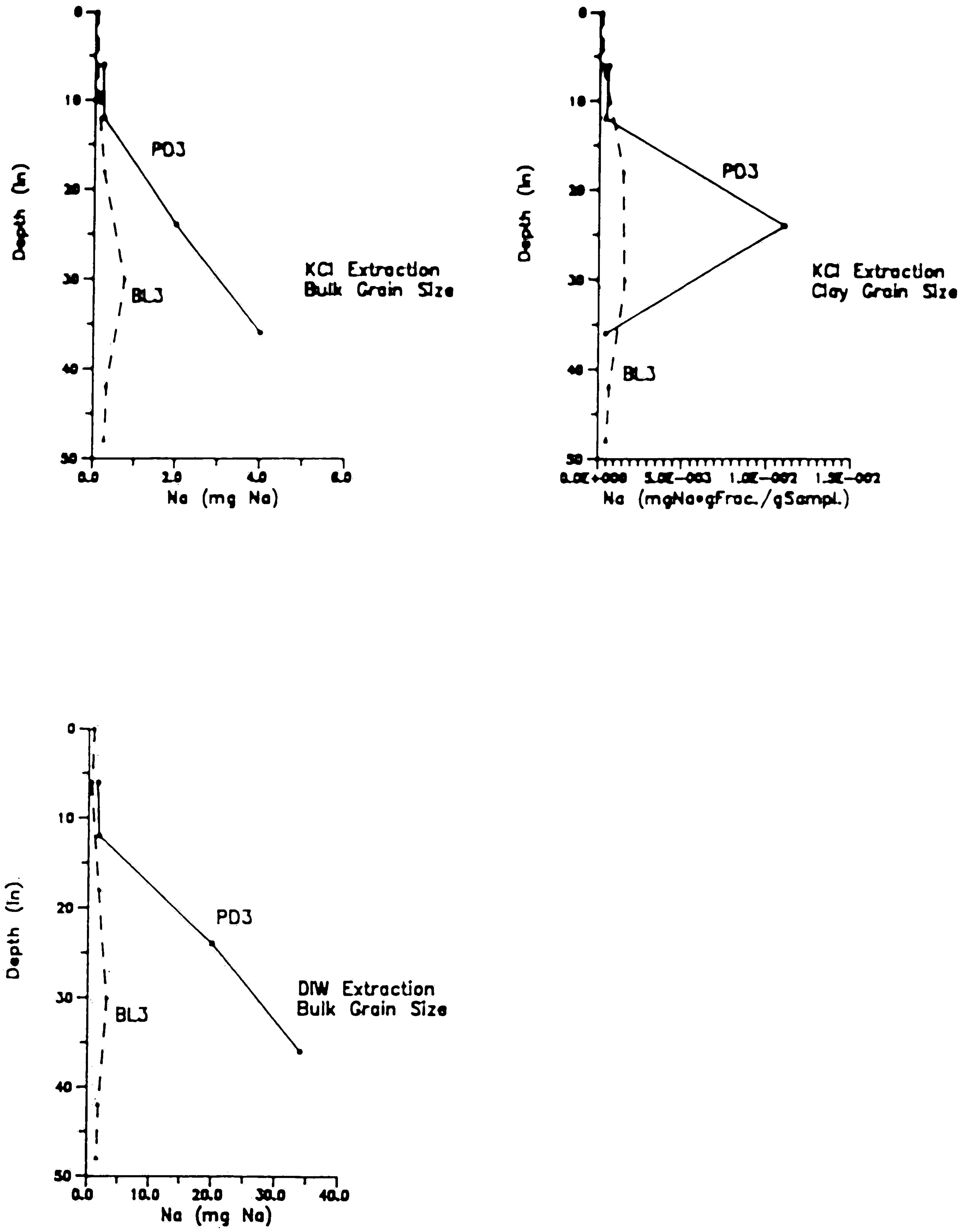


Figure 9 : Depth vs Concentration for PD3 and BL3, for Element Na in Extractions DIW and KCl, in Bulk and Clay size fractions.

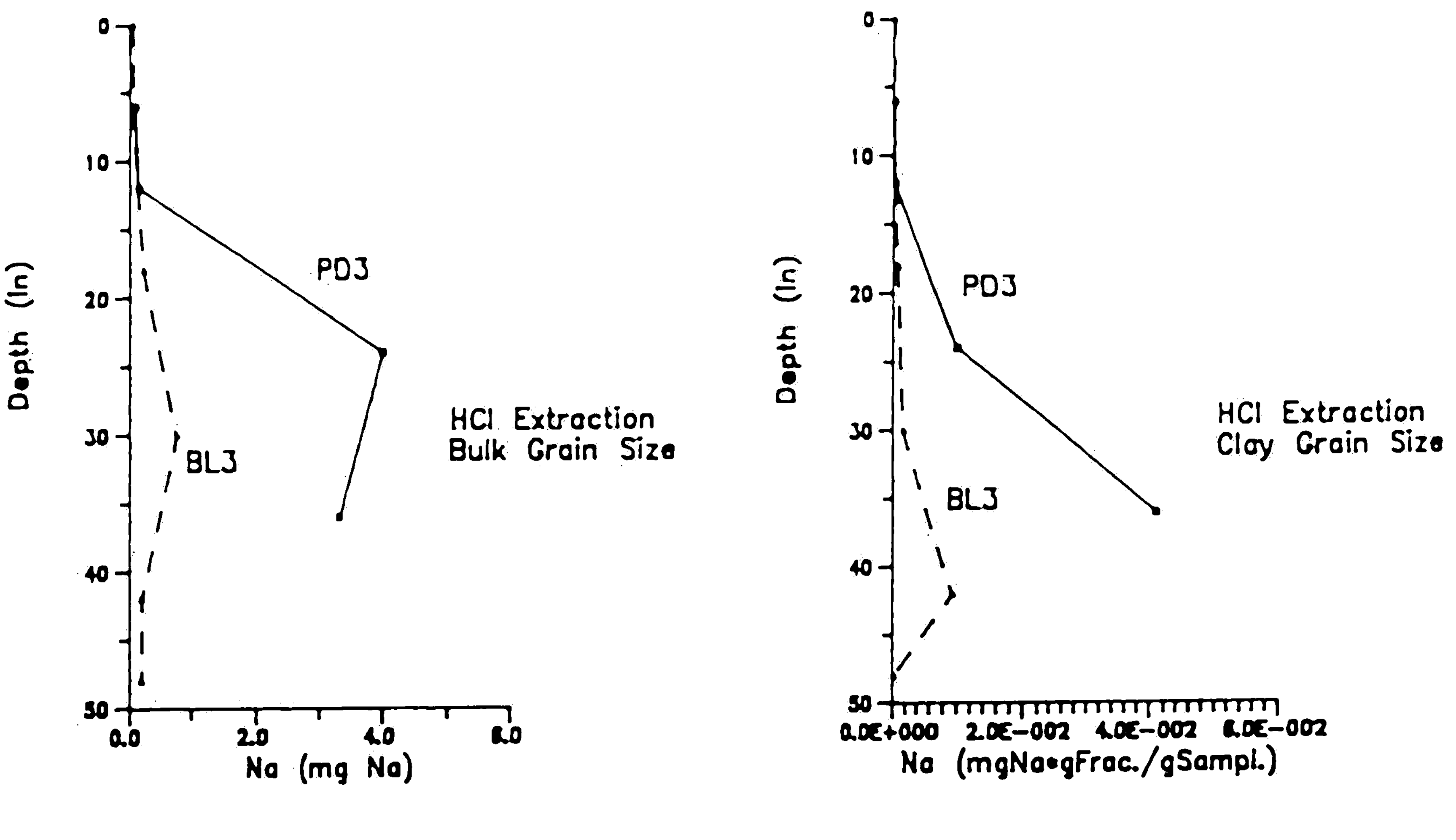


Figure 10 : Depth vs Concentration for PD3 and BL3, for Element Na in Extraction HCl, in Bulk and Clay size fractions.

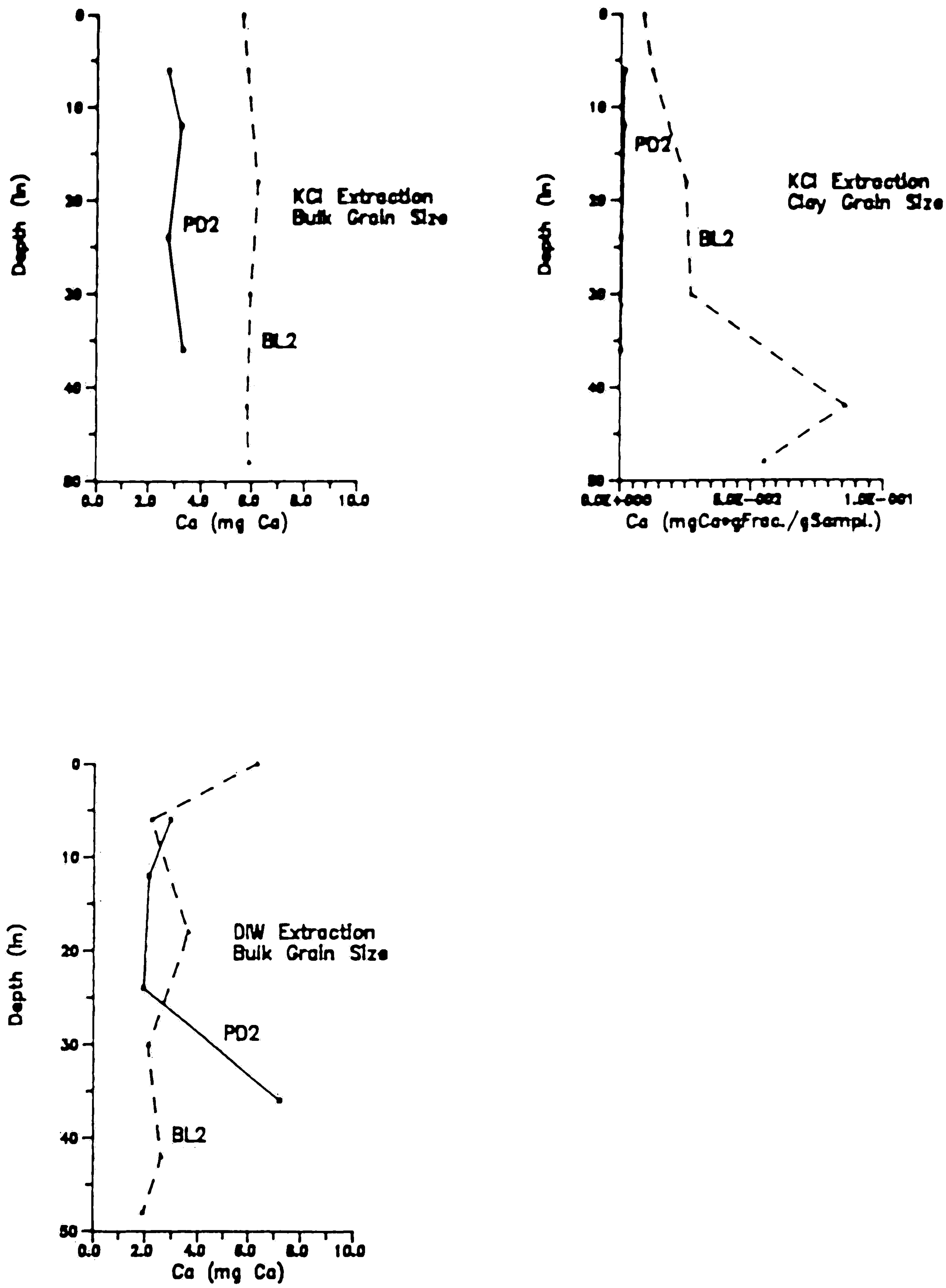


Figure 11 : Depth vs Concentration for PD2 and BL2, for Element Ca in Extractions DIW and KCl, in Bulk and Clay size fractions.

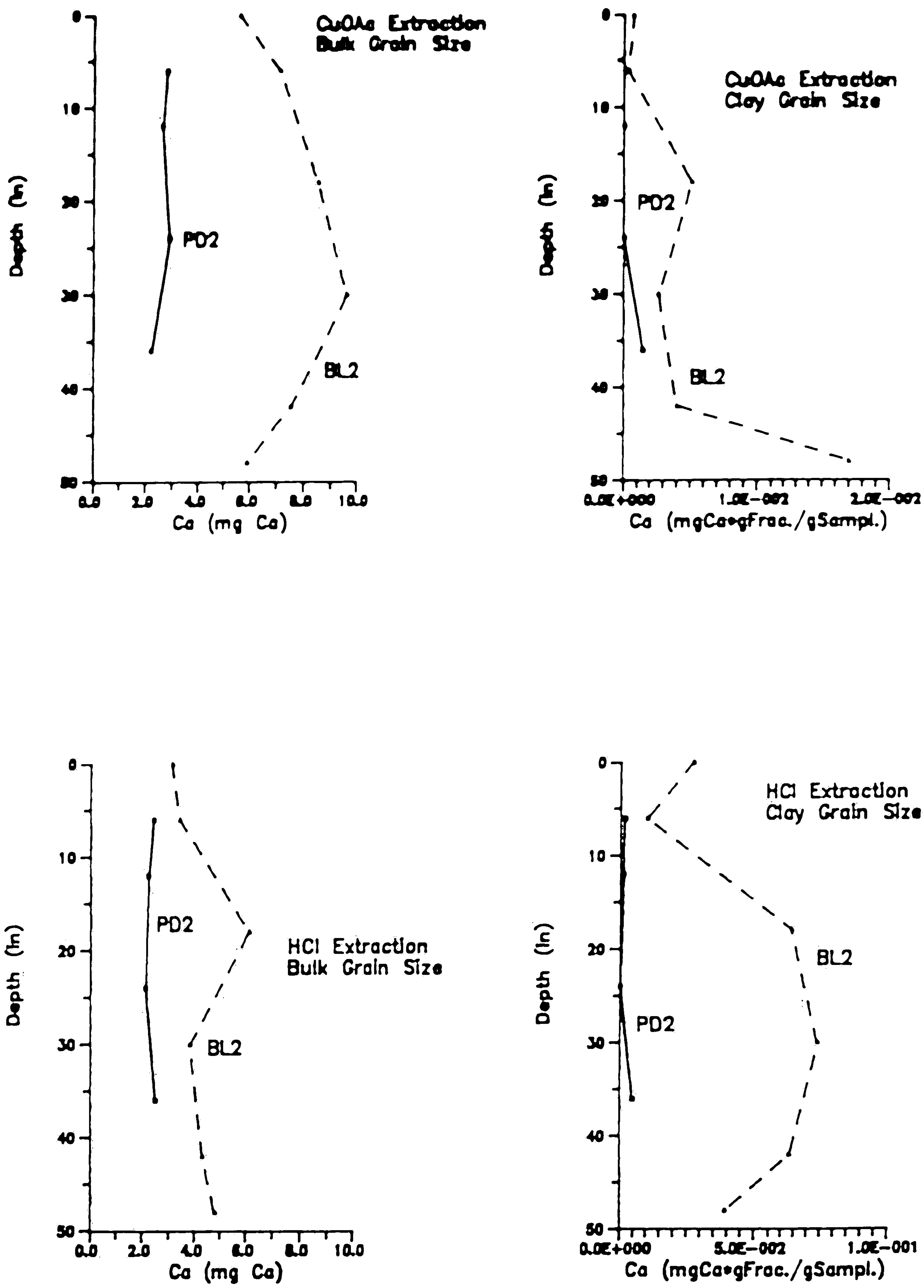


Figure 12 : Depth vs Concentration for PD2 and BL2 , for Element Ca in Extractions HCl and CuOAc, in Bulk and Clay size fractions.

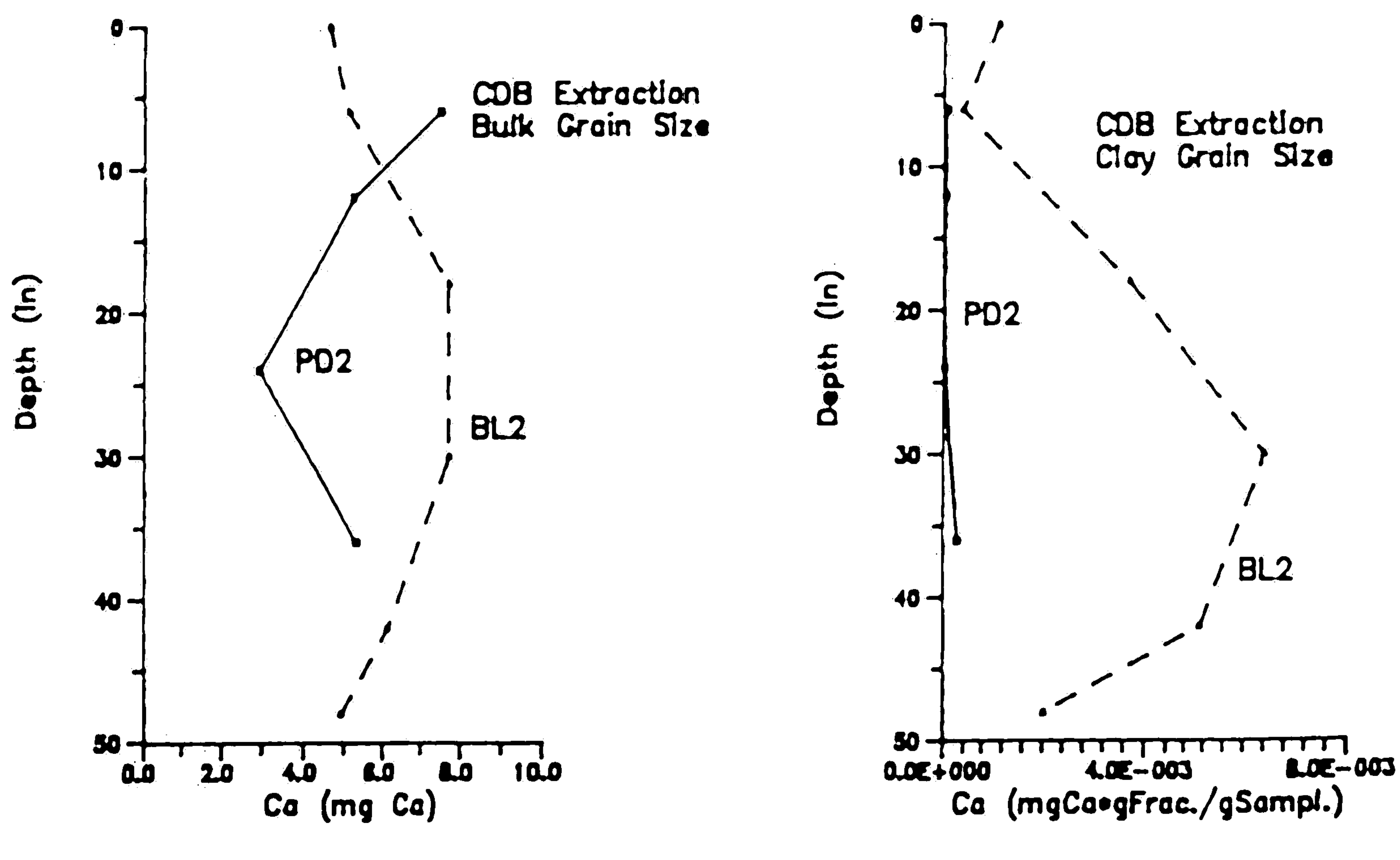


Figure 13 : Depth vs Concentration for PD2 vs BL2, for Element Ca in Extraction CDB, in Bulk and Clay Size fractions.

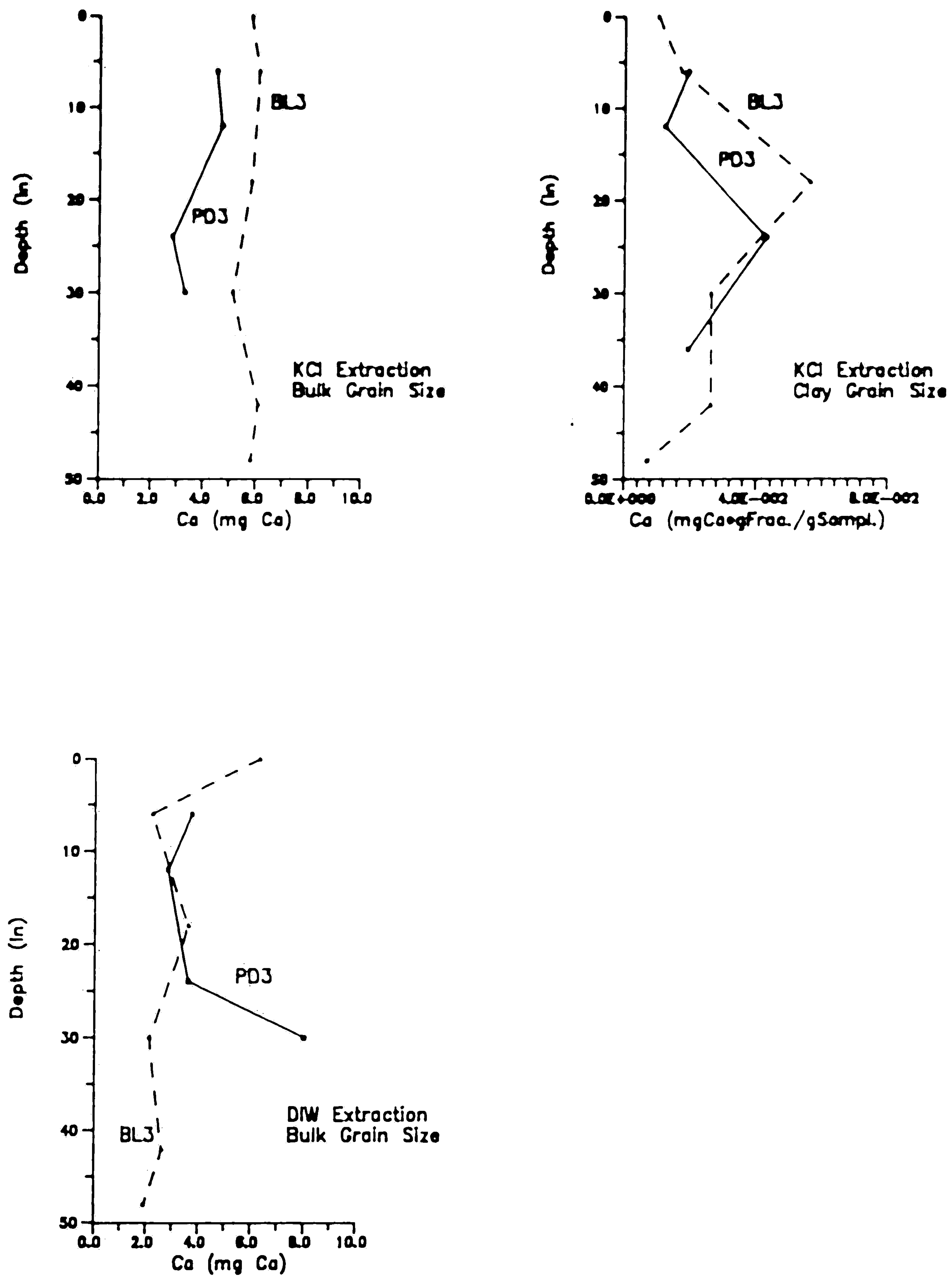


Figure 14 : Depth vs Concentration for PD3 vs BL3 , for Element Ca in Extractions DIW and KCl, in Bulk and Clay size fractions.

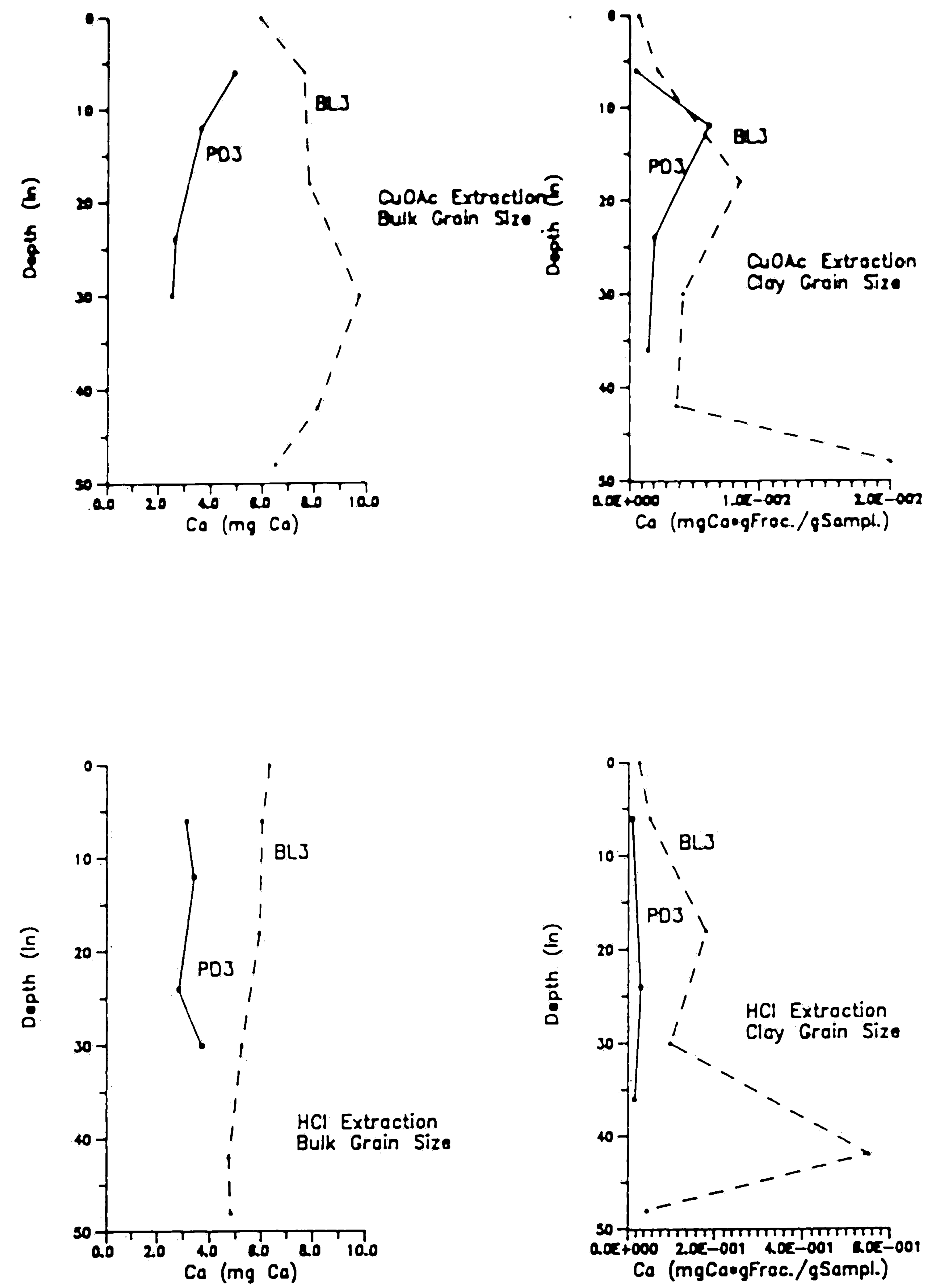


Figure 15 : Depth vs Concentration for PD3 and BL3, for Element Ca in Extractions HCl and CuOAc, in Bulk and Clay Size fractions.

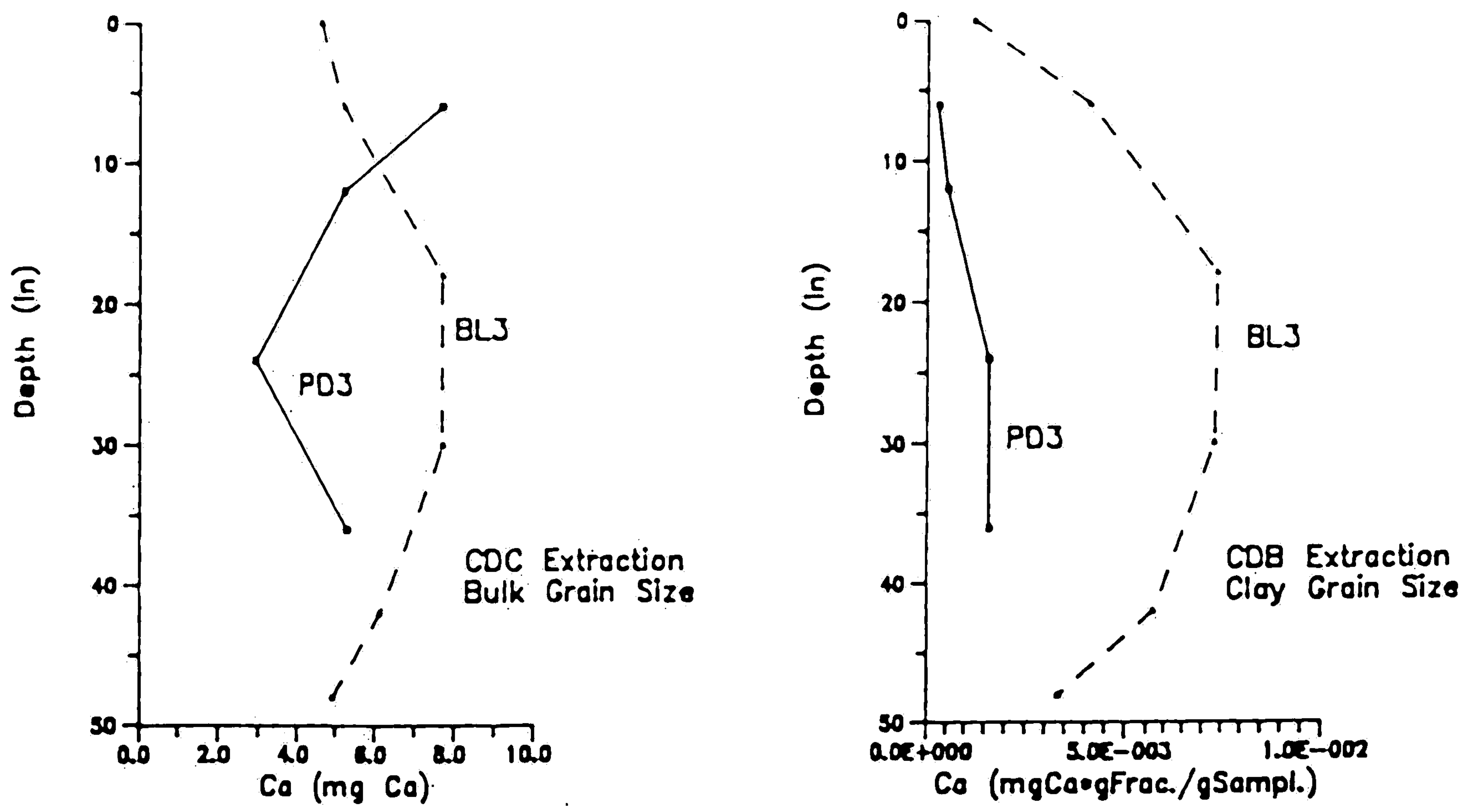
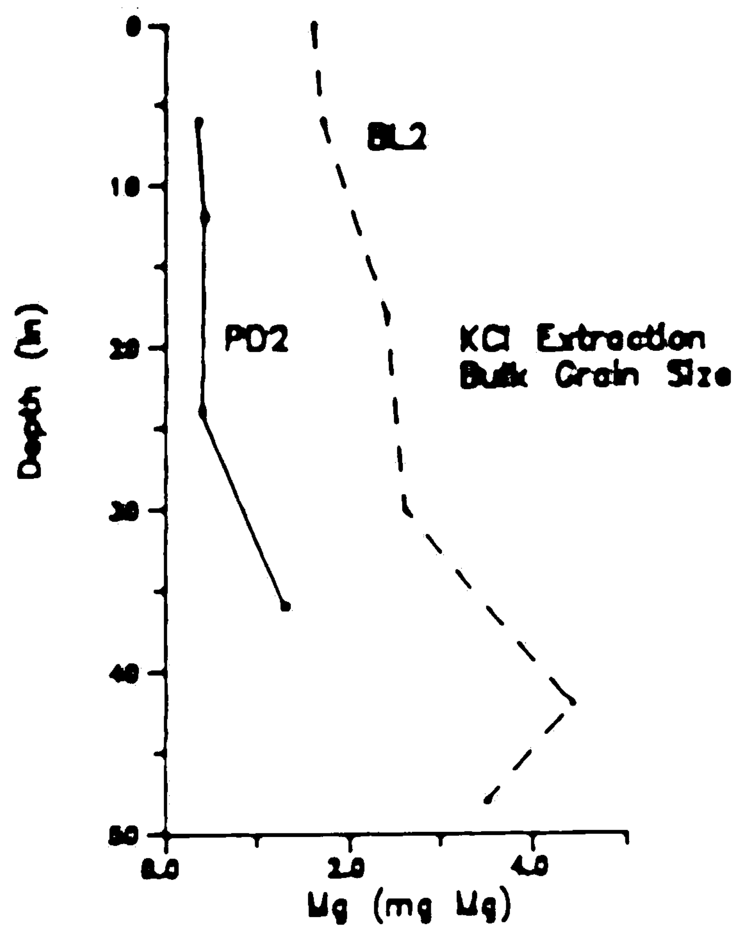
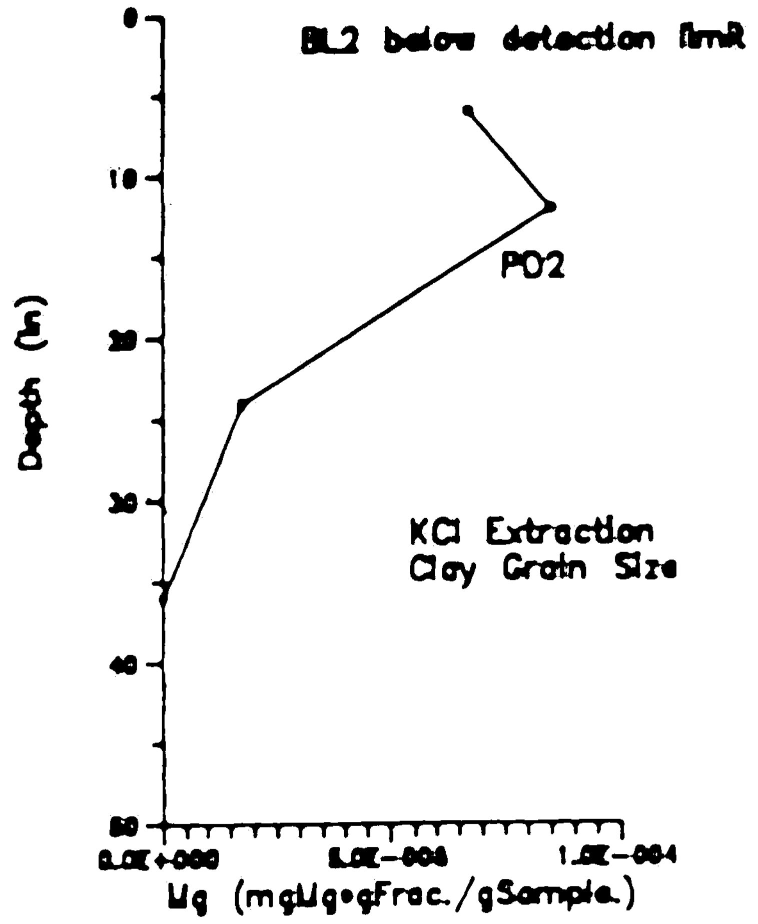


Figure 16 : Depth vs Concentration for PD3 and BL3, for Element Ca in Extraction CDB, in Bulk and Clay size fraction.





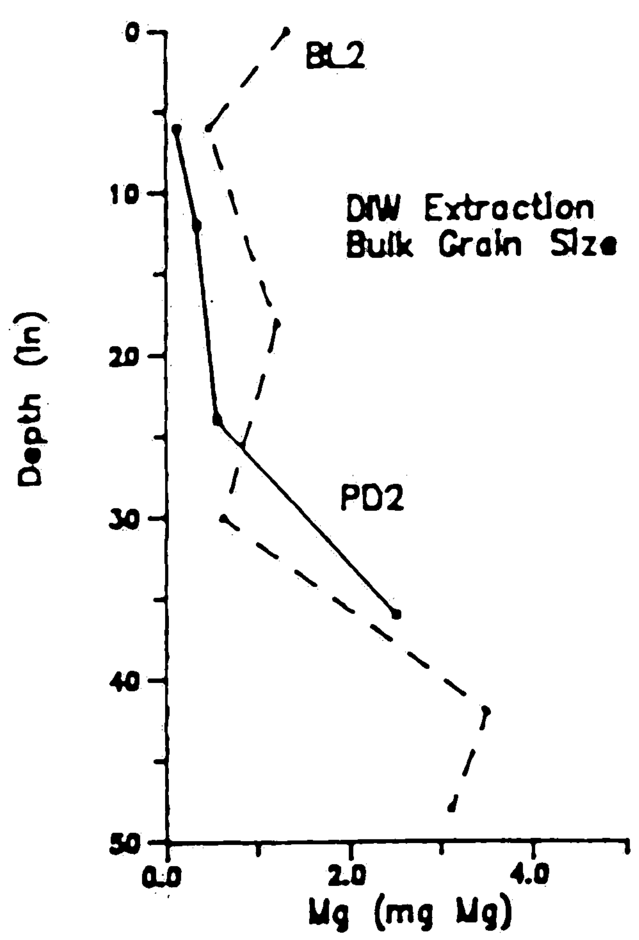


Figure 17 : Depth vs Concentration for PD2 and BL2, for Element Mg in Extractions DIW and KCl, in Bulk and Clay size fractions.

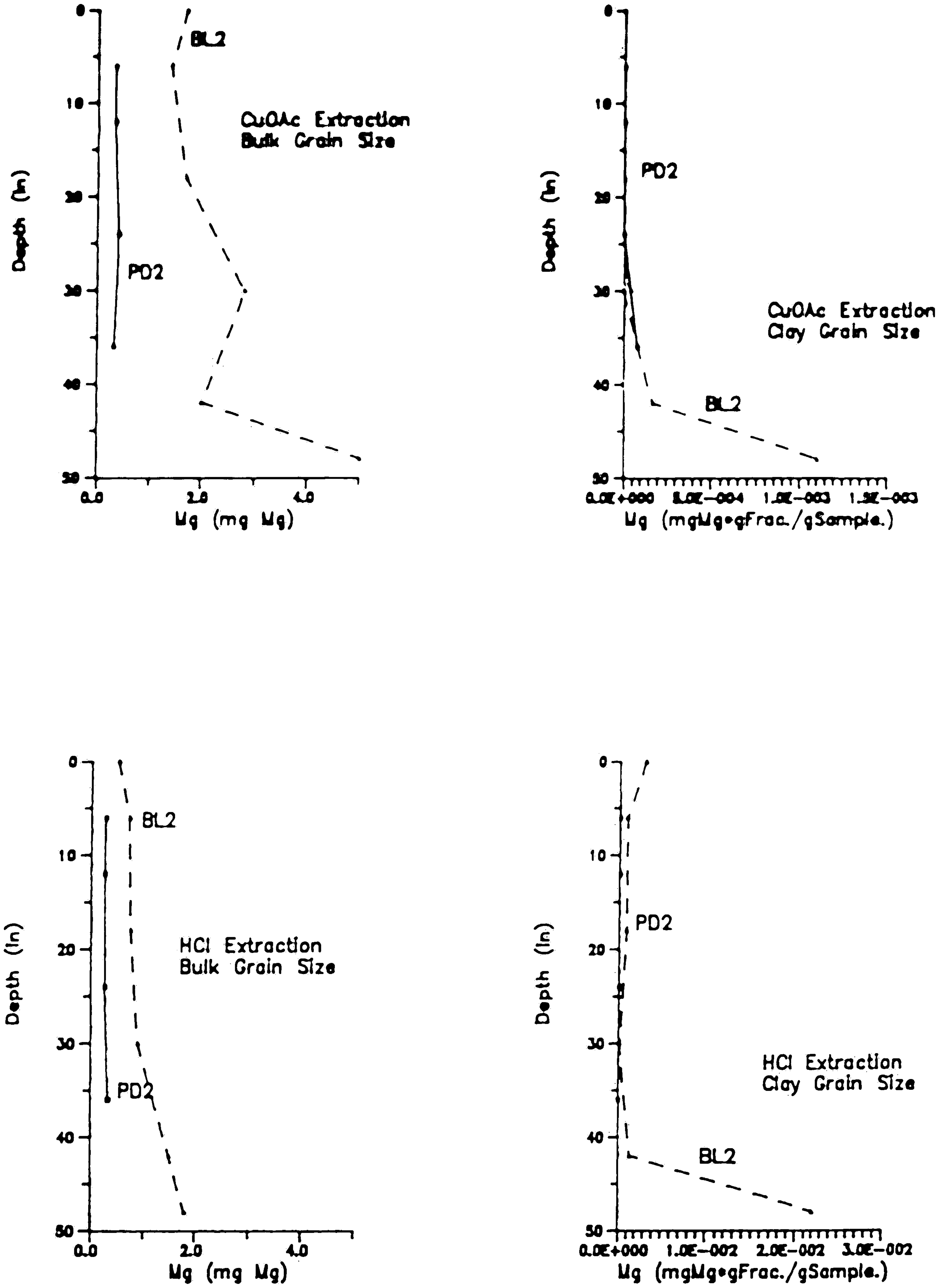


Figure 18 : Depth vs Concentration for PD2 and BL2, for Element Mg in Extractions HCL and CuOAc , in Bulk and Clay size fractions.

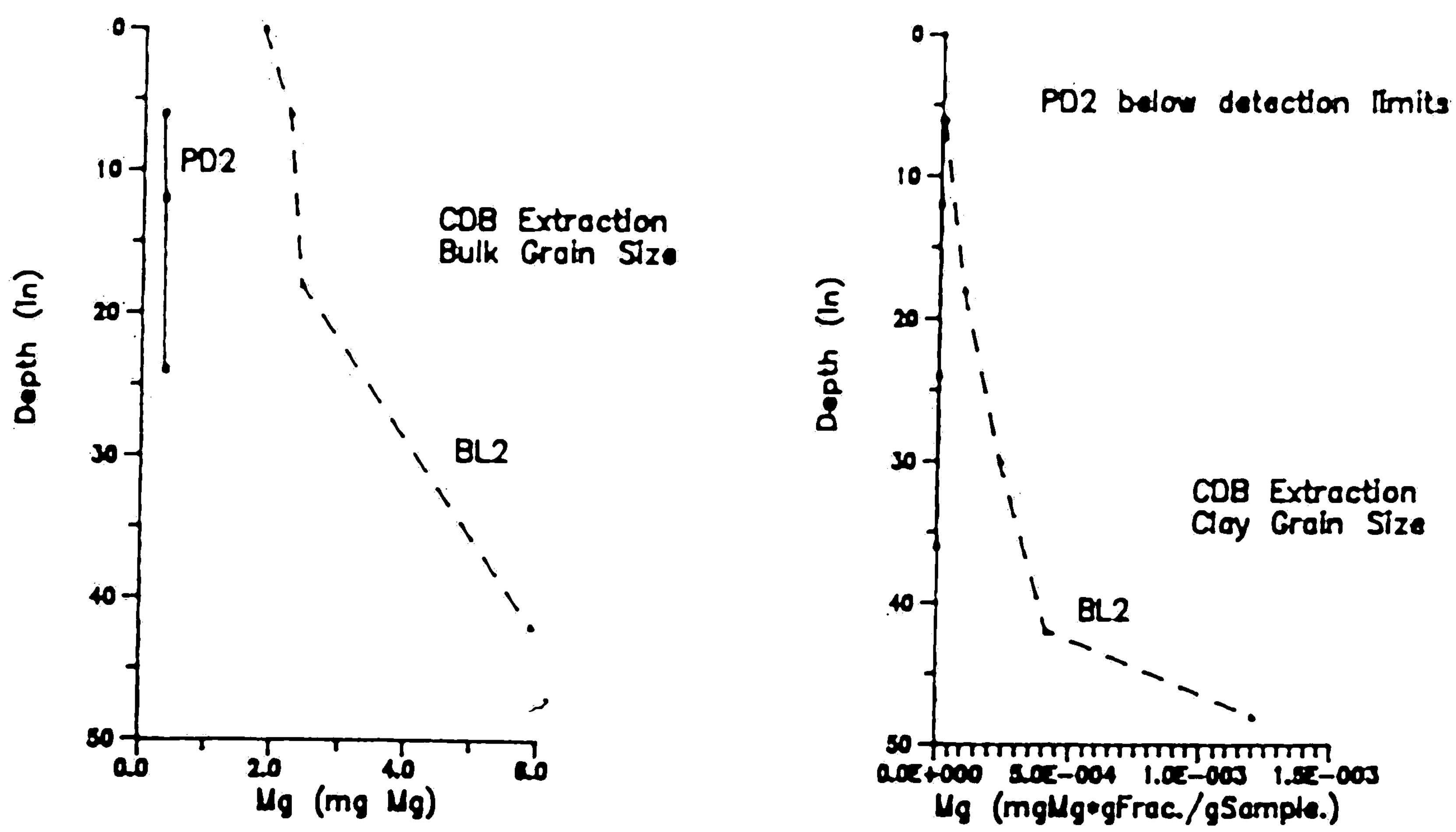


Figure 19 : Depth vs Concentration for PD2 and BL2, for Element Mg in Extraction CDB, in Bulk and Clay size fractions.

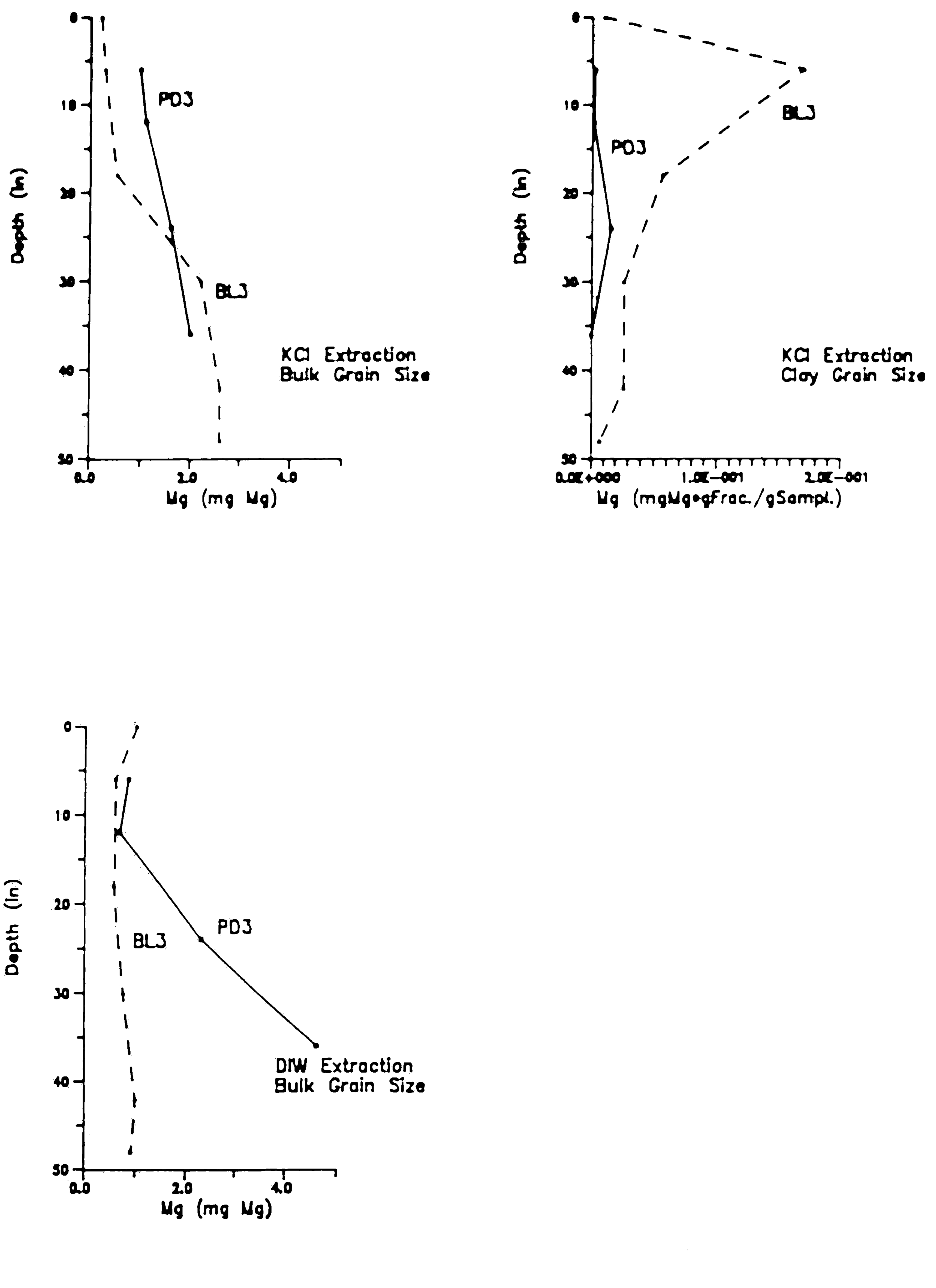


Figure 20 : Depth vs Concentration for PD3 and BL3, for Element Mg in Extractions DIW and KCl, in Bulk and Clay size fractions.

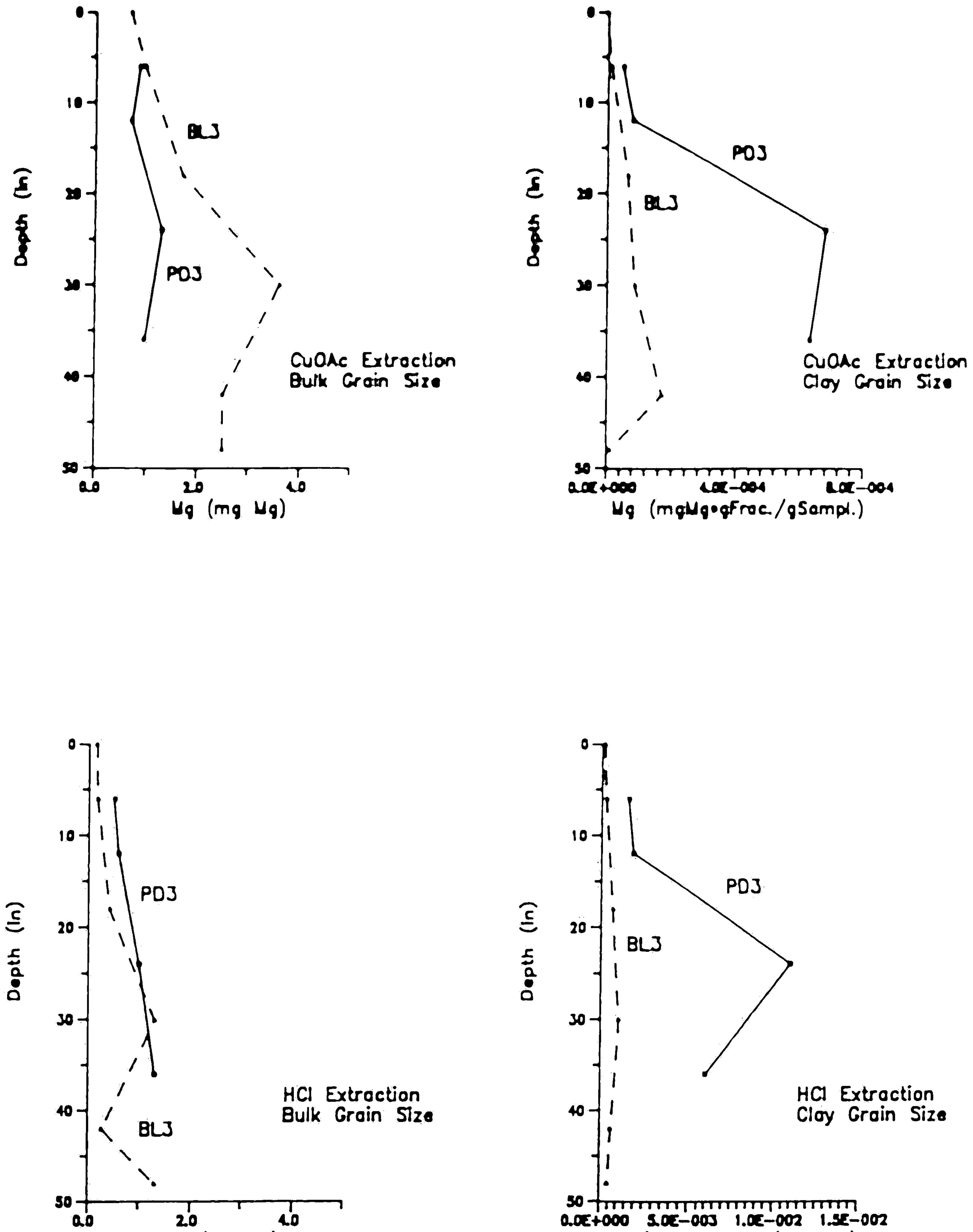


Figure 21 : Depth vs Concentration for PD3 and BL3, for Element Mg in Extractions HCl and CuOAc, in Bulk and Clay size fractions.

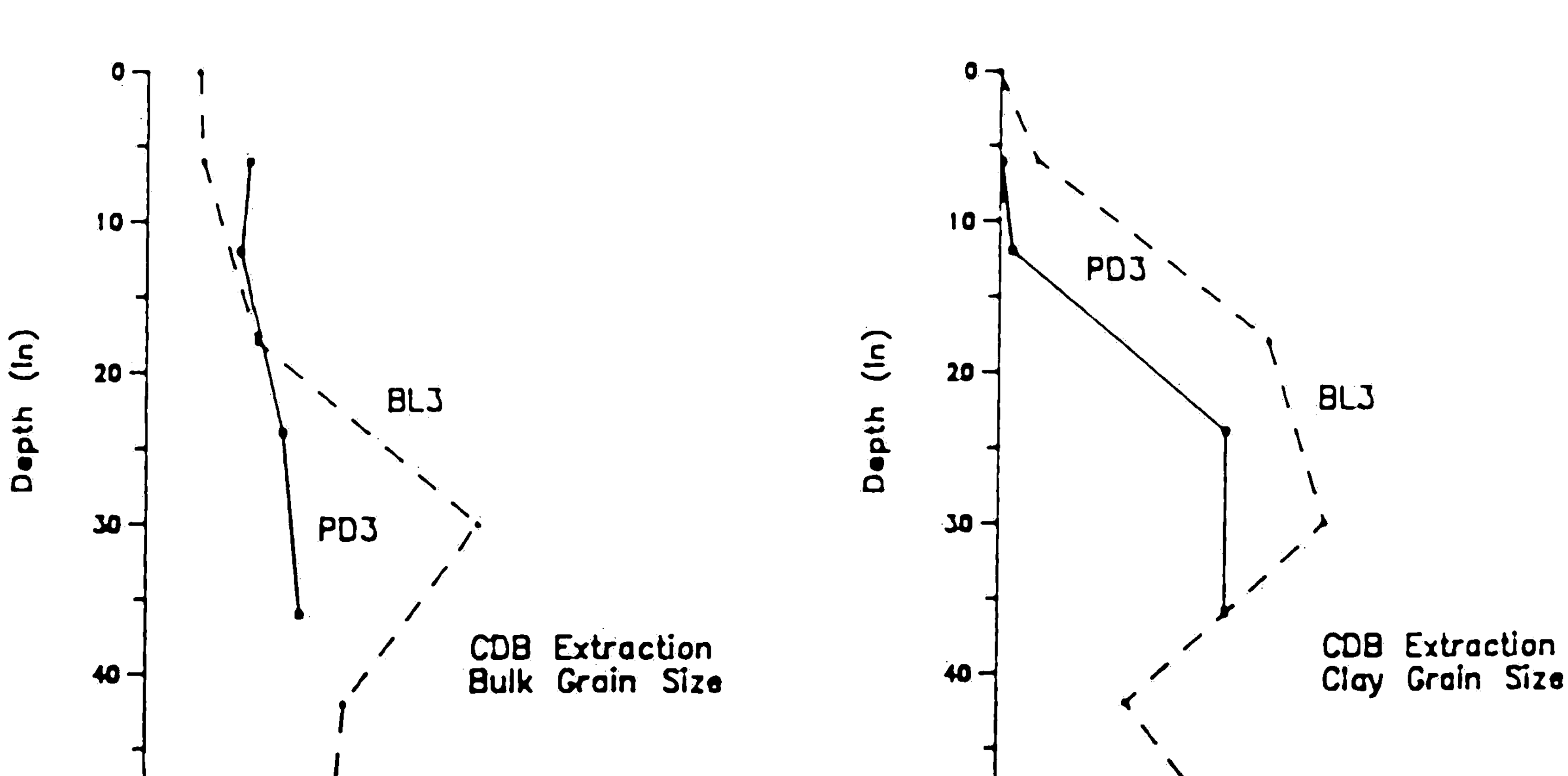


Figure 22 : Depth vs Concentration for PD3 and BL3, for Element Mg in Extraction CDB, in Bulk and Clay size fraction.

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Appendix 1

Pilot study soil chemistry data

Location	Soil Depth (in)	Extraction	Grain Size (um)	Na(a)	Ca(a)	Mg(a)	Mn(a)	Fe(a)	Al(a)	K(a)
Pd 1	0-6	DIW	Bulk	1.4E-03	3.7E-04	1.2E-04	3.2E-04	< Dl(b)	2.9E-04	< Dl
Pd 1	12-18	DIW	Bulk	1.3E-03	5.9E-04	2.0E-04	3.3E-04	< Dl	3.3E-04	< Dl
Pd 1	24-30	DIW	Bulk	1.3E-03	3.2E-04	1.2E-04	3.2E-04	< Dl	3.2E-04	< Dl
Pd 1	0-6	DIW	> 62.5	2.0E-03	7.4E-04	1.7E-04	4.1E-04	< Dl	4.3E-04	2.4E-04
Pd 1	12-18	DIW	> 62.5	1.2E-03	4.1E-04	1.2E-04	2.9E-04	< Dl	2.7E-04	< Dl
Pd 1	24-30	DIW	> 62.5	1.8E-03	6.7E-04	1.5E-04	3.5E-04	< Dl	3.6E-04	1.2E-04
Pd 1	0-6	KCl	Bulk	2.8E-03	1.5E-03	7.1E-04	3.3E-04	< Dl	3.7E-04	3.2E-04
Pd 1	12-18	KCl	Bulk	1.7E-03	3.8E-04	1.3E-04	3.2E-04	< Dl	3.4E-04	1.9E-04
Pd 1	24-30	KCl	Bulk	1.6E-03	1.0E-03	1.3E-04	3.1E-04	< Dl	3.1E-04	1.6E-04
Pd 1	0-6	KCl	> 62.5	1.6E-03	6.1E-04	1.3E-04	3.0E-04	< Dl	3.2E-04	2.0E-04
Pd 1	12-18	KCl	> 62.5	1.7E-03	1.7E-03	1.6E-04	3.0E-04	< Dl	3.1E-04	3.2E-04
Pd 1	24-30	KCl	> 62.5	1.3E-03	8.4E-04	1.5E-04	3.2E-04	< Dl	3.2E-04	2.3E-04
Pd 1	0-6	HCl	Bulk	1.6E-03	1.7E-03	1.8E-04	3.2E-04	< Dl	3.0E-04	< Dl
Pd 1	12-18	HCl	Bulk	2.5E-03	1.0E-03	4.3E-04	3.2E-04	< Dl	3.3E-04	3.6E-04
Pd 1	24-30	HCl	Bulk	2.4E-03	1.3E-03	2.2E-04	2.8E-04	< Dl	2.9E-04	2.9E-01
Pd 1	0-6	HCl	> 62.5	1.4E-03	1.5E-03	2.4E-04	3.1E-04	< Dl	2.6E-04	2.8E-01
Pd 1	12-18	HCl	> 62.5	1.2E-03	7.1E-04	1.6E-04	2.8E-04	< Dl	2.3E-04	2.5E-01
Pd 1	24-30	HCl	> 62.5	5.5E-04	8.0E-03	9.1E-04	3.4E-04	< Dl	< Dl	4.1E-01
Pd 1	0-6	HCl	62.5-4	1.6E-03	3.7E-03	4.8E-04	3.0E-04	< Dl	2.7E-04	2.5E-01
Pd 1	12-18	HCl	62.5-4	2.5E-03	3.1E-03	3.8E-04	3.3E-04	< Dl	2.8E-04	3.3E-01
Pd 1	24-30	HCl	62.5-4	2.8E-03	2.6E-03	1.3E-03	3.1E-04	< Dl	2.7E-04	2.1E-01
Pd 1	0-6	HCl	4-2	2.6E-03	2.1E-03	3.7E-04	3.1E-04	< Dl	7.2E-04	3.1E-01
Pd 1	12-18	HCl	4-2	2.1E-03	1.5E-03	2.4E-04	2.6E-04	< Dl	2.3E-04	2.7E-01
Pd 1	24-30	HCl	4-2	2.2E-03	1.2E-03	2.3E-04	3.1E-04	< Dl	2.7E-04	2.9E-01
Pd 1	0-6	HCl	2-0	2.2E-03	5.4E-03	5.6E-04	3.1E-04	< Dl	2.6E-04	2.9E-01
Pd 1	12-18	HCl	2-0	2.3E-03	4.5E-03	5.6E-04	3.2E-04	< Dl	2.8E-04	2.5E-01
Pd 1	24-30	HCl	2-0	2.0E-03	3.6E-03	4.5E-04	2.9E-04	< Dl	2.4E-04	2.4E-01
Pd 1	0-6	CuOAc	Bulk	2.5E-03	2.6E-03	1.0E-03	3.1E-04	< Dl	2.9E-04	2.5E-01
Pd 1	12-18	CuOAc	Bulk	1.5E-03	2.0E-03	2.8E-04	2.8E-04	< Dl	2.8E-04	2.2E-03
Pd 1	24-30	CuOAc	Bulk	1.8E-03	1.3E-03	1.8E-04	2.5E-04	< Dl	3.0E-04	5.1E-04
Pd 1	0-6	CuOAc	> 62.5	-(c)	-	-	-	-	-	-

Appendix 1

Pilot study soil chemistry data

Location	Soil Depth (in)	Extraction	Grain Size (um)	Na(a)	Ca(a)	Mg(a)	Mn(a)	Fe(a)	Al(a)	K(a)
Pd 1	12-18	CuOAc	> 62.5	1.8E-03	2.5E-03	3.2E-04	3.8E-04	< Dl	3.4E-04	5.0E-04
Pd 1	24-30	CuOAc	> 62.5	1.0E-03	2.3E-03	2.8E-04	2.9E-04	< Dl	3.0E-04	1.2E-03
Pd 1	0-6	CuOAc	62.5-4	2.5E-03	2.7E-03	2.9E-04	3.2E-04	< Dl	2.6E-04	2.0E-04
Pd 1	12-18	CuOAc	62.5-4	1.4E-03	3.0E-03	1.1E-03	2.5E-04	< Dl	2.5E-04	3.1E-04
Pd 1	24-30	CuOAc	62.5-4	3.2E-04	1.3E-03	3.0E-04	2.8E-04	< Dl	1.4E-04	1.8E-04
Pd 1	0-6	CuOAc	4-2	2.3E-04	8.1E-04	2.3E-04	2.8E-04	< Dl	1.8E-04	< Dl
Pd 1	12-18	CuOAc	4-2	1.3E-04	4.5E-04	1.9E-04	2.3E-04	< Dl	8.2E-05	< Dl
Pd 1	24-30	CuOAc	4-2	2.2E-04	2.4E-03	3.8E-04	2.8E-04	< Dl	< Dl	< Dl
Pd 1	0-6	CuOAc	2-0	< Dl	2.2E-03	4.1E-04	2.8E-04	< Dl	8.6E-05	< Dl
Pd 1	12-18	CuOAc	2-0	8.1E-04	4.4E-03	2.9E-04	2.4E-04	< Dl	2.3E-04	< Dl
Pd 1	24-30	CuOAc	2-0	2.6E-03	4.9E-03	1.9E-03	2.6E-04	< Dl	2.3E-04	1.8E-04
Pd 1	0-6	CDB	Bulk	-	1.4E-03	1.7E-04	2.4E-04	< Dl	2.9E-04	3.7E-04
Pd 1	12-18	CDB	Bulk	-	4.2E-04	8.5E-05	2.4E-04	< Dl	1.4E-03	1.1E-04
Pd 1	24-30	CDB	Bulk	-	3.9E-04	5.4E-05	2.4E-04	< Dl	9.7E-04	6.1E-05
Pd 1	0-6	CDB	> 62.5	-	8.6E-04	6.9E-05	2.2E-04	< Dl	2.0E-04	< Dl
Pd 1	12-18	CDB	> 62.5	-	6.3E-04	5.9E-05	2.5E-04	< Dl	2.8E-03	< Dl
Pd 1	24-30	CDB	> 62.5	-	1.6E-03	1.4E-04	2.6E-04	< Dl	2.4E-04	< Dl
Pd 1	0-6	CDB	62.5-4	-	1.9E-03	9.0E-04	2.5E-04	< Dl	2.3E-04	3.1E-04
Pd 1	12-18	CDB	62.5-4	-	-	-	-	-	-	-
Pd 1	24-30	CDB	62.5-4	-	1.1E-03	5.9E-04	1.1E-03	< Dl	1.5E-03	3.7E-03
Pd 1	0-6	CDB	4-2	-	1.2E-02	2.8E-03	4.4E-03	< Dl	1.2E-02	3.6E-03
Pd 1	12-18	CDB	4-2	-	6.9E-03	9.1E-04	1.4E-03	< Dl	1.5E-03	4.5E-03
Pd 1	24-30	CDB	4-2	-	7.1E-03	1.2E-03	1.8E-03	< Dl	3.9E-03	6.7E-04
Pd 1	0-6	CDB	2-0	-	7.1E-03	6.3E-04	1.5E-03	< Dl	1.6E-03	1.5E-03
Pd 1	12-18	CDB	2-0	-	3.9E-03	6.5E-04	7.2E-04	< Dl	1.4E-03	9.9E-04
Pd 1	24-30	CDB	2-0	-	1.3E-01	1.5E-02	9.7E-03	< Dl	3.2E-02	4.1E-02
BL 1	12-18	DIW	Bulk	2.3E+00	5.8E-03	1.9E-03	1.7E-03	< Dl	9.5E-03	1.1E-02
BL 1	18-24	DIW	Bulk	2.9E+00	1.3E-02	3.7E-03	3.5E-03	< Dl	1.5E-02	1.2E-02
BL 1	30-36	DIW	Bulk	2.7E-01	2.9E-02	3.3E-03	3.2E-03	< Dl	1.3E-02	7.7E-03
BL 1	84-92	DIW	Bulk	1.5E-01	1.3E-02	1.2E-03	2.2E-03	< Dl	3.3E-03	4.9E-03
BL 1	12-18	DIW	> 62.5	-	-	-	-	-	-	-

Appendix 1

Pilot study soil chemistry data

Location	Soil Depth (in)	Extraction	Grain Size (um)	Na(a)	Ca(a)	Mg(a)	Mn(a)	Fe(a)	Al(a)	K(a)
BL 1	18-24	DIW	> 62.5	-	-	-	-	-	-	-
BL 1	30-36	DIW	> 62.5	1.7E-03	9.4E-03	1.1E-03	2.3E-04	< Dl	3.1E-04	1.5E-03
BL 1	84-92	DIW	> 62.5	3.3E-03	6.3E-03	6.6E-04	2.4E-04	< Dl	3.1E-04	1.6E-03
BL 1	12-18	KCl	Bulk	1.3E-03	2.6E-03	4.0E-04	2.1E-04	< Dl	2.4E-04	1.6E-04
BL 1	18-24	KCl	Bulk	1.5E-03	7.8E-03	5.9E-04	2.4E-04	< Dl	3.0E-04	4.8E-04
BL 1	30-36	KCl	Bulk	1.3E-03	6.5E-03	6.0E-04	2.3E-04	< Dl	2.8E-04	2.3E-04
BL 1	84-92	KCl	Bulk	1.2E-03	2.0E-02	7.2E-04	2.6E-04	< Dl	3.0E-04	3.3E-04
BL 1	12-18	KCl	> 62.5	1.5E-03	3.4E-03	8.5E-04	2.2E-04	< Dl	2.6E-04	4.2E-04
BL 1	18-24	KCl	> 62.5	1.3E-04	1.00E-03	8.9E-05	8.9E-06	< Dl	5.7E-06	2.6E-04
BL 1	30-36	KCl	> 62.5	7.3E-04	5.1E-03	4.6E-04	2.8E-05	< Dl	3.6E-05	9.4E-04
BL 1	84-92	KCl	> 62.5	-	-	-	-	-	-	-
BL 1	12-18	HCl	Bulk	6.0E-04	5.0E-04	0.0E+00	1.5E-05	< Dl	7.0E-05	7.3E-04
BL 1	18-24	HCl	Bulk	3.0E-03	1.2E-02	1.1E-03	5.5E-05	< Dl	3.9E-05	1.8E-03
BL 1	30-36	HCl	Bulk	1.0E-03	3.5E-02	1.8E-03	8.7E-05	< Dl	6.7E-06	9.2E-04
BL 1	84-92	HCl	Bulk	1.6E-03	4.5E-03	1.5E-03	3.2E-06	< Dl	1.8E-05	8.5E-04
BL 1	12-18	HCl	> 62.5	6.0E-03	8.1E-03	8.0E-04	1.1E-04	< Dl	1.4E-05	9.2E-04
BL 1	18-24	HCl	> 62.5	4.2E-02	5.0E-04	0.0E+00	2.1E-05	< Dl	< Dl	6.0E-04
BL 1	30-36	HCl	> 62.5	3.7E-02	3.7E-04	0.0E+00	3.9E-06	< Dl	< Dl	5.5E-04
BL 1	84-92	HCl	> 62.5	8.6E-03	5.8E-03	3.9E-04	1.4E-04	< Dl	< Dl	7.5E-04
BL 1	12-18	HCl	62.5-4	1.0E-02	3.8E-03	3.6E-04	8.6E-05	< Dl	< Dl	6.0E-04
BL 1	18-24	HCl	62.5-4	5.8E-03	1.5E-02	1.1E-03	7.0E-05	< Dl	< Dl	8.5E-04
BL 1	30-36	HCl	62.5-4	3.2E-02	8.0E-04	1.8E-04	7.3E-06	< Dl	< Dl	6.1E-04
BL 1	84-92	HCl	62.5-4	1.4E-01	4.1E-02	3.7E-03	6.6E-04	< Dl	< Dl	2.4E-02
BL 1	12-18	HCl	4 - 2	7.1E-01	3.3E-02	2.3E-03	4.4E-04	< Dl	< Dl	1.9E-02
BL 1	18-24	HCl	4 - 2	1.6E+00	6.0E-03	< Dl	< Dl	< Dl	< Dl	1.7E-02
BL 1	30-36	HCl	4 - 2	2.6E-01	3.2E-02	3.5E-03	2.9E-04	< Dl	< Dl	4.3E-03
BL 1	84-92	HCl	4 - 2	1.5E-01	2.4E-02	3.0E-03	1.4E-04	< Dl	< Dl	5.6E-03
BL 1	12-18	HCl	2 - 0	6.6E-02	3.6E-02	3.0E-03	1.2E-04	< Dl	< Dl	3.6E-03
BL 1	18-24	HCl	2 - 0	3.8E-01	3.1E-03	1.4E-03	1.6E-05	< Dl	< Dl	3.6E-03
BL 1	30-36	HCl	2 - 0	4.5E-01	8.6E-02	8.1E-03	1.7E-03	< Dl	< Dl	3.9E-02
BL 1	84-92	HCl	2 - 0	1.6E+00	4.8E-03	< Dl	< Dl	< Dl	< Dl	1.2E-02

Appendix 1

Pilot study soil chemistry data

Location	Soil Depth (in)	Extraction	Grain Size (um)	Na(a)	Ca(a)	Mg(a)	Mn(a)	Fe(a)	Al(a)	K(a)
BL 1	12-18	CuOAc	Bulk	1.4E+00	7.6E-03	< Dl	1.2E-04	< Dl	5.2E-04	1.4E-02
BL 1	18-24	CuOAc	Bulk	3.3E-01	0.0E+00	5.1E-03	5.5E-04	< Dl	2.5E-05	8.6E-03
BL 1	30-36	CuOAc	Bulk	2.5E-01	3.7E-02	5.0E-03	3.1E-04	< Dl	2.8E-04	9.1E-03
BL 1	84-92	CuOAc	Bulk	1.3E-01	3.9E-02	3.0E-03	1.4E-04	< Dl	0.0E+00	8.8E-03
BL 1	12-18	CuOAc	> 62.5	< Dl	1.1E-03	3.2E-03	9.9E-07	< Dl	4.2E-04	2.4E-03
BL 1	18-24	CuOAc	> 62.5	< Dl	1.3E-02	8.7E-04	7.5E-04	1.4E-02	< Dl	< Dl
BL 1	30-36	CuOAc	> 62.5	< Dl	9.3E-03	6.1E-04	4.2E-04	1.6E-02	5.6E-04	< Dl
BL 1	84-92	CuOAc	> 62.5	< Dl	6.4E-03	5.9E-04	3.4E-04	1.4E-02	1.2E-03	< Dl
BL 1	12-18	CuOAc	62.5-4	< Dl	2.1E-03	2.9E-03	1.0E-03	1.2E-02	1.2E-03	< Dl
BL 1	18-24	CuOAc	62.5-4	< Dl	1.9E-02	1.7E-03	1.5E-03	1.3E-02	1.4E-03	< Dl
BL 1	30-36	CuOAc	62.5-4	< Dl	2.9E-02	2.6E-03	2.4E-04	3.9E-03	< Dl	< Dl
BL 1	84-92	CuOAc	62.5-4	< Dl	1.9E-02	1.1E-02	6.1E-04	7.4E-03	< Dl	< Dl
BL 1	12-18	CuOAc	4 - 2	< Dl	1.2E-02	9.5E-04	8.0E-04	1.1E-02	8.3E-04	< Dl
BL 1	18-24	CuOAc	4 - 2	< Dl	9.1E-03	5.6E-04	5.2E-04	1.1E-02	1.1E-03	< Dl
BL 1	30-36	CuOAc	4 - 2	< Dl	4.6E-03	3.9E-04	2.6E-04	8.3E-03	4.2E-04	< Dl
BL 1	84-92	CuOAc	4 - 2	< Dl	2.5E-02	1.9E-03	1.7E-03	1.2E-02	1.1E-03	< Dl
BL 1	12-18	CuOAc	2 - 0	< Dl	2.1E-02	1.9E-03	1.1E-03	9.4E-03	1.2E-03	< Dl
BL 1	18-24	CuOAc	2 - 0	< Dl	2.5E-02	2.1E-03	2.4E-04	2.8E-03	5.8E-04	< Dl
BL 1	30-36	CuOAc	2 - 0	< Dl	1.6E-01	2.2E-02	2.6E-03	1.9E-02	< Dl	< Dl
BL 1	84-92	CuOAc	2 - 0	< Dl	1.5E-02	1.2E-03	1.1E-03	2.5E-02	2.6E-03	< Dl
BL 1	12-18	CDB	Bulk	-	9.7E-03	8.0E-04	6.1E-04	2.2E-02	3.0E-03	< Dl
BL 1	18-24	CDB	Bulk	-	5.5E-03	5.0E-04	3.1E-04	2.0E-02	1.6E-03	< Dl
BL 1	30-36	CDB	Bulk	-	2.4E-02	1.8E-03	1.6E-03	1.7E-02	1.5E-03	< Dl
BL 1	84-92	CDB	Bulk	-	1.9E-02	1.4E-03	1.2E-03	1.3E-02	7.8E-04	< Dl
BL 1	12-18	CDB	> 62.5	-	1.8E-02	1.8E-03	3.1E-04	4.2E-03	1.6E-04	< Dl
BL 1	18-24	CDB	> 62.5	-	1.6E-02	3.0E-03	6.1E-04	9.4E-03	2.5E-04	< Dl
BL 1	30-36	CDB	> 62.5	-	9.8E-02	9.6E-03	3.1E-03	5.6E-02	1.6E-02	< Dl
BL 1	84-92	CDB	> 62.5	-	8.0E-02	7.5E-03	2.4E-03	7.1E-02	2.8E-02	< Dl
BL 1	12-18	CDB	62.5-4	-	8.0E-02	8.6E-03	1.6E-03	9.6E-02	2.1E-02	< Dl
BL 1	18-24	CDB	62.5-4	-	4.7E-02	4.7E-03	7.7E-04	1.4E-02	8.7E-03	< Dl
BL 1	30-36	CDB	62.5-4	-	5.5E-02	3.8E-03	5.6E-04	1.0E-02	6.1E-03	< Dl

Appendix 1

Pilot study soil chemistry data

Location	Soil Depth (in)	Extraction	Grain Size (um)	Na(a)	Ca(a)	Mg(a)	Mn(a)	Fe(a)	Al(a)	K(a)
BL 1	84-92	CDB	62.5-4	-	1.5E-02	3.5E-03	2.5E-04	1.2E-03	2.8E-03	< Dl
BL 1	12-18	CDB	4 - 2	-	1.5E-02	5.3E-03	1.3E-04	3.3E-03	1.3E-03	< Dl
BL 1	18-24	CDB	4 - 2	-	2.0E-01	2.0E-02	6.3E-03	7.1E-02	1.4E-02	< Dl
BL 1	30-36	CDB	4 - 2	-	1.8E-01	1.5E-02	4.0E-03	7.7E-02	2.4E-02	< Dl
BL 1	84-92	CDB	4 - 2	-	3.1E-01	3.2E-02	3.5E-03	2.0E-01	4.5E-02	< Dl
BL 1	12-18	CDB	2 - 0	-	6.0E-02	9.0E-03	1.5E-03	3.1E-02	7.9E-03	< Dl
BL 1	18-24	CDB	2 - 0	-	6.6E-02	7.7E-03	8.3E-04	1.5E-02	1.1E-02	< Dl
BL 1	30-36	CDB	2 - 0	-	8.5E-02	7.0E-03	4.2E-04	2.3E-03	< Dl	< Dl
BL 1	84-92	CDB	2 - 0	-	1.4E-02	5.0E-03	1.2E-04	3.4E-03	1.5E-03	< Dl

a Pinedale and Bull Lake 1 in units of mg cation * g sample
b sample concentration below detection limit
c sample concentration not measured

Appendix 2

Soil Chemistry for sample sites Pinedale 2 and 3 and Bull Lake 2 and 3

Location	Grain Size	Soil Depth (in)	Extraction	Na(a,b)	Ca(a,b)	Mg(a,b)	Mn(a,b)	Al(a,b)	Fe(a,b)
Pd 2	Bulk	6-12	DIW	4.9E-01	2.9E+00	1.2E-01	< DL(c)	< DL(c)	< DL(c)
Pd 2	Bulk	12-18	DIW	6.3E-01	2.1E+00	3.4E-01	< DL	< DL	< DL
Pd 2	Bulk	24-30	DIW	4.5E-01	1.9E+00	5.6E-01	< DL	< DL	< DL
Pd 2	Bulk	36-42	DIW	8.3E-01	7.2E+00	2.5E+00	< DL	< DL	< DL
Pd 3	Bulk	6-12	DIW	1.6E+00	3.7E+00	8.5E-01	< DL	< DL	< DL
Pd 3	Bulk	12-18	DIW	1.8E+00	2.8E+00	6.8E-01	< DL	< DL	< DL
Pd 3	Bulk	24-30	DIW	2.0E+01	3.6E+00	2.3E+00	< DL	< DL	< DL
Pd 3	Bulk	36-42	DIW	3.4E+01	8.0E+00	4.6E+00	< DL	< DL	< DL
BL 2	Bulk	0-6	DIW	1.2E+00	6.3E+00	1.3E+00	< DL	< DL	< DL
BL 2	Bulk	6-12	DIW	6.6E-01	2.2E+00	4.6E-01	< DL	< DL	< DL
BL 2	Bulk	18-24	DIW	1.9E+00	3.6E+00	1.2E+00	< DL	< DL	< DL
BL 2	Bulk	30-36	DIW	8.2E+00	2.1E+00	6.1E-01	< DL	< DL	< DL
BL 2	Bulk	42-48	DIW	3.0E+01	2.6E+00	3.5E+00	< DL	< DL	< DL
BL 2	Bulk	48-60	DIW	3.4E+01	1.9E+00	3.1E+00	< DL	< DL	< DL
BL 3	Bulk	0-6	DIW	8.4E-01	5.7E+00	1.0E+00	< DL	< DL	< DL
BL 3	Bulk	6-12	DIW	5.5E-01	3.5E+00	5.9E-01	< DL	< DL	< DL
BL 3	Bulk	18-24	DIW	1.8E+00	5.3E+00	5.7E-01	< DL	< DL	< DL
BL 3	Bulk	30-36	DIW	3.1E+00	2.1E+00	7.6E-01	< DL	< DL	< DL
BL 3	Bulk	42-48	DIW	1.8E+00	2.6E+00	1.0E+00	< DL	< DL	< DL
BL 3	Bulk	48-60	DIW	1.6E+00	1.7E+00	9.1E-01	< DL	< DL	< DL
Pd 2	Bulk	6-12	KCL	2.9E-02	2.7E+00	3.5E-01	6.7E-03	< DL	< DL
Pd 2	Bulk	12-18	KCL	3.3E-02	3.2E+00	4.3E-01	5.1E-03	< DL	< DL
Pd 2	Bulk	24-30	KCL	2.3E-01	2.7E+00	3.9E-01	1.1E-02	< DL	< DL
Pd 2	Bulk	36-42	KCL	2.7E-01	3.3E+00	1.3E+00	1.7E-02	< DL	< DL
Pd 3	Bulk	6-12	KCL	2.2E-01	4.5E+00	9.8E-01	6.5E-03	< DL	< DL
Pd 3	Bulk	12-18	KCL	2.4E-01	4.7E+00	1.1E+00	7.0E-03	< DL	< DL
Pd 3	Bulk	24-30	KCL	2.0E+00	2.8E+00	1.6E+00	7.0E-03	< DL	< DL
Pd 3	Bulk	36-42	KCL	4.0E+00	3.3E+00	2.0E+00	1.2E-04	< DL	< DL
BL 2	Bulk	0-6	KCL	1.8E-01	5.6E+00	1.6E+00	9.5E-03	< DL	< DL
BL 2	Bulk	6-12	KCL	1.5E-01	5.8E+00	1.7E+00	7.9E-03	< DL	< DL
BL 2	Bulk	18-24	KCL	2.9E-01	6.2E+00	2.4E+00	7.0E-04	< DL	< DL

Appendix 2

Soil Chemistry for sample sites Pinedale 2 and 3 and Bull Lake 2 and 3

Location	Grain Size	Soil Depth (in)	Extraction	Na(a,b)	Ca(a,b)	Mg(a,b)	Mn(a,b)	Al(a,b)	Fe(a,b)
BL 2	Bulk	30-36	KCL	2.1E+00	5.9E+00	2.6E+00	< DL	< DL	< DL
BL 2	Bulk	42-48	KCL	4.0E+00	5.8E+00	4.4E+00	< DL	< DL	< DL
BL 2	Bulk	48-60	KCL	4.5E+00	5.9E+00	3.5E+00	< DL	< DL	< DL
BL 3	Bulk	0-6	KCL	6.4E-02	5.8E+00	2.2E-01	2.1E-03	< DL	< DL
BL 3	Bulk	6-12	KCL	6.0E-02	6.1E+00	3.0E-01	< DL	< DL	< DL
BL 3	Bulk	18-24	KCL	2.5E-01	5.8E+00	5.4E-01	< DL	< DL	< DL
BL 3	Bulk	30-36	KCL	7.5E-01	5.1E+00	2.2E+00	< DL	< DL	< DL
BL 3	Bulk	42-48	KCL	3.2E-01	6.1E+00	2.6E+00	< DL	< DL	< DL
BL 3	Bulk	48-60	KCL	2.8E-01	5.8E+00	2.6E+00	< DL	< DL	< DL
Pd 2	Clay	6-12	KCL	3.5E-05	1.5E-03	6.7E-05	< DL	< DL	< DL
Pd 2	Clay	12-18	KCL	3.8E-05	1.3E-03	8.5E-05	< DL	< DL	< DL
Pd 2	Clay	24-30	KCL	6.0E-06	2.3E-04	1.7E-05	< DL	< DL	< DL
Pd 2	Clay	36-42	KCL	8.6E-06	2.6E-04	0.0E+00	< DL	< DL	< DL
Pd 3	Clay	6-12	KCL	5.9E-04	1.9E-02	2.7E-03	< DL	< DL	< DL
Pd 3	Clay	12-18	KCL	4.1E-04	1.2E-02	1.7E-03	< DL	< DL	< DL
Pd 3	Clay	24-30	KCL	1.1E-02	4.3E-02	1.6E-02	< DL	< DL	< DL
Pd 3	Clay	36-42	KCL	4.7E-04	1.9E-02	< DL	< DL	< DL	< DL
BL 2	Clay	0-6	KCL	2.1E-04	8.5E-03	< DL	< DL	< DL	< DL
BL 2	Clay	6-12	KCL	1.7E-04	1.2E-02	< DL	< DL	< DL	< DL
BL 2	Clay	18-24	KCL	5.0E-04	2.5E-02	< DL	< DL	< DL	< DL
BL 2	Clay	30-36	KCL	2.3E-03	2.7E-02	< DL	< DL	< DL	< DL
BL 2	Clay	42-48	KCL	6.7E-04	8.6E-02	< DL	< DL	< DL	< DL
BL 2	Clay	48-60	KCL	9.4E-03	5.5E-02	< DL	< DL	< DL	< DL
BL 3	Clay	0-6	KCL	1.7E-04	1.0E-02	< DL	< DL	< DL	< DL
BL 3	Clay	6-12	KCL	2.6E-04	1.7E-02	< DL	< DL	< DL	< DL
BL 3	Clay	18-24	KCL	1.5E-03	5.6E-02	< DL	< DL	< DL	< DL
BL 3	Clay	30-36	KCL	1.6E-03	2.6E-02	< DL	< DL	< DL	< DL
BL 3	Clay	42-48	KCL	6.6E-04	2.6E-02	< DL	< DL	< DL	< DL
BL 3	Clay	48-60	KCL	5.1E-04	6.9E-03	< DL	< DL	< DL	< DL
Pd 2	Bulk	6-12	HCL	1.9E-01	2.4E+00	2.7E-01	1.7E-02	< DL	< DL
Pd 2	Bulk	12-18	HCL	1.5E-01	2.2E+00	2.5E-01	1.3E-02	< DL	< DL

Appendix 2

Soil Chemistry for sample sites Pinedale 2 and 3 and Bull Lake 2 and 3

Location	Grain Size	Soil Depth (in)	Extraction	Na(a,b)	Ca(a,b)	Mg(a,b)	Mn(a,b)	Al(a,b)	Fe(a,b)
Pd 2	Bulk	24-30	HCL	1.7E+00	2.1E+00	2.6E-01	3.2E-02	< DL	< DL
Pd 2	Bulk	36-42	HCL	8.4E-01	2.5E+00	3.3E-01	1.8E-02	< DL	< DL
Pd 3	Bulk	6-12	HCL	1.1E-01	3.1E+00	5.1E-01	1.5E-02	< DL	< DL
Pd 3	Bulk	12-18	HCL	1.7E-01	3.4E+00	6.0E-01	1.3E-02	< DL	< DL
Pd 3	Bulk	24-30	HCL	4.0E+00	2.8E+00	1.0E+00	2.5E-02	< DL	< DL
Pd 3	Bulk	36-42	HCL	3.3E+00	3.7E+00	1.3E+00	9.3E-03	< DL	< DL
BL 2	Bulk	0-6	HCL	6.5E-02	3.1E+00	5.0E-01	2.2E-02	< DL	< DL
BL 2	Bulk	6-12	HCL	4.5E-02	3.4E+00	7.1E-01	2.1E-02	< DL	< DL
BL 2	Bulk	18-24	HCL	1.3E-01	6.1E+00	7.4E-01	< DL	< DL	< DL
BL 2	Bulk	30-36	HCL	1.4E+00	3.8E+00	8.8E-01	< DL	< DL	< DL
BL 2	Bulk	42-48	HCL	2.4E+00	4.3E+00	1.5E+00	< DL	< DL	< DL
BL 2	Bulk	48-60	HCL	2.5E+00	4.8E+00	1.8E+00	< DL	< DL	< DL
BL 3	Bulk	0-6	HCL	5.6E-02	6.3E+00	1.6E-01	< DL	< DL	< DL
BL 3	Bulk	6-12	HCL	7.5E-02	6.0E+00	1.9E-01	< DL	< DL	< DL
BL 3	Bulk	18-24	HCL	2.4E-01	5.9E+00	4.3E-01	< DL	< DL	< DL
BL 3	Bulk	30-36	HCL	7.6E-01	5.2E+00	1.3E+00	< DL	< DL	< DL
BL 3	Bulk	42-48	HCL	2.0E-01	4.7E+00	2.8E-01	< DL	< DL	< DL
BL 3	Bulk	48-60	HCL	2.0E-01	4.8E+00	1.3E+00	< DL	< DL	< DL
Pd 2	Clay	6-12	HCL	7.0E-05	1.9E-03	1.3E-04	1.3E-04	< DL	< DL
Pd 2	Clay	12-18	HCL	3.8E-05	1.4E-03	1.1E-04	8.5E-05	< DL	< DL
Pd 2	Clay	24-30	HCL	2.4E-06	1.5E-04	1.4E-05	1.2E-05	< DL	< DL
Pd 2	Clay	36-42	HCL	1.6E-04	5.0E-03	6.5E-04	1.5E-04	< DL	< DL
Pd 3	Clay	6-12	HCL	4.0E-04	1.2E-02	1.6E-03	3.5E-04	< DL	< DL
Pd 3	Clay	12-18	HCL	5.4E-04	1.4E-02	1.9E-03	3.8E-04	< DL	< DL
Pd 3	Clay	24-30	HCL	1.0E-02	3.2E-02	1.1E-02	3.5E-04	< DL	< DL
Pd 3	Clay	36-42	HCL	4.1E-02	1.7E-02	6.0E-03	3.8E-04	< DL	< DL
BL 2	Clay	0-6	HCL	3.3E-04	2.7E-02	2.0E-03	7.1E-04	< DL	< DL
BL 2	Clay	6-12	HCL	2.3E-04	1.0E-02	8.8E-04	3.6E-04	< DL	< DL
BL 2	Clay	18-24	HCL	3.8E-04	6.4E-02	8.5E-04	5.9E-04	< DL	< DL
BL 2	Clay	30-36	HCL	3.0E-03	7.4E-02	8.5E-04	8.0E-04	< DL	< DL
BL 2	Clay	42-48	HCL	5.6E-03	6.3E-02	1.4E-03	7.5E-04	< DL	< DL

Appendix 2

Soil Chemistry for sample sites Pinedale 2 and 3 and Bull Lake 2 and 3

Location	Grain Size	Soil Depth (in)	Extraction	Na(a,b)	Ca(a,b)	Mg(a,b)	Mn(a,b)	Al(a,b)	Fe(a,b)
BL 2	Clay	48-60	HCL	5.6E-03	3.9E-02	2.2E-02	4.3E-04	< DL	< DL
BL 3	Clay	0-6	HCL	2.1E-04	2.7E-02	1.9E-04	2.4E-04	< DL	< DL
BL 3	Clay	6-12	HCL	1.6E-04	5.3E-02	3.3E-04	3.6E-04	< DL	< DL
BL 3	Clay	18-24	HCL	8.9E-04	1.8E-01	7.3E-04	1.0E-03	< DL	< DL
BL 3	Clay	30-36	HCL	1.8E-03	1.0E-01	1.1E-03	9.4E-04	< DL	< DL
BL 3	Clay	42-48	HCL	9.3E-03	5.5E-01	6.5E-04	1.4E-03	< DL	< DL
BL 3	Clay	48-60	HCL	2.4E-04	4.6E-02	4.9E-04	5.1E-04	3.5E-02	< DL
Pd 2	Bulk	6-12	CuOAc	< DL	2.8E+00	3.3E-01	< DL	2.9E-02	< DL
Pd 2	Bulk	12-18	CuOAc	< DL	2.6E+00	3.3E-01	< DL	1.5E-02	< DL
Pd 2	Bulk	24-30	CuOAc	< DL	2.9E+00	4.1E-01	< DL	4.8E-02	< DL
Pd 2	Bulk	36-42	CuOAc	< DL	2.2E+00	3.1E-01	< DL	3.5E-02	< DL
Pd 3	Bulk	6-12	CuOAc	< DL	4.9E+00	8.6E-01	< DL	2.2E-02	< DL
Pd 3	Bulk	12-18	CuOAc	< DL	3.6E+00	7.0E-01	< DL	1.6E-02	< DL
Pd 3	Bulk	24-30	CuOAc	1.8E+00	2.6E+00	1.3E+00	< DL	7.9E-03	< DL
Pd 3	Bulk	36-42	CuOAc	1.7E+00	2.5E+00	9.6E-01	< DL	7.9E-03	< DL
BL 2	Bulk	0-6	CuOAc	< DL	5.6E+00	1.7E+00	< DL	5.0E-02	< DL
BL 2	Bulk	6-12	CuOAc	< DL	7.1E+00	1.4E+00	< DL	2.9E-02	< DL
BL 2	Bulk	18-24	CuOAc	< DL	8.5E+00	1.7E+00	< DL	< DL	< DL
BL 2	Bulk	30-36	CuOAc	1.9E+00	9.6E+00	2.8E+00	< DL	4.8E-02	< DL
BL 2	Bulk	42-48	CuOAc	1.1E+00	7.5E+00	2.0E+00	< DL	< DL	< DL
BL 2	Bulk	48-60	CuOAc	4.7E+00	5.9E+00	5.0E+00	< DL	< DL	< DL
BL 3	Bulk	0-6	CuOAc	< DL	5.9E+00	6.9E-01	< DL	< DL	< DL
BL 3	Bulk	6-12	CuOAc	< DL	7.6E+00	9.7E-01	< DL	< DL	< DL
BL 3	Bulk	18-24	CuOAc	2.2E-01	7.8E+00	1.7E+00	< DL	< DL	< DL
BL 3	Bulk	30-36	CuOAc	7.0E-01	9.7E+00	3.6E+00	< DL	< DL	< DL
BL 3	Bulk	42-48	CuOAc	9.6E-02	8.1E+00	2.5E+00	< DL	< DL	< DL
BL 3	Bulk	48-60	CuOAc	6.2E-02	6.5E+00	2.5E+00	< DL	< DL	< DL
Pd 2	Clay	6-12	CuOAc	6.4E-07	8.4E-05	2.4E-06	< DL	4.3E-06	< DL
Pd 2	Clay	12-18	CuOAc	3.6E-07	4.5E-05	9.2E-07	< DL	2.6E-06	< DL
Pd 2	Clay	24-30	CuOAc	< DL	5.1E-05	< DL	< DL	3.6E-06	< DL
Pd 2	Clay	36-42	CuOAc	5.4E-06	1.5E-03	8.2E-05	< DL	5.9E-05	< DL

Appendix 2

Soil Chemistry for sample sites Pinedale 2 and 3 and Bull Lake 2 and 3

Location	Grain Size	Soil Depth (in)	Extraction	Na(a,b)	Ca(a,b)	Mg(a,b)	Mn(a,b)	Al(a,b)	Fe(a,b)
Pd 3	Clay	6-12	CuOAc	1.7E-05	5.7E-04	4.9E-05	< DL	1.0E-05	< DL
Pd 3	Clay	12-18	CuOAc	2.0E-05	6.2E-04	8.1E-05	< DL	1.2E-05	< DL
Pd 3	Clay	24-30	CuOAc	5.9E-04	2.0E-03	6.8E-04	< DL	3.3E-05	< DL
Pd 3	Clay	36-42	CuOAc	5.5E-04	1.5E-03	6.3E-04	< DL	1.8E-05	< DL
BL 2	Clay	0-6	CuOAc	7.4E-06	7.2E-04	< DL	< DL	1.1E-05	< DL
BL 2	Clay	6-12	CuOAc	2.1E-06	3.5E-04	1.2E-07	< DL	9.0E-06	< DL
BL 2	Clay	18-24	CuOAc	2.3E-05	5.1E-03	2.4E-06	< DL	2.8E-05	< DL
BL 2	Clay	30-36	CuOAc	4.7E-05	2.6E-03	0.0E+00	< DL	2.0E-05	< DL
BL 2	Clay	42-48	CuOAc	3.0E-04	4.0E-03	1.7E-04	< DL	2.7E-05	< DL
BL 2	Clay	48-60	CuOAc	3.1E-04	1.7E-02	1.1E-03	< DL	1.4E-05	< DL
BL 3	Clay	0-6	CuOAc	9.1E-06	7.7E-04	< DL	< DL	9.0E-06	< DL
BL 3	Clay	6-12	CuOAc	2.4E-05	2.3E-03	1.3E-05	< DL	3.1E-05	< DL
BL 3	Clay	18-24	CuOAc	4.0E-05	8.5E-03	6.5E-05	< DL	5.0E-05	< DL
BL 3	Clay	30-36	CuOAc	8.4E-05	4.2E-03	8.8E-05	< DL	2.9E-05	< DL
BL 3	Clay	42-48	CuOAc	3.3E-04	3.7E-03	1.7E-04	< DL	2.9E-05	< DL
BL 3	Clay	48-60	CuOAc	3.0E-05	2.0E-02	1.1E-05	< DL	1.9E-05	< DL
Pd 2	Bulk	6-12	CDB	-(d)	2.5E+00	3.1E-01	1.8E-01	6.4E-01	5.1E+00
Pd 2	Bulk	12-18	CDB	-	2.5E+00	3.4E-01	1.4E-01	6.8E-01	8.6E+00
Pd 2	Bulk	24-30	CDB	-	2.5E+00	3.6E-01	3.8E-01	6.5E-01	9.8E+00
Pd 2	Bulk	36-42	CDB	-	-	-	-	-	-
Pd 3	Bulk	6-12	CDB	-	7.7E+00	1.2E+00	2.1E-01	1.3E+00	1.1E+01
Pd 3	Bulk	12-18	CDB	-	5.2E+00	1.1E+00	1.2E-01	9.6E-01	8.2E+00
Pd 3	Bulk	24-30	CDB	-	2.9E+00	1.6E+00	9.9E-02	4.7E-01	6.6E+00
Pd 3	Bulk	36-42	CDB	-	5.3E+00	1.8E+00	8.8E-02	2.8E-01	5.2E+00
BL 2	Bulk	0-6	CDB	-	6.1E+00	1.8E+00	5.7E-01	1.1E+00	9.3E+00
BL 2	Bulk	6-12	CDB	-	7.3E+00	2.2E+00	4.5E-01	8.5E-01	6.8E+00
BL 2	Bulk	18-24	CDB	-	8.7E+00	2.4E+00	3.4E-01	3.2E-01	3.6E+00
BL 2	Bulk	30-36	CDB	-	-	-	-	-	-
BL 2	Bulk	42-48	CDB	-	5.7E+00	5.9E+00	2.4E-01	1.7E-01	3.9E+00
BL 2	Bulk	48-60	CDB	-	-	-	-	-	-
BL 3	Bulk	0-6	CDB	-	4.6E+00	6.0E-01	3.4E-01	6.3E-01	5.5E+00

Appendix 2

Soil Chemistry for sample sites Pinedale 2 and 3 and Bull Lake 2 and 3

Location	Grain Size	Soil Depth (in)	Extraction	Na(a,b)	Ca(a,b)	Mg(a,b)	Mn(a,b)	Al(a,b)	Fe(a,b)
BL 3	Bulk	6-12	CDB	-	5.1E+00	6.7E-01	2.2E-02	5.4E-01	2.2E+00
BL 3	Bulk	18-24	CDB	-	7.7E+00	1.3E+00	3.9E-02	2.9E-01	2.3E+00
BL 3	Bulk	30-36	CDB	-	7.7E+00	3.9E+00	1.1E-01	2.0E-01	2.8E+00
BL 3	Bulk	42-48	CDB	-	6.1E+00	2.3E+00	1.1E-01	1.5E-01	2.7E+00
BL 3	Bulk	48-60	CDB	-	4.9E+00	2.2E+00	2.8E-01	1.1E-01	3.0E+00
Pd 2	Clay	6-12	CDB	-	-	-	-	-	-
Pd 2	Clay	12-18	CDB	-	5.4E-05	< DL	< DL	1.6E-06	1.4E-05
Pd 2	Clay	24-30	CDB	-	3.5E-05	< DL	< DL	1.7E-06	1.3E-05
Pd 2	Clay	36-42	CDB	-	3.0E-04	< DL	< DL	1.4E-05	1.3E-04
Pd 3	Clay	6-12	CDB	-	3.1E-04	4.4E-06	< DL	4.4E-06	4.3E-05
Pd 3	Clay	12-18	CDB	-	5.6E-04	2.0E-05	< DL	8.7E-06	7.1E-05
Pd 3	Clay	24-30	CDB	-	1.6E-03	3.2E-04	< DL	6.4E-06	1.8E-04
Pd 3	Clay	36-42	CDB	-	1.6E-03	3.2E-04	< DL	8.6E-06	7.2E-05
BL 2	Clay	0-6	CDB	-	1.1E-03	1.3E-06	< DL	1.2E-05	8.4E-05
BL 2	Clay	6-12	CDB	-	3.8E-04	1.2E-05	< DL	6.0E-06	4.8E-05
BL 2	Clay	18-24	CDB	-	3.7E-03	9.3E-05	< DL	4.8E-06	9.0E-05
BL 2	Clay	30-36	CDB	-	6.4E-03	2.3E-04	< DL	8.3E-06	1.1E-04
BL 2	Clay	42-48	CDB	-	5.1E-03	4.1E-04	< DL	7.3E-06	1.2E-04
BL 2	Clay	48-60	CDB	-	2.0E-03	1.2E-03	< DL	4.4E-06	6.1E-05
BL 3	Clay	0-6	CDB	-	1.2E-03	< DL	< DL	2.5E-06	2.9E-05
BL 3	Clay	6-12	CDB	-	4.1E-03	5.4E-05	< DL	4.3E-06	7.5E-05
BL 3	Clay	18-24	CDB	-	7.4E-03	3.8E-04	< DL	1.0E-05	1.7E-04
BL 3	Clay	30-36	CDB	-	7.3E-03	4.6E-04	< DL	1.3E-05	1.3E-04
BL 3	Clay	42-48	CDB	-	5.7E-03	1.8E-04	< DL	9.0E-06	1.2E-04
BL 3	Clay	48-60	CDB	-	3.3E-03	2.8E-04	< DL	1.3E-05	1.2E-04

a Bulk sample concentrations in mg of cation
b clay sample concentrations in mg cation * g fraction / g sample
c sample concentration below detection limit
d sample concentration not measured

Appendix 3

Results of Discriminant Function Analysis

Test	Location	Element	Extraction	Horizon	Grain Size	% Bull Lake	% Pine-dale	Total n BL	Total n PD
1	BL 2	All	All	All	Bulk	73.33	26.67	192	
	PD 2	All	All	All	Bulk	26.67	95		128
2	BL 2	All	All	1-1	Bulk	80	20	32	
	PD 2	All	All	1-1	Bulk	0	100		32
3	BL 2	All	All	2-2	Bulk	77.5	22.5	32	
	PD 2	All	All	2-2	Bulk	22.5	100		32
4	BL 2	All	All	2-3	Bulk	100	0	32	
	PD 2	All	All	2-3	Bulk	0	100		32
5	BL 2	All	All	2-4	Bulk	100	0	32	
	PD 2	All	All	2-4	Bulk	0	100		32
6	BL 2	All	All	3-5	Bulk	100	0	32	
	PD 2	All	All	3-5	Bulk	0	100		32
7	BL 2	All	All	4-6	Bulk	100	0	32	
	PD 2	All	All	4-6	Bulk	20	80		32
8	BL 3	All	All	All	Bulk	86.67	13.33	192	
	PD 3	All	All	All	Bulk	18.13	81.88		128
9	BL 3	All	All	1-1	Bulk	100	0	32	
	PD 3	All	All	1-1	Bulk	0	100		32
10	BL 3	All	All	2-2	Bulk	80	20	32	
	PD 3	All	All	2-2	Bulk	0	100		32
11	BL 3	All	All	2-3	Bulk	100	0	32	
	PD 3	All	All	2-3	Bulk	0	100		32
12	BL 3	All	All	2-4	Bulk	80	20	32	
	PD 3	All	All	2-4	Bulk	0	100		32
13	BL 3	All	All	3-5	Bulk	80	20	32	
	PD 3	All	All	3-5	Bulk	0	100		32
14	BL 3	All	All	4-6	Bulk	80	20	32	
	PD 3	All	All	4-6	Bulk	2.5	97.5		32
15	BL 2	All	All	All	Clay	72.92	27.08	192	
	PD 2	All	All	All	Clay	46.25	53.75		128
16	BL 2	All	All	1-1	Clay	75	25	32	
	PD 2	All	All	1-1	Clay	37.5	62.5		32
17	BL 2	All	All	2-2	Clay	75	25	32	
	PD 2	All	All	2-2	Clay	3.13	96.88		32
18	BL 2	All	All	2-3	Clay	75	25	32	
	PD 2	All	All	2-3	Clay	0	100		32
19	BL 2	All	All	2-4	Clay	75	25	32	
	PD 2	All	All	2-4	Clay	0	100		32
20	BL 2	All	All	3-5	Clay	75	25	32	
	PD 2	All	All	3-5	Clay	0	100		32
21	BL 2	All	All	4-6	Clay	93.6	9.38	32	
	PD 2	All	All	4-6	Clay	12.5	87.5		32
22	BL 3	All	All	All	Clay	66.67	33.33	192	
	PD 3	All	All	All	Clay	31.25	68.75		128

Appendix 3

Results of Discriminant Function Analysis

Test	Location	Element	Extraction	Horizon	Grain Size	% Bull Lake	% Pine-dale	Total n BL	Total n PD
23	BL 3	All	All	1-1	Clay	71.88	28.13	32	
	PD 3	All	All	1-1	Clay	21.88	78.13		32
24	BL 3	All	All	2-2	Clay	71.88	28.13	32	
	PD 3	All	All	2-2	Clay	12.5	87.5		32
25	BL 3	All	All	2-3	Clay	87.5	12.5	32	
	PD 3	All	All	2-3	Clay	12.5	87.5		32
26	BL 3	All	All	2-4	Clay	75	25	32	
	PD 3	All	All	2-4	Clay	12.5	87.5		32
27	BL 3	All	All	3-5	Clay	81.25	18.75	32	
	PD 3	All	All	3-5	Clay	25	75		32
28	BL 3	All	All	4-6	Clay	87.5	12.5	32	
	PD 3	All	All	4-6	Clay	12.5	87.5		32
29	BL 2	Fe	CDB	All	Bulk	66.67	33.33	48	
	PD 2	Fe	CDB	All	Bulk	25	75		32
30	BL 2	Fe	CDB	1-1	Bulk	100	0	8	
	PD 2	Fe	CDB	1-1	Bulk	0	100		8
31	BL 2	Fe	CDB	2-2	Bulk	100	0	8	
	PD 2	Fe	CDB	2-2	Bulk	0	100		8
32	BL 2	Fe	CDB	2-3	Bulk	100	0	8	
	PD 2	Fe	CDB	2-3	Bulk	0	100		8
33	BL 2	Fe	CDB	2-4	Bulk	100	0	8	
	PD 2	Fe	CDB	2-4	Bulk	0	100		8
34	BL 2	Fe	CDB	3-5	Bulk	100	0	8	
	PD 2	Fe	CDB	3-5	Bulk	0	100		8
35	BL 2	Fe	CDB	4-6	Bulk	100	0	8	
	PD 2	Fe	CDB	4-6	Bulk	0	100		8
36	BL 3	Fe	CDB	All	Bulk	87.5	12.5	48	
	PD 3	Fe	CDB	All	Bulk	25	75		32
37	BL 3	Fe	CDB	1-1	Bulk	100	0	8	
	PD 3	Fe	CDB	1-1	Bulk	0	100		8
38	BL 3	Fe	CDB	2-2	Bulk	100	0	8	
	PD 3	Fe	CDB	2-2	Bulk	0	100		8
39	BL 3	Fe	CDB	2-3	Bulk	100	0	8	
	PD 3	Fe	CDB	2-3	Bulk	0	100		8
40	BL 3	Fe	CDB	2-4	Bulk	100	0	8	
	PD 3	Fe	CDB	2-4	Bulk	0	100		8
41	BL 3	Fe	CDB	3-5	Bulk	100	0	8	
	PD 3	Fe	CDB	3-5	Bulk	0	100		8
42	BL 3	Fe	CDB	4-6	Bulk	100	0	8	
	PD 3	Fe	CDB	4-6	Bulk	0	100		8
43	BL 2	Fe	CDB	All	Clay	70.83	29.17	48	
	PD 2	Fe	CDB	All	Clay	25	75		32
44	BL 2	Fe	CDB	1-1	Clay	100	0	8	
	PD 2	Fe	CDB	1-1	Clay	0	100		8

Appendix 3

Results of Discriminant Function Analysis

Test	Location	Element	Extraction	Horizon	Grain Size	% Bull Lake	% Pine-dale	Total n BL	Total n PD
45	BL 2	Fe	CDB	2-2	Clay	50	50	8	
	PD 2	Fe	CDB	2-2	Clay	25	75		8
46	BL 2	Fe	CDB	2-3	Clay	100	0	8	
	PD 2	Fe	CDB	2-3	Clay	0	100		8
47	BL 2	Fe	CDB	2-4	Clay	100	0	8	
	PD 2	Fe	CDB	2-4	Clay	0	100		8
48	BL 2	Fe	CDB	3-5	Clay	100	0	8	
	PD 2	Fe	CDB	3-5	Clay	0	100		8
49	BL 2	Fe	CDB	4-6	Clay	100	0	8	
	PD 2	Fe	CDB	4-6	Clay	0	100		8
50	BL 3	Fe	CDB	All	Clay	64.58	35.42	48	
	PD 3	Fe	CDB	All	Clay	25	75		32
51	BL 3	Fe	CDB	1-1	Clay	65.5	37.5	8	
	PD 3	Fe	CDB	1-1	Clay	65.5	37.5		8
52	BL 3	Fe	CDB	2-2	Clay	100	0	8	
	PD 3	Fe	CDB	2-2	Clay	0	100		8
53	BL 3	Fe	CDB	2-3	Clay	100	0	8	
	PD 3	Fe	CDB	2-3	Clay	0	100		8
54	BL 3	Fe	CDB	2-4	Clay	100	0	8	
	PD 3	Fe	CDB	2-4	Clay	0	100		8
55	BL 3	Fe	CDB	3-5	Clay	87.5	12.5	8	
	PD 3	Fe	CDB	3-5	Clay	0	100		8
56	BL 3	Fe	CDB	4-6	Clay	75	25	8	
	PD 3	Fe	CDB	4-6	Clay	0	100		8
57	BL 2	Al	CDB	All	Bulk	64.58	35.42	48	
	PD 2	Al	CDB	All	Bulk	25	75		32
58	BL 2	Al	CDB	1-1	Bulk	100	0	8	
	PD 2	Al	CDB	1-1	Bulk	0	100		8
59	BL 2	Al	CDB	2-2	Bulk	100	0	8	
	PD 2	Al	CDB	2-2	Bulk	0	100		8
60	BL 2	Al	CDB	2-3	Bulk	100	0	8	
	PD 2	Al	CDB	2-3	Bulk	0	100		8
61	BL 2	Al	CDB	2-4	Bulk	100	0	8	
	PD 2	Al	CDB	2-4	Bulk	0	100		8
62	BL 2	Al	CDB	3-5	Bulk	100	0	8	
	PD 2	Al	CDB	3-5	Bulk	0	100		8
63	BL 2	Al	CDB	4-6	Bulk	100	0	8	
	PD 2	Al	CDB	4-6	Bulk	0	100		8
64	BL 3	Al	CDB	All	Bulk	81.25	18.75	48	
	PD 3	Al	CDB	All	Bulk	50	50		32
65	BL 3	Al	CDB	1-1	Bulk	100	0	8	
	PD 3	Al	CDB	1-1	Bulk	0	100		8
66	BL 3	Al	CDB	2-2	Bulk	100	0	8	
	PD 3	Al	CDB	2-2	Bulk	0	100		8

Appendix 3

Results of Discriminant Function Analysis

Test	Location	Element	Extraction	Horizon	Grain Size	% Bull Lake	% Pine-dale	Total n BL	Total n PD
67	BL 3	Al	CDB	2-3	Bulk	100	0	8	
	PD 3	Al	CDB	2-3	Bulk	0	100		8
68	BL 3	Al	CDB	2-4	Bulk	100	0	8	
	PD 3	Al	CDB	2-4	Bulk	0	100		8
69	BL 3	Al	CDB	3-5	Bulk	100	0	8	
	PD 3	Al	CDB	3-5	Bulk	0	100		8
70	BL 3	Al	CDB	4-6	Bulk	87.5	12.5	8	
	PD 3	Al	CDB	4-6	Bulk	12.5	87.5		8
71	BL 2	Al	CDB	All	Clay	66.67	33.33	48	
	PD 2	Al	CDB	All	Clay	56.25	43.75		32
72	BL 2	Al	CDB	1-1	Clay	62.5	37.5	8	
	PD 2	Al	CDB	1-1	Clay	0	100		8
73	BL 2	Al	CDB	2-2	Clay	87.5	12.5	8	
	PD 2	Al	CDB	2-2	Clay	37.5	62.5		8
74	BL 2	Al	CDB	2-3	Clay	75	25	8	
	PD 2	Al	CDB	2-3	Clay	37.5	62.5		8
75	BL 2	Al	CDB	2-4	Clay	87.5	12.5	8	
	PD 2	Al	CDB	2-4	Clay	37.5	62.5		8
76	BL 2	Al	CDB	3-5	Clay	62.5	37.5	8	
	PD 2	Al	CDB	3-5	Clay	37.5	62.5		8
77	BL 2	Al	CDB	4-6	Clay	75	25	8	
	PD 2	Al	CDB	4-6	Clay	37.5	62.5		8
78	BL 3	Al	CDB	All	Clay	35.42	64.58	48	
	PD 3	Al	CDB	All	Clay	40.63	59.38		32
79	BL 3	Al	CDB	1-1	Clay	62.5	37.5	8	
	PD 3	Al	CDB	1-1	Clay	50	50		8
80	BL 3	Al	CDB	2-2	Clay	37.5	62.5	8	
	PD 3	Al	CDB	2-2	Clay	50	50		8
81	BL 3	Al	CDB	2-3	Clay	37.5	62.5	8	
	PD 3	Al	CDB	2-3	Clay	50	50		8
82	BL 3	Al	CDB	2-4	Clay	37.5	62.5	8	
	PD 3	Al	CDB	2-4	Clay	37.5	62.5		8
83	BL 3	Al	CDB	3-5	Clay	62.5	37.5	8	
	PD 3	Al	CDB	3-5	Clay	25	75		8
84	BL 3	Al	CDB	4-6	Clay	50	50	8	
	PD 3	Al	CDB	4-6	Clay	37.5	62.5		8
85	BL 2	Mg	DIW	All	Bulk	43.75	56.25	48	
	PD 2	Mg	DIW	All	Bulk	25	75		32
86	BL 2	Mg	DIW	1-1	Bulk	100	0	8	
	PD 2	Mg	DIW	1-1	Bulk	0	100		8
87	BL 2	Mg	DIW	2-2	Bulk	100	0	8	
	PD 2	Mg	DIW	2-2	Bulk	0	100		8
88	BL 2	Mg	DIW	2-3	Bulk	100	0	8	
	PD 2	Mg	DIW	2-3	Bulk	0	100		8

Appendix 3

Results of Discriminant Function Analysis

Test	Location	Element	Extraction	Horizon	Grain Size	% Bull Lake	% Pine-dale	Total n BL	Total n PD
89	BL 2	Mg	DIW	2-4	Bulk	100	0	8	
	PD 2	Mg	DIW	2-4	Bulk	0	100		8
90	BL 2	Mg	DIW	3-5	Bulk	100	0	8	
	PD 2	Mg	DIW	3-5	Bulk	0	100		8
91	BL 2	Mg	DIW	4-6	Bulk	100	0	8	
	PD 2	Mg	DIW	4-6	Bulk	0	100		8
92	BL 3	Mg	DIW	All	Bulk	100	0	48	
	PD 3	Mg	DIW	All	Bulk	0	100		32
93	BL 3	Mg	DIW	1-1	Bulk	100	0	8	
	PD 3	Mg	DIW	1-1	Bulk	0	100		8
94	BL 3	Mg	DIW	2-2	Bulk	100	0	8	
	PD 3	Mg	DIW	2-2	Bulk	0	100		8
95	BL 3	Mg	DIW	2-3	Bulk	100	0	8	
	PD 3	Mg	DIW	2-3	Bulk	0	100		8
96	BL 3	Mg	DIW	2-4	Bulk	100	0	8	
	PD 3	Mg	DIW	2-4	Bulk	0	100		8
97	BL 3	Mg	DIW	3-5	Bulk	100	0	8	
	PD 3	Mg	DIW	3-5	Bulk	0	100		8
98	BL 3	Mg	DIW	4-6	Bulk	100	0	8	
	PD 3	Mg	DIW	4-6	Bulk	0	100		8
99	BL 2	Mg	KCl	All	Bulk	81.25	18.75	48	
	PD 2	Mg	KCl	All	Bulk	0	100		32
100	BL 2	Mg	KCl	1-1	Bulk	100	0	8	
	PD 2	Mg	KCl	1-1	Bulk	0	100		8
101	BL 2	Mg	KCl	2-2	Bulk	100	0	8	
	PD 2	Mg	KCl	2-2	Bulk	0	100		8
102	BL 2	Mg	KCl	2-3	Bulk	100	0	8	
	PD 2	Mg	KCl	2-3	Bulk	0	100		8
103	BL 2	Mg	KCl	2-4	Bulk	100	0	8	
	PD 2	Mg	KCl	2-4	Bulk	0	100		8
104	BL 2	Mg	KCl	3-5	Bulk	100	0	8	
	PD 2	Mg	KCl	3-5	Bulk	0	100		8
105	BL 2	Mg	KCl	4-6	Bulk	100	0	8	
	PD 2	Mg	KCl	4-6	Bulk	0	100		8
106	BL 3	Mg	KCl	All	Bulk	50	50	48	
	PD 3	Mg	KCl	All	Bulk	50	50		32
107	BL 3	Mg	KCl	1-1	Bulk	100	0	8	
	PD 3	Mg	KCl	1-1	Bulk	0	100		8
108	BL 3	Mg	KCl	2-2	Bulk	100	0	8	
	PD 3	Mg	KCl	2-2	Bulk	0	100		8
109	BL 3	Mg	KCl	2-3	Bulk	100	0	8	
	PD 3	Mg	KCl	2-3	Bulk	0	100		8
110	BL 3	Mg	KCl	2-4	Bulk	100	0	8	
	PD 3	Mg	KCl	2-4	Bulk	0	100		8

Appendix 3

Results of Discriminant Function Analysis

Test	Location	Element	Extraction	Horizon	Grain Size	% Bull Lake	% Pinedale	Total n BL	Total n PD
111	BL 3	Mg	KCl	3-5	Bulk	100	0	8	
	PD 3	Mg	KCl	3-5	Bulk	0	100		8
112	BL 3	Mg	KCl	4-6	Bulk	100	0	8	
	PD 3	Mg	KCl	4-6	Bulk	0	100		8
113	BL 2	Mg	KCl	All	Clay	100	0	48	
	PD 2	Mg	KCl	All	Clay	46.88	53.13		32
114	BL 2	Mg	KCl	1-1	Clay	100	0	8	
	PD 2	Mg	KCl	1-1	Clay	50	50		8
115	BL 2	Mg	KCl	2-2	Clay	100	0	8	
	PD 2	Mg	KCl	2-2	Clay	25	75		8
116	BL 2	Mg	KCl	2-3	Clay	100	0	8	
	PD 2	Mg	KCl	2-3	Clay	25	75		8
117	BL 2	Mg	KCl	2-4	Clay	100	0	8	
	PD 2	Mg	KCl	2-4	Clay	25	75		8
118	BL 2	Mg	KCl	3-5	Clay	100	0	8	
	PD 2	Mg	KCl	3-5	Clay	37.5	62.5		8
119	BL 2	Mg	KCl	4-6	Clay	0	0	8	
	PD 2	Mg	KCl	4-6	Clay	0	0		8
120	BL 3	Mg	KCl	All	Clay	100	0	48	
	PD 3	Mg	KCl	All	Clay	43.75	56.25		32
121	BL 3	Mg	KCl	1-1	Clay	100	0	8	
	PD 3	Mg	KCl	1-1	Clay	37.5	62.5		8
122	BL 3	Mg	KCl	2-2	Clay	100	0	8	
	PD 3	Mg	KCl	2-2	Clay	37.5	62.5		8
123	BL 3	Mg	KCl	2-3	Clay	100	0	8	
	PD 3	Mg	KCl	2-3	Clay	37.5	62.5		8
124	BL 3	Mg	KCl	2-4	Clay	100	0	8	
	PD 3	Mg	KCl	2-4	Clay	37.5	62.5		8
125	BL 3	Mg	KCl	3-5	Clay	100	0	8	
	PD 3	Mg	KCl	3-5	Clay	25	75		8
126	BL 3	Mg	KCl	4-6	Clay	0	0	8	
	PD 3	Mg	KCl	4-6	Clay	0	0		8
127	BL 2	Mg	HCl	All	Bulk	83.33	16.67	48	
	PD 2	Mg	HCl	All	Bulk	0	100		32
128	BL 2	Mg	HCl	1-1	Bulk	100	0	8	
	PD 2	Mg	HCl	1-1	Bulk	0	100		8
129	BL 2	Mg	HCl	2-2	Bulk	100	0	8	
	PD 2	Mg	HCl	2-2	Bulk	0	100		8
130	BL 2	Mg	HCl	2-3	Bulk	100	0	8	
	PD 2	Mg	HCl	2-3	Bulk	0	100		8
131	BL 2	Mg	HCl	2-4	Bulk	100	0	8	
	PD 2	Mg	HCl	2-4	Bulk	0	100		8
132	BL 2	Mg	HCl	3-5	Bulk	100	0	8	
	PD 2	Mg	HCl	3-5	Bulk	0	100		8

Appendix 3

Results of Discriminant Function Analysis

Test	Location	Element	Extraction	Horizon	Grain Size	% Bull Lake	% Pine-dale	Total n BL	Total n PD
133	BL 2	Mg	HCl	4-6	Bulk	100	0	8	
	PD 2	Mg	HCl	4-6	Bulk	0	100		8
134	BL 3	Mg	HCl	All	Bulk	66.67	33.33	48	
	PD 3	Mg	HCl	All	Bulk	50	50		32
135	BL 3	Mg	HCl	1-1	Bulk	100	0	8	
	PD 3	Mg	HCl	1-1	Bulk	0	100		8
136	BL 3	Mg	HCl	2-2	Bulk	100	0	8	
	PD 3	Mg	HCl	2-2	Bulk	0	100		8
137	BL 3	Mg	HCl	2-3	Bulk	100	0	8	
	PD 3	Mg	HCl	2-3	Bulk	0	100		8
138	BL 3	Mg	HCl	2-4	Bulk	100	0	8	
	PD 3	Mg	HCl	2-4	Bulk	0	100		8
139	BL 3	Mg	HCl	3-5	Bulk	100	0	8	
	PD 3	Mg	HCl	3-5	Bulk	0	100		8
140	BL 3	Mg	HCl	4-6	Bulk	100	0	8	
	PD 3	Mg	HCl	4-6	Bulk	87.5	12.5		8
141	BL 2	Mg	HCl	All	Clay	16.67	83.33	48	
	PD 2	Mg	HCl	All	Clay	0	100		32
142	BL 2	Mg	HCl	1-1	Clay	100	0	8	
	PD 2	Mg	HCl	1-1	Clay	0	100		8
143	BL 2	Mg	HCl	2-2	Clay	100	0	8	
	PD 2	Mg	HCl	2-2	Clay	0	100		8
144	BL 2	Mg	HCl	2-3	Clay	100	0	8	
	PD 2	Mg	HCl	2-3	Clay	0	100		8
145	BL 2	Mg	HCl	2-4	Clay	100	0	8	
	PD 2	Mg	HCl	2-4	Clay	0	100		8
146	BL 2	Mg	HCl	3-5	Clay	100	0	8	
	PD 2	Mg	HCl	3-5	Clay	0	100		8
147	BL 2	Mg	HCl	4-6	Clay	100	0	8	
	PD 2	Mg	HCl	4-6	Clay	0	100		8
148	BL 3	Mg	HCl	All	Clay	100	0	48	
	PD 3	Mg	HCl	All	Clay	50	50		8
149	BL 3	Mg	HCl	1-1	Clay	100	0	8	
	PD 3	Mg	HCl	1-1	Clay	0	100		8
150	BL 3	Mg	HCl	2-2	Clay	100	0	8	
	PD 3	Mg	HCl	2-2	Clay	0	100		8
151	BL 3	Mg	HCl	2-3	Clay	100	0	8	
	PD 3	Mg	HCl	2-3	Clay	0	100		8
152	BL 3	Mg	HCl	2-4	Clay	100	0	8	
	PD 3	Mg	HCl	2-4	Clay	0	100		8
153	BL 3	Mg	HCl	3-5	Clay	100	0	8	
	PD 3	Mg	HCl	3-5	Clay	0	100		8
154	BL 3	Mg	HCl	4-6	Clay	100	0	8	
	PD 3	Mg	HCl	4-6	Clay	0	100		8

Appendix 3

Results of Discriminant Function Analysis

Test	Location	Element	Extraction	Horizon	Grain Size	% Bull Lake	% Pine-dale	Total n BL	Total n PD
155	BL 2	Mg	CuOAc	All	Bulk	100	0	48	
	PD 2	Mg	CuOAc	All	Bulk	0	100		32
156	BL 2	Mg	CuOAc	1-1	Bulk	100	0	8	
	PD 2	Mg	CuOAc	1-1	Bulk	0	100		8
157	BL 2	Mg	CuOAc	2-2	Bulk	100	0	8	
	PD 2	Mg	CuOAc	2-2	Bulk	0	100		8
158	BL 2	Mg	CuOAc	2-3	Bulk	100	0	8	
	PD 2	Mg	CuOAc	2-3	Bulk	0	100		8
159	BL 2	Mg	CuOAc	2-4	Bulk	100	0	8	
	PD 2	Mg	CuOAc	2-4	Bulk	0	100		8
160	BL 2	Mg	CuOAc	3-5	Bulk	100	0	8	
	PD 2	Mg	CuOAc	3-5	Bulk	0	100		8
161	BL 2	Mg	CuOAc	4-6	Bulk	100	0	8	
	PD 2	Mg	CuOAc	4-6	Bulk	0	100		8
162	BL 3	Mg	CuOAc	All	Bulk	66.67	33.33	48	
	PD 3	Mg	CuOAc	All	Bulk	0	100		32
163	BL 3	Mg	CuOAc	1-1	Bulk	100	0	8	
	PD 3	Mg	CuOAc	1-1	Bulk	0	100		8
164	BL 3	Mg	CuOAc	2-2	Bulk	100	0	8	
	PD 3	Mg	CuOAc	2-2	Bulk	0	100		8
165	BL 3	Mg	CuOAc	2-3	Bulk	100	0	8	
	PD 3	Mg	CuOAc	2-3	Bulk	0	100		8
166	BL 3	Mg	CuOAc	2-4	Bulk	100	0	8	
	PD 3	Mg	CuOAc	2-4	Bulk	0	100		8
167	BL 3	Mg	CuOAc	3-5	Bulk	100	0	8	
	PD 3	Mg	CuOAc	3-5	Bulk	0	100		8
168	BL 3	Mg	CuOAc	4-6	Bulk	100	0	8	
	PD 3	Mg	CuOAc	4-6	Bulk	0	100		8
169	BL 2	Mg	CuOAc	All	Clay	33.33	66.67	48	
	PD 2	Mg	CuOAc	All	Clay	6.25	93.75		32
170	BL 2	Mg	CuOAc	1-1	Clay	100	0	8	
	PD 2	Mg	CuOAc	1-1	Clay	37.5	62.5		8
171	BL 2	Mg	CuOAc	2-2	Clay	37.5	62.5	8	
	PD 2	Mg	CuOAc	2-2	Clay	12.5	87.5		8
172	BL 2	Mg	CuOAc	2-3	Clay	50	50	8	
	PD 2	Mg	CuOAc	2-3	Clay	12.5	87.5		8
173	BL 2	Mg	CuOAc	2-4	Clay	100	0	8	
	PD 2	Mg	CuOAc	2-4	Clay	62.5	37.5		8
174	BL 2	Mg	CuOAc	3-5	Clay	100	0	8	
	PD 2	Mg	CuOAc	3-5	Clay	0	100		8
175	BL 2	Mg	CuOAc	4-6	Clay	100	0	8	
	PD 2	Mg	CuOAc	4-6	Clay	0	100		8
176	BL 3	Mg	CuOAc	All	Clay	91.67	8.33	48	
	PD 3	Mg	CuOAc	All	Clay	46.88	53.13		32

Appendix 3

Results of Discriminant Function Analysis

Test	Location	Element	Extraction	Horizon	Grain Size	% Bull Lake	% Pine-dale	Total n BL	Total n PD
177	BL 3	Mg	CuOAc	1-1	Clay	100	0	8	
	PD 3	Mg	CuOAc	1-1	Clay	0	100		8
178	BL 3	Mg	CuOAc	2-2	Clay	62.5	37.5	8	
	PD 3	Mg	CuOAc	2-2	Clay	62.5	37.5		8
179	BL 3	Mg	CuOAc	2-3	Clay	62.5	37.5	8	
	PD 3	Mg	CuOAc	2-3	Clay	12.5	87.5		8
180	BL 3	Mg	CuOAc	2-4	Clay	62.5	37.5	8	
	PD 3	Mg	CuOAc	2-4	Clay	12.5	87.5		8
181	BL 3	Mg	CuOAc	3-5	Clay	87.5	12.5	8	
	PD 3	Mg	CuOAc	3-5	Clay	0	100		8
182	BL 3	Mg	CuOAc	4-6	Clay	100	0	8	
	PD 3	Mg	CuOAc	4-6	Clay	0	100		8
183	BL 2	Mg	CDB	All	Bulk	66.67	33.33	48	
	PD 2	Mg	CDB	All	Bulk	0	100		32
184	BL 2	Mg	CDB	1-1	Bulk	100	0	8	
	PD 2	Mg	CDB	1-1	Bulk	0	100		8
185	BL 2	Mg	CDB	2-2	Bulk	100	0	8	
	PD 2	Mg	CDB	2-2	Bulk	0	100		8
186	BL 2	Mg	CDB	2-3	Bulk	100	0	8	
	PD 2	Mg	CDB	2-3	Bulk	0	100		8
187	BL 2	Mg	CDB	2-4	Bulk	100	0	8	
	PD 2	Mg	CDB	2-4	Bulk	0	100		8
189	BL 2	Mg	CDB	3-5	Bulk	100	0	8	
	PD 2	Mg	CDB	3-5	Bulk	0	100		8
190	BL 2	Mg	CDB	4-6	Bulk	0	0	8	
	PD 2	Mg	CDB	4-6	Bulk	0	0		8
191	BL 3	Mg	CDB	All	Bulk	50	50	48	
	PD 3	Mg	CDB	All	Bulk	25	75		32
192	BL 3	Mg	CDB	1-1	Bulk	100	0	8	
	PD 3	Mg	CDB	1-1	Bulk	0	100		8
193	BL 3	Mg	CDB	2-2	Bulk	100	0	8	
	PD 3	Mg	CDB	2-2	Bulk	0	100		8
194	BL 3	Mg	CDB	2-3	Bulk	100	0	8	
	PD 3	Mg	CDB	2-3	Bulk	0	100		8
195	BL 3	Mg	CDB	2-4	Bulk	100	0	8	
	PD 3	Mg	CDB	2-4	Bulk	0	100		8
196	BL 3	Mg	CDB	3-5	Bulk	100	0	8	
	PD 3	Mg	CDB	3-5	Bulk	0	100		8
197	BL 3	Mg	CDB	4-6	Bulk	100	0	8	
	PD 3	Mg	CDB	4-6	Bulk	0	100		8
198	BL 2	Mg	CDB	All	Clay	50	50	48	
	PD 2	Mg	CDB	All	Clay	0	100		32
199	BL 2	Mg	CDB	1-1	Clay	75	25	8	
	PD 2	Mg	CDB	1-1	Clay	0	100		8

Appendix 3

Results of Discriminant Function Analysis

Test	Location	Element	Extraction	Horizon	Grain Size	% Bull Lake	% Pine-dale	Total n BL	Total n PD
200	BL 2	Mg	CDB	2-2	Clay	100	0	8	
	PD 2	Mg	CDB	2-2	Clay	0	100		8
201	BL 2	Mg	CDB	2-3	Clay	100	0	8	
	PD 2	Mg	CDB	2-3	Clay	0	100		8
202	BL 2	Mg	CDB	2-4	Clay	100	0	8	
	PD 2	Mg	CDB	2-4	Clay	0	100		8
203	BL 2	Mg	CDB	3-5	Clay	100	0	8	
	PD 2	Mg	CDB	3-5	Clay	0	100		8
204	BL 2	Mg	CDB	4-6	Clay	100	0	8	
	PD 2	Mg	CDB	4-6	Clay	0	100		8
205	BL 3	Mg	CDB	All	Clay	50	50	48	
	PD 3	Mg	CDB	All	Clay	50	50		32
206	BL 3	Mg	CDB	1-1	Clay	100	0	8	
	PD 3	Mg	CDB	1-1	Clay	0	100		8
207	BL 3	Mg	CDB	2-2	Clay	100	0	8	
	PD 3	Mg	CDB	2-2	Clay	0	100		8
208	BL 3	Mg	CDB	2-3	Clay	100	0	8	
	PD 3	Mg	CDB	2-3	Clay	0	100		8
209	BL 3	Mg	CDB	2-4	Clay	100	0	8	
	PD 3	Mg	CDB	2-4	Clay	0	100		8
210	BL 3	Mg	CDB	3-5	Clay	100	0	8	
	PD 3	Mg	CDB	3-5	Clay	0	100		8
211	BL 3	Mg	CDB	4-6	Clay	100	0	8	
	PD 3	Mg	CDB	4-6	Clay	0	100		8
212	BL 2	Mn	HCl	All	Bulk	66.67	33.33	48	
	PD 2	Mn	HCl	All	Bulk	25	75		32
213	BL 2	Mn	HCl	1-1	Bulk	100	0	8	
	PD 2	Mn	HCl	1-1	Bulk	0	100		8
214	BL 2	Mn	HCl	2-2	Bulk	100	0	8	
	PD 2	Mn	HCl	2-2	Bulk	0	100		8
215	BL 2	Mn	HCl	2-3	Bulk	100	0	8	
	PD 2	Mn	HCl	2-3	Bulk	0	100		8
216	BL 2	Mn	HCl	2-4	Bulk	100	0	8	
	PD 2	Mn	HCl	2-4	Bulk	0	100		8
217	BL 2	Mn	HCl	3-5	Bulk	100	0	8	
	PD 2	Mn	HCl	3-5	Bulk	0	100		8
218	BL 2	Mn	HCl	4-6	Bulk	100	0	8	
	PD 2	Mn	HCl	4-6	Bulk	0	100		8
219	BL 3	Mn	HCl	All	Bulk	100	0	48	
	PD 3	Mn	HCl	All	Bulk	0	100		32
220	BL 3	Mn	HCl	1-1	Bulk	100	0	8	
	PD 3	Mn	HCl	1-1	Bulk	0	100		8
221	BL 3	Mn	HCl	2-2	Bulk	100	0	8	
	PD 3	Mn	HCl	2-2	Bulk	0	100		8

Appendix 3

Results of Discriminant Function Analysis

Test	Location	Element	Extraction	Horizon	Grain Size	% Bull Lake	% Pine-dale	Total n BL	Total n PD
222	BL 3	Mn	HCl	2-3	Bulk	100	0	8	
	PD 3	Mn	HCl	2-3	Bulk	0	100		8
223	BL 3	Mn	HCl	2-4	Bulk	100	0	8	
	PD 3	Mn	HCl	2-4	Bulk	0	100		8
224	BL 3	Mn	HCl	3-5	Bulk	100	0	8	
	PD 3	Mn	HCl	3-5	Bulk	0	100		8
225	BL 3	Mn	HCl	4-6	Bulk	100	0	8	
	PD 3	Mn	HCl	4-6	Bulk	0	100		8
226	BL 2	Mn	HCl	All	Clay	100	0	48	
	PD 2	Mn	HCl	All	Clay	0	100		32
227	BL 2	Mn	HCl	1-1	Clay	100	0	8	
	PD 2	Mn	HCl	1-1	Clay	0	100		8
228	BL 2	Mn	HCl	2-2	Clay	100	0	8	
	PD 2	Mn	HCl	2-2	Clay	0	100		8
229	BL 2	Mn	HCl	2-3	Clay	100	0	8	
	PD 2	Mn	HCl	2-3	Clay	0	100		8
230	BL 2	Mn	HCl	2-4	Clay	100	0	8	
	PD 2	Mn	HCl	2-4	Clay	0	100		8
231	BL 2	Mn	HCl	3-5	Clay	100	0	8	
	PD 2	Mn	HCl	3-5	Clay	0	100		8
232	BL 2	Mn	HCl	4-6	Clay	100	0	8	
	PD 2	Mn	HCl	4-6	Clay	0	100		8
234	BL 3	Mn	HCl	All	Clay	50	50	48	
	PD 3	Mn	HCl	All	Clay	25	75		32
235	BL 3	Mn	HCl	1-1	Clay	100	0	8	
	PD 3	Mn	HCl	1-1	Clay	0	100		8
236	BL 3	Mn	HCl	2-2	Clay	100	0	8	
	PD 3	Mn	HCl	2-2	Clay	0	100		8
237	BL 3	Mn	HCl	2-3	Clay	100	0	8	
	PD 3	Mn	HCl	2-3	Clay	0	100		8
238	BL 3	Mn	HCl	2-4	Clay	100	0	8	
	PD 3	Mn	HCl	2-4	Clay	0	100		8
239	BL 3	Mn	HCl	3-5	Clay	100	0	8	
	PD 3	Mn	HCl	3-5	Clay	0	100		8
240	BL 3	Mn	HCl	4-6	Clay	100	0	8	
	PD 3	Mn	HCl	4-6	Clay	0	100		8
241	BL 2	Mn	CDB	All	Bulk	64.52	35.42	48	
	PD 2	Mn	CDB	All	Bulk	25	75		32
242	BL 2	Mn	CDB	1-1	Bulk	100	0	8	
	PD 2	Mn	CDB	1-1	Bulk	0	100		8
243	BL 2	Mn	CDB	2-2	Bulk	100	0	8	
	PD 2	Mn	CDB	2-2	Bulk	0	100		8
244	BL 2	Mn	CDB	2-3	Bulk	100	0	8	
	PD 2	Mn	CDB	2-3	Bulk	0	100		8

Appendix 3

Results of Discriminant Function Analysis

Test	Location	Element	Extraction	Horizon	Grain Size	% Bull Lake	% Pine-dale	Total n BL	Total n PD
245	BL 2	Mn	CDB	2-4	Bulk	100	0	8	
	PD 2	Mn	CDB	2-4	Bulk	0	100		8
246	BL 2	Mn	CDB	3-5	Bulk	100	0	8	
	PD 2	Mn	CDB	3-5	Bulk	0	100		8
247	BL 2	Mn	CDB	4-6	Bulk	0	0	8	
	PD 2	Mn	CDB	4-6	Bulk	0	0		8
248	BL 3	Mn	CDB	All	Bulk	33.42	64.58	48	
	PD 3	Mn	CDB	All	Bulk	31.25	68.75		32
249	BL 3	Mn	CDB	1-1	Bulk	100	0	8	
	PD 3	Mn	CDB	1-1	Bulk	0	100		8
250	BL 3	Mn	CDB	2-2	Bulk	100	0	8	
	PD 3	Mn	CDB	2-2	Bulk	0	100		8
251	BL 3	Mn	CDB	2-3	Bulk	100	0	8	
	PD 3	Mn	CDB	2-3	Bulk	12.5	87.5		8
252	BL 3	Mn	CDB	2-4	Bulk	50	50	8	
	PD 3	Mn	CDB	2-4	Bulk	37.5	62.5		8
253	BL 3	Mn	CDB	3-5	Bulk	75	25	8	
	PD 3	Mn	CDB	3-5	Bulk	37.5	62.5		8
254	BL 3	Mn	CDB	4-6	Bulk	100	0	8	
	PD 3	Mn	CDB	4-6	Bulk	0	100		8
255	BL 2	Mn	CDB	All	Clay	0	0	48	
	PD 2	Mn	CDB	All	Clay	0	0		32
256	BL 2	Mn	CDB	1-1	Clay	0	0	8	
	PD 2	Mn	CDB	1-1	Clay	0	0		8
257	BL 2	Mn	CDB	2-2	Clay	0	0	8	
	PD 2	Mn	CDB	2-2	Clay	0	0		8
258	BL 2	Mn	CDB	2-3	Clay	0	0	8	
	PD 2	Mn	CDB	2-3	Clay	0	0		8
259	BL 2	Mn	CDB	2-4	Clay	0	0	8	
	PD 2	Mn	CDB	2-4	Clay	0	0		8
260	BL 2	Mn	CDB	3-5	Clay	0	0	8	
	PD 2	Mn	CDB	3-5	Clay	0	0		8
261	BL 2	Mn	CDB	4-6	Clay	0	0	8	
	PD 2	Mn	CDB	4-6	Clay	0	0		8
262	BL 3	Mn	CDB	All	Clay	0	0	48	
	PD 3	Mn	CDB	All	Clay	0	0		32
263	BL 3	Mn	CDB	1-1	Clay	0	0	8	
	PD 3	Mn	CDB	1-1	Clay	0	0		8
264	BL 3	Mn	CDB	2-2	Clay	0	0	8	
	PD 3	Mn	CDB	2-2	Clay	0	0		8
265	BL 3	Mn	CDB	2-3	Clay	0	0	8	
	PD 3	Mn	CDB	2-3	Clay	0	0		8
266	BL 3	Mn	CDB	2-4	Clay	0	0	8	
	PD 3	Mn	CDB	2-4	Clay	0	0		8

Appendix 3

Results of Discriminant Function Analysis

Test	Location	Element	Extraction	Horizon	Grain Size	% Bull Lake	% Pine-dale	Total n BL	Total n PD
267	BL 3	Mn	CDB	3-5	Clay	0	0	8	
	PD 3	Mn	CDB	3-5	Clay	0	0		8
268	BL 3	Mn	CDB	4-6	Clay	0	0	8	
	PD 3	Mn	CDB	4-6	Clay	0	0		8
269	BL 2	Na	KCl	All	Bulk	50	50	48	
	PD 2	Na	KCl	All	Bulk	0	100		32
270	BL 2	Na	KCl	1-1	Bulk	50	50	8	
	PD 2	Na	KCl	1-1	Bulk	25	75		8
271	BL 2	Na	KCl	2-2	Bulk	62.5	37.5	8	
	PD 2	Na	KCl	2-2	Bulk	75	25		8
272	BL 2	Na	KCl	2-3	Bulk	87.5	12.5	8	
	PD 2	Na	KCl	2-3	Bulk	25	75		8
273	BL 2	Na	KCl	2-4	Bulk	87.5	12.5	8	
	PD 2	Na	KCl	2-4	Bulk	0	100		8
274	BL 2	Na	KCl	3-5	Bulk	100	0	8	
	PD 2	Na	KCl	3-5	Bulk	0	100		8
275	BL 2	Na	KCl	4-6	Bulk	100	0	8	
	PD 2	Na	KCl	4-6	Bulk	0	100		8
276	BL 3	Na	KCl	All	Bulk	100	0	48	
	PD 3	Na	KCl	All	Bulk	50	50		32
277	BL 3	Na	KCl	1-1	Bulk	87.5	12.5	8	
	PD 3	Na	KCl	1-1	Bulk	12.5	87.5		8
278	BL 3	Na	KCl	2-2	Bulk	87.5	12.5	8	
	PD 3	Na	KCl	2-2	Bulk	50	50		8
279	BL 3	Na	KCl	2-3	Bulk	37.5	62.5	8	
	PD 3	Na	KCl	2-3	Bulk	37.5	62.5		8
280	BL 3	Na	KCl	2-4	Bulk	87.5	12.5	8	
	PD 3	Na	KCl	2-4	Bulk	0	100		8
281	BL 3	Na	KCl	3-5	Bulk	100	0	8	
	PD 3	Na	KCl	3-5	Bulk	0	100		8
282	BL 3	Na	KCl	4-6	Bulk	100	0	8	
	PD 3	Na	KCl	4-6	Bulk	0	100		8
283	BL 2	Na	KCl	All	Clay	81.25	18.75	48	
	PD 2	Na	KCl	All	Clay	65.53	34.38		32
284	BL 2	Na	KCl	1-1	Clay	75	25	8	
	PD 2	Na	KCl	1-1	Clay	75	25		8
285	BL 2	Na	KCl	2-2	Clay	50	50	8	
	PD 2	Na	KCl	2-2	Clay	62.5	37.5		8
286	BL 2	Na	KCl	2-3	Clay	62.5	37.5	8	
	PD 2	Na	KCl	2-3	Clay	37.5	62.5		8
287	BL 2	Na	KCl	2-4	Clay	12.5	87.5	8	
	PD 2	Na	KCl	2-4	Clay	12.5	87.5		8
288	BL 2	Na	KCl	3-5	Clay	100	0	8	
	PD 2	Na	KCl	3-5	Clay	62.5	37.5		8

Appendix 3

Results of Discriminant Function Analysis

Test	Location	Element	Extraction	Horizon	Grain Size	% Bull Lake	% Pine-dale	Total n BL	Total n PD
289	BL 2	Na	KCl	4-6	Clay	87.5	12.5	8	
	PD 2	Na	KCl	4-6	Clay	62.5	37.5		8
290	BL 3	Na	KCl	All	Clay	62.5	37.5	48	
	PD 3	Na	KCl	All	Clay	62.5	37.5		32
291	BL 3	Na	KCl	1-1	Clay	87.5	12.5	8	
	PD 3	Na	KCl	1-1	Clay	37.5	62.5		8
292	BL 3	Na	KCl	2-2	Clay	50	50	8	
	PD 3	Na	KCl	2-2	Clay	25	75		8
293	BL 3	Na	KCl	2-3	Clay	100	0	8	
	PD 3	Na	KCl	2-3	Clay	37.5	62.5		8
294	BL 3	Na	KCl	2-4	Clay	50	50	8	
	PD 3	Na	KCl	2-4	Clay	50	50		8
295	BL 3	Na	KCl	3-5	Clay	50	50	8	
	PD 3	Na	KCl	3-5	Clay	25	75		8
296	BL 3	Na	KCl	4-6	Clay	62.5	37.5	8	
	PD 3	Na	KCl	4-6	Clay	75	25		8
297	BL 2	Na	HCl	All	Bulk	50	50	48	
	PD 2	Na	HCl	All	Bulk	25	75		32
298	BL 2	Na	HCl	1-1	Bulk	100	0	8	
	PD 2	Na	HCl	1-1	Bulk	12.5	87.5		8
299	BL 2	Na	HCl	2-2	Bulk	100	0	8	
	PD 2	Na	HCl	2-2	Bulk	0	100		8
300	BL 2	Na	HCl	2-3	Bulk	87.5	12.5	8	
	PD 2	Na	HCl	2-3	Bulk	50	50		8
301	BL 2	Na	HCl	2-4	Bulk	100	0	8	
	PD 2	Na	HCl	2-4	Bulk	0	100		8
302	BL 2	Na	HCl	3-5	Bulk	100	0	8	
	PD 2	Na	HCl	3-5	Bulk	0	100		8
303	BL 2	Na	HCl	4-6	Bulk	100	0	8	
	PD 2	Na	HCl	4-6	Bulk	0	100		8
304	BL 3	Na	HCl	All	Bulk	100	0	48	
	PD 3	Na	HCl	All	Bulk	50	50		32
305	BL 3	Na	HCl	1-1	Bulk	100	0	8	
	PD 3	Na	HCl	1-1	Bulk	37.5	62.5		8
306	BL 3	Na	HCl	2-2	Bulk	100	0	8	
	PD 3	Na	HCl	2-2	Bulk	12.5	87.5		8
307	BL 3	Na	HCl	2-3	Bulk	100	0	8	
	PD 3	Na	HCl	2-3	Bulk	25	75		8
308	BL 3	Na	HCl	2-4	Bulk	100	0	8	
	PD 3	Na	HCl	2-4	Bulk	0	100		8
309	BL 3	Na	HCl	3-5	Bulk	100	0	8	
	PD 3	Na	HCl	3-5	Bulk	0	100		8
310	BL 3	Na	HCl	4-6	Bulk	100	0	8	
	PD 3	Na	HCl	4-6	Bulk	0	100		8

Appendix 3

Results of Discriminant Function Analysis

Test	Location	Element	Extraction	Horizon	Grain Size	% Bull Lake	% Pine-dale	Total n BL	Total n PD
311	BL 2	Na	HCl	All	Clay	75	25	48	
	PD 2	Na	HCl	All	Clay	46.88	53.13		32
312	BL 2	Na	HCl	1-1	Clay	100	0	8	
	PD 2	Na	HCl	1-1	Clay	37.5	62.5		8
313	BL 2	Na	HCl	2-2	Clay	100	0	8	
	PD 2	Na	HCl	2-2	Clay	37.5	62.5		8
314	BL 2	Na	HCl	2-3	Clay	100	0	8	
	PD 2	Na	HCl	2-3	Clay	37.5	62.5		8
315	BL 2	Na	HCl	2-4	Clay	100	0	8	
	PD 2	Na	HCl	2-4	Clay	50	50		8
316	BL 2	Na	HCl	3-5	Clay	100	0	8	
	PD 2	Na	HCl	3-5	Clay	62.5	37.5		8
317	BL 2	Na	HCl	4-6	Clay	87.5	12.5	8	
	PD 2	Na	HCl	4-6	Clay	50	50		8
318	BL 3	Na	HCl	All	Clay	83.33	16.67	48	
	PD 3	Na	HCl	All	Clay	43.75	56.25		32
319	BL 3	Na	HCl	1-1	Clay	100	0	8	
	PD 3	Na	HCl	1-1	Clay	50	50		8
320	BL 3	Na	HCl	2-2	Clay	100	0	8	
	PD 3	Na	HCl	2-2	Clay	50	50		8
321	BL 3	Na	HCl	2-3	Clay	100	0	8	
	PD 3	Na	HCl	2-3	Clay	50	50		8
322	BL 3	Na	HCl	2-4	Clay	100	0	8	
	PD 3	Na	HCl	2-4	Clay	50	50		8
323	BL 3	Na	HCl	3-5	Clay	100	0	8	
	PD 3	Na	HCl	3-5	Clay	62.5	37.5		8
324	BL 3	Na	HCl	4-6	Clay	100	0	8	
	PD 3	Na	HCl	4-6	Clay	12.5	87.5		8
325	BL 2	Na	CuOAc	All	Bulk	50	50	48	
	PD 2	Na	CuOAc	All	Bulk	0	100		32
326	BL 2	Na	CuOAc	1-1	Bulk	0	0	8	
	PD 2	Na	CuOAc	1-1	Bulk	0	0		8
327	BL 2	Na	CuOAc	2-2	Bulk	0	0	8	
	PD 2	Na	CuOAc	2-2	Bulk	0	0		8
328	BL 2	Na	CuOAc	2-3	Bulk	0	0	8	
	PD 2	Na	CuOAc	2-3	Bulk	0	0		8
329	BL 2	Na	CuOAc	2-4	Bulk	100	0	8	
	PD 2	Na	CuOAc	2-4	Bulk	0	100		8
330	BL 2	Na	CuOAc	3-5	Bulk	100	0	8	
	PD 2	Na	CuOAc	3-5	Bulk	0	100		8
331	BL 2	Na	CuOAc	4-6	Bulk	100	0	8	
	PD 2	Na	CuOAc	4-6	Bulk	0	100		8
332	BL 3	Na	CuOAc	All	Bulk	83.33	16.67	48	
	PD 3	Na	CuOAc	All	Bulk	50	50		32

Appendix 3

Results of Discriminant Function Analysis

Test	Location	Element	Extraction	Horizon	Grain Size	% Bull Lake	% Pine-dale	Total n BL	Total n PD
333	BL 3	Na	CuOAc	1-1	Bulk	0	0	8	
	PD 3	Na	CuOAc	1-1	Bulk	0	0		8
334	BL 3	Na	CuOAc	2-2	Bulk	0	0	8	
	PD 3	Na	CuOAc	2-2	Bulk	0	0		8
335	BL 3	Na	CuOAc	2-3	Bulk	100	0	8	
	PD 3	Na	CuOAc	2-3	Bulk	0	100		8
336	BL 3	Na	CuOAc	2-4	Bulk	100	0	8	
	PD 3	Na	CuOAc	2-4	Bulk	0	100		8
337	BL 3	Na	CuOAc	3-5	Bulk	100	0	8	
	PD 3	Na	CuOAc	3-5	Bulk	0	100		8
338	BL 3	Na	CuOAc	4-6	Bulk	100	0	8	
	PD 3	Na	CuOAc	4-6	Bulk	0	100		8
339	BL 2	Na	CuOAc	All	Clay	58.33	41.67	48	
	PD 2	Na	CuOAc	All	Clay	3.13	96.88		32
340	BL 2	Na	CuOAc	1-1	Clay	75	25	8	
	PD 2	Na	CuOAc	1-1	Clay	0	100		8
341	BL 2	Na	CuOAc	2-2	Clay	37.5	62.5	8	
	PD 2	Na	CuOAc	2-2	Clay	12.5	87.5		8
342	BL 2	Na	CuOAc	2-3	Clay	62.5	37.5	8	
	PD 2	Na	CuOAc	2-3	Clay	12.5	87.5		8
343	BL 2	Na	CuOAc	2-4	Clay	75	25	8	
	PD 2	Na	CuOAc	2-4	Clay	12.5	87.5		8
345	BL 2	Na	CuOAc	3-5	Clay	62.5	37.5	8	
	PD 2	Na	CuOAc	3-5	Clay	0	100		8
346	BL 2	Na	CuOAc	4-6	Clay	62.5	37.5	8	
	PD 2	Na	CuOAc	4-6	Clay	0	100		8
347	BL 3	Na	CuOAc	All	Clay	56.25	43.75	48	
	PD 3	Na	CuOAc	All	Clay	6.25	93.75		32
348	BL 3	Na	CuOAc	1-1	Clay	75	25	8	
	PD 3	Na	CuOAc	1-1	Clay	0	100		8
349	BL 3	Na	CuOAc	2-2	Clay	65.5	37.5	8	
	PD 3	Na	CuOAc	2-2	Clay	12.5	87.5		8
350	BL 3	Na	CuOAc	2-3	Clay	75	25	8	
	PD 3	Na	CuOAc	2-3	Clay	12.5	87.5		8
351	BL 3	Na	CuOAc	2-4	Clay	62.5	37.5	8	
	PD 3	Na	CuOAc	2-4	Clay	12.5	87.5		8
352	BL 3	Na	CuOAc	3-5	Clay	62.5	37.5	8	
	PD 3	Na	CuOAc	3-5	Clay	0	100		8
353	BL 3	Na	CuOAc	4-6	Clay	50	50	8	
	PD 3	Na	CuOAc	4-6	Clay	0	100		8
354	BL 2	Ca	KCl	All	Bulk	66.67	33.33	48	
	PD 2	Ca	KCl	All	Bulk	75	25		32
355	BL 2	Ca	KCl	1-1	Bulk	100	0	8	
	PD 2	Ca	KCl	1-1	Bulk	0	100		8

Appendix 3

Results of Discriminant Function Analysis

Test	Location	Element	Extraction	Horizon	Grain Size	% Bull Lake	% Pinedale	Total n BL	Total n PD
356	BL 2	Ca	KCl	2-2	Bulk	100	0	8	
	PD 2	Ca	KCl	2-2	Bulk	0	100		8
357	BL 2	Ca	KCl	2-3	Bulk	100	0	8	
	PD 2	Ca	KCl	2-3	Bulk	0	100		8
358	BL 2	Ca	KCl	2-4	Bulk	87.5	12.5	8	
	PD 2	Ca	KCl	2-4	Bulk	25	75		8
359	BL 2	Ca	KCl	3-5	Bulk	100	0	8	
	PD 2	Ca	KCl	3-5	Bulk	0	100		8
360	BL 2	Ca	KCl	4-6	Bulk	100	0	8	
	PD 2	Ca	KCl	4-6	Bulk	0	100		8
361	BL 3	Ca	KCl	All	Bulk	0	0	48	
	PD 3	Ca	KCl	All	Bulk	0	0		32
362	BL 3	Ca	KCl	1-1	Bulk	100	0	8	
	PD 3	Ca	KCl	1-1	Bulk	0	100		8
363	BL 3	Ca	KCl	2-2	Bulk	100	0	8	
	PD 3	Ca	KCl	2-2	Bulk	0	100		8
364	BL 3	Ca	KCl	2-3	Bulk	100	0	8	
	PD 3	Ca	KCl	2-3	Bulk	0	100		8
365	BL 3	Ca	KCl	2-4	Bulk	100	0	8	
	PD 3	Ca	KCl	2-4	Bulk	0	100		8
366	BL 3	Ca	KCl	3-5	Bulk	100	0	8	
	PD 3	Ca	KCl	3-5	Bulk	0	100		8
367	BL 3	Ca	KCl	4-6	Bulk	100	0	8	
	PD 3	Ca	KCl	4-6	Bulk	0	100		8
368	BL 2	Ca	KCl	All	Clay	79.17	20.83	48	
	PD 2	Ca	KCl	All	Clay	65.63	34.38		32
369	BL 2	Ca	KCl	1-1	Clay	75	25	8	
	PD 2	Ca	KCl	1-1	Clay	75	25		8
370	BL 2	Ca	KCl	2-2	Clay	50	50	8	
	PD 2	Ca	KCl	2-2	Clay	62.5	37.5		8
371	BL 2	Ca	KCl	2-3	Clay	62.5	37.5	8	
	PD 2	Ca	KCl	2-3	Clay	37.5	62.5		8
372	BL 2	Ca	KCl	2-4	Clay	12.5	87.5	8	
	PD 2	Ca	KCl	2-4	Clay	12.5	87.5		8
373	BL 2	Ca	KCl	3-5	Clay	100	0	8	
	PD 2	Ca	KCl	3-5	Clay	62.5	37.5		8
374	BL 2	Ca	KCl	4-6	Clay	87.5	12.5	8	
	PD 2	Ca	KCl	4-6	Clay	65.5	37.5		8
375	BL 3	Ca	KCl	All	Clay	62.5	37.5	48	
	PD 3	Ca	KCl	All	Clay	62.5	37.5		32
376	BL 3	Ca	KCl	1-1	Clay	87.5	12.5	8	
	PD 3	Ca	KCl	1-1	Clay	37.5	62.5		8
378	BL 3	Ca	KCl	2-2	Clay	50	50	8	
	PD 3	Ca	KCl	2-2	Clay	25	75		8

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Results of Discriminant Function Analysis

Test	Location	Element	Extraction	Horizon	Grain Size	% Bull Lake	% Pine-dale	Total n BL	Total n PD
379	BL 3	Ca	KCl	2-3	Clay	100	0	8	
	PD 3	Ca	KCl	2-3	Clay	37.5	62.5		8
380	BL 3	Ca	KCl	2-4	Clay	50	50	8	
	PD 3	Ca	KCl	2-4	Clay	50	50		8
381	BL 3	Ca	KCl	3-5	Clay	50	50	8	
	PD 3	Ca	KCl	3-5	Clay	25	75		8
382	BL 3	Ca	KCl	4-6	Clay	62.5	37.5	8	
	PD 3	Ca	KCl	4-6	Clay	25	75		8
383	BL 2	Ca	HCl	All	Bulk	83.33	16.67	48	
	PD 2	Ca	HCl	All	Bulk	0	100		32
384	BL 2	Ca	HCl	1-1	Bulk	100	0	8	
	PD 2	Ca	HCl	1-1	Bulk	0	100		8
385	BL 2	Ca	HCl	2-2	Bulk	100	0	8	
	PD 2	Ca	HCl	2-2	Bulk	12.5	87.5		8
386	BL 2	Ca	HCl	2-3	Bulk	100	0	8	
	PD 2	Ca	HCl	2-3	Bulk	0	100		8
387	BL 2	Ca	HCl	2-4	Bulk	100	0	8	
	PD 2	Ca	HCl	2-4	Bulk	0	100		8
388	BL 2	Ca	HCl	3-5	Bulk	100	0	8	
	PD 2	Ca	HCl	3-5	Bulk	0	100		8
389	BL 2	Ca	HCl	4-6	Bulk	100	0	8	
	PD 2	Ca	HCl	4-6	Bulk	0	100		8
390	BL 3	Ca	HCl	All	Bulk	0	0	48	
	PD 3	Ca	HCl	All	Bulk	0	0		32
391	BL 3	Ca	HCl	1-1	Bulk	100	0	8	
	PD 3	Ca	HCl	1-1	Bulk	0	100		8
392	BL 3	Ca	HCl	2-2	Bulk	100	0	8	
	PD 3	Ca	HCl	2-2	Bulk	0	100		8
393	BL 3	Ca	HCl	2-3	Bulk	100	0	8	
	PD 3	Ca	HCl	2-3	Bulk	0	100		8
394	BL 3	Ca	HCl	2-4	Bulk	100	0	8	
	PD 3	Ca	HCl	2-4	Bulk	12.5	87.5		8
395	BL 3	Ca	HCl	3-5	Bulk	100	0	8	
	PD 3	Ca	HCl	3-5	Bulk	0	100		8
396	BL 3	Ca	HCl	4-6	Bulk	100	0	8	
	PD 3	Ca	HCl	4-6	Bulk	12.5	87.5		8
397	BL 2	Ca	HCl	All	Clay	83.33	16.67	48	
	PD 2	Ca	HCl	All	Clay	0	100		32
398	BL 2	Ca	HCl	1-1	Clay	100	0	8	
	PD 2	Ca	HCl	1-1	Clay	0	100		8
399	BL 2	Ca	HCl	2-2	Clay	100	0	8	
	PD 2	Ca	HCl	2-2	Clay	0	100		8
400	BL 2	Ca	HCl	2-3	Clay	100	0	8	
	PD 2	Ca	HCl	2-3	Clay	0	100		8

Appendix 3

Results of Discriminant Function Analysis

Test	Location	Element	Extraction	Horizon	Grain Size	% Bull Lake	% Pine-dale	Total n BL	Total n PD
401	BL 2	Ca	HCl	2-4	Clay	100	0	8	
	PD 2	Ca	HCl	2-4	Clay	0	100		8
402	BL 2	Ca	HCl	3-5	Clay	100	0	8	
	PD 2	Ca	HCl	3-5	Clay	0	100		8
403	BL 2	Ca	HCl	4-6	Clay	100	0	8	
	PD 2	Ca	HCl	4-6	Clay	0	100		8
404	BL 3	Ca	HCl	All	Clay	50	50	48	
	PD 3	Ca	HCl	All	Clay	0	100		32
405	BL 3	Ca	HCl	1-1	Clay	100	0	8	
	PD 3	Ca	HCl	1-1	Clay	0	100		8
406	BL 3	Ca	HCl	2-2	Clay	100	0	8	
	PD 3	Ca	HCl	2-2	Clay	0	100		8
407	BL 3	Ca	HCl	2-3	Clay	100	0	8	
	PD 3	Ca	HCl	2-3	Clay	0	100		8
408	BL 3	Ca	HCl	2-4	Clay	100	0	8	
	PD 3	Ca	HCl	2-4	Clay	0	100		8
409	BL 3	Ca	HCl	3-5	Clay	100	0	8	
	PD 3	Ca	HCl	3-5	Clay	0	100		8
410	BL 3	Ca	HCl	4-6	Clay	100	0	8	
	PD 3	Ca	HCl	4-6	Clay	0	100		8
411	BL 2	Ca	CuOAc	All	Bulk	100	0	48	
	PD 2	Ca	CuOAc	All	Bulk	0	100		32
412	BL 2	Ca	CuOAc	1-1	Bulk	100	0	8	
	PD 2	Ca	CuOAc	1-1	Bulk	0	100		8
413	BL 2	Ca	CuOAc	2-2	Bulk	100	0	8	
	PD 2	Ca	CuOAc	2-2	Bulk	0	100		8
414	BL 2	Ca	CuOAc	2-3	Bulk	100	0	8	
	PD 2	Ca	CuOAc	2-3	Bulk	0	100		8
415	BL 2	Ca	CuOAc	2-4	Bulk	100	0	8	
	PD 2	Ca	CuOAc	2-4	Bulk	0	100		8
416	BL 2	Ca	CuOAc	3-5	Bulk	100	0	8	
	PD 2	Ca	CuOAc	3-5	Bulk	0	100		8
417	BL 2	Ca	CuOAc	4-6	Bulk	100	0	8	
	PD 2	Ca	CuOAc	4-6	Bulk	0	100		8
418	BL 3	Ca	CuOAc	All	Bulk	100	0	48	
	PD 3	Ca	CuOAc	All	Bulk	0	100		32
419	BL 3	Ca	CuOAc	1-1	Bulk	100	0	8	
	PD 3	Ca	CuOAc	1-1	Bulk	0	100		8
420	BL 3	Ca	CuOAc	2-2	Bulk	100	0	8	
	PD 3	Ca	CuOAc	2-2	Bulk	0	100		8
421	BL 3	Ca	CuOAc	2-3	Bulk	100	0	8	
	PD 3	Ca	CuOAc	2-3	Bulk	0	100		8
422	BL 3	Ca	CuOAc	2-4	Bulk	100	0	8	
	PD 3	Ca	CuOAc	2-4	Bulk	0	100		8

Appendix 3

Results of Discriminant Function Analysis

Test	Location	Element	Extraction	Horizon	Grain Size	% Bull Lake	% Pine-dale	Total n BL	Total n PD
423	BL 3	Ca	CuOAc	3-5	Bulk	100	0	8	
	PD 3	Ca	CuOAc	3-5	Bulk	0	100		8
424	BL 3	Ca	CuOAc	4-6	Bulk	100	0	8	
	PD 3	Ca	CuOAc	4-6	Bulk	0	100		8
425	BL 2	Ca	CuOAc	All	Clay	50	50	48	
	PD 2	Ca	CuOAc	All	Clay	0	100		32
426	BL 2	Ca	CuOAc	1-1	Clay	100	0	8	
	PD 2	Ca	CuOAc	1-1	Clay	0	100		8
427	BL 2	Ca	CuOAc	2-2	Clay	100	0	8	
	PD 2	Ca	CuOAc	2-2	Clay	12.5	87.5		8
428	BL 2	Ca	CuOAc	2-3	Clay	100	0	8	
	PD 2	Ca	CuOAc	2-3	Clay	0	100		8
429	BL 2	Ca	CuOAc	2-4	Clay	100	0	8	
	PD 2	Ca	CuOAc	2-4	Clay	0	100		8
430	BL 2	Ca	CuOAc	3-5	Clay	100	0	8	
	PD 2	Ca	CuOAc	3-5	Clay	0	100		8
431	BL 2	Ca	CuOAc	4-6	Clay	100	0	8	
	PD 2	Ca	CuOAc	4-6	Clay	0	100		8
432	BL 3	Ca	CuOAc	All	Clay	50	50	48	
	PD 3	Ca	CuOAc	All	Clay	0	100		32
433	BL 3	Ca	CuOAc	1-1	Clay	100	0	8	
	PD 3	Ca	CuOAc	1-1	Clay	0	100		8
434	BL 3	Ca	CuOAc	2-2	Clay	100	0	8	
	PD 3	Ca	CuOAc	2-2	Clay	12.5	87.5		8
435	BL 3	Ca	CuOAc	2-3	Clay	100	0	8	
	PD 3	Ca	CuOAc	2-3	Clay	0	100		8
436	BL 3	Ca	CuOAc	2-4	Clay	100	0	8	
	PD 3	Ca	CuOAc	2-4	Clay	0	100		8
437	BL 3	Ca	CuOAc	3-5	Clay	100	0	8	
	PD 3	Ca	CuOAc	3-5	Clay	0	100		8
438	BL 3	Ca	CuOAc	4-6	Clay	100	0	8	
	PD 3	Ca	CuOAc	4-6	Clay	0	100		8
439	BL 2	Ca	CDB	All	Bulk	66.67	33.33	48	
	PD 2	Ca	CDB	All	Bulk	3.13	96.88		32
440	BL 2	Ca	CDB	1-1	Bulk	100	0	8	
	PD 2	Ca	CDB	1-1	Bulk	0	100		8
441	BL 2	Ca	CDB	2-2	Bulk	100	0	8	
	PD 2	Ca	CDB	2-2	Bulk	0	100		8
442	BL 2	Ca	CDB	2-3	Bulk	100	0	8	
	PD 2	Ca	CDB	2-3	Bulk	0	100		8
443	BL 2	Ca	CDB	2-4	Bulk	100	0	8	
	PD 2	Ca	CDB	2-4	Bulk	0	100		8
444	BL 2	Ca	CDB	3-5	Bulk	100	0	8	
	PD 2	Ca	CDB	3-5	Bulk	0	100		8

Appendix 3

Results of Discriminant Function Analysis

Test	Location	Element	Extraction	Horizon	Grain Size	% Bull Lake	% Pine-dale	Total n BL	Total n PD
445	BL 2	Ca	CDB	4-6	Bulk	100	0	8	
	PD 2	Ca	CDB	4-6	Bulk	0	100		8
446	BL 3	Ca	CDB	All	Bulk	87.5	12.5	48	
	PD 3	Ca	CDB	All	Bulk	25	75		32
447	BL 3	Ca	CDB	1-1	Bulk	100	0	8	
	PD 3	Ca	CDB	1-1	Bulk	0	100		8
448	BL 3	Ca	CDB	2-2	Bulk	62.5	37.5	8	
	PD 3	Ca	CDB	2-2	Bulk	62.5	37.5		8
449	BL 3	Ca	CDB	2-3	Bulk	100	0	8	
	PD 3	Ca	CDB	2-3	Bulk	0	100		8
450	BL 3	Ca	CDB	2-4	Bulk	100	0	8	
	PD 3	Ca	CDB	2-4	Bulk	0	100		8
451	BL 3	Ca	CDB	3-5	Bulk	100	0	8	
	PD 3	Ca	CDB	3-5	Bulk	0	100		8
452	BL 3	Ca	CDB	4-6	Bulk	87.5	12.5	8	
	PD 3	Ca	CDB	4-6	Bulk	0	100		8
453	BL 2	Ca	CDB	All	Clay	66.67	33.33	48	
	PD 2	Ca	CDB	All	Clay	0	100		32
454	BL 2	Ca	CDB	1-1	Clay	100	0	8	
	PD 2	Ca	CDB	1-1	Clay	0	100		8
455	BL 2	Ca	CDB	2-2	Clay	100	0	8	
	PD 2	Ca	CDB	2-2	Clay	0	100		8
456	BL 2	Ca	CDB	2-3	Clay	100	0	8	
	PD 2	Ca	CDB	2-3	Clay	0	100		8
457	BL 2	Ca	CDB	2-4	Clay	100	0	8	
	PD 2	Ca	CDB	2-4	Clay	0	100		8
458	BL 2	Ca	CDB	3-5	Clay	100	0	8	
	PD 2	Ca	CDB	3-5	Clay	0	100		8
459	BL 2	Ca	CDB	4-6	Clay	100	0	8	
	PD 2	Ca	CDB	4-6	Clay	0	100		8
460	BL 3	Ca	CDB	All	Clay	83.33	13.67	48	
	PD 3	Ca	CDB	All	Clay	0	100		32
461	BL 3	Ca	CDB	1-1	Clay	100	0	8	
	PD 3	Ca	CDB	1-1	Clay	0	100		8
462	BL 3	Ca	CDB	2-2	Clay	100	0	8	
	PD 3	Ca	CDB	2-2	Clay	0	100		8
463	BL 3	Ca	CDB	2-3	Clay	100	0	8	
	PD 3	Ca	CDB	2-3	Clay	0	100		8
464	BL 3	Ca	CDB	2-4	Clay	100	0	8	
	PD 3	Ca	CDB	2-4	Clay	0	100		8
465	BL 3	Ca	CDB	3-5	Clay	100	0	8	
	PD 3	Ca	CDB	3-5	Clay	0	100		8
466	BL 3	Ca	CDB	4-6	Clay	100	0	8	
	PD 3	Ca	CDB	4-6	Clay	0	100		8

VITA

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