ISM Monograph 1

Podzols and podzolization in temperate regions

D.L. Mokma and P. Buurman

International Soil Museum - Wageningen - The Netherlands

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Foreword

This is the first of an envisaged series of ISM Monographs to be published by the International Soil Museum in addition to the series appearing under the name 'Soil Monolith Papers'. While a Soil Monolith Paper deals specifically with a soil unit of the FAO-Unesco Soil Legend, based on one representative example in the ISM soil monolith collection, the new series is open for a wider range of subjects in soil science. In particular it may describe the results of studies in soil genesis and classification, soil analysis and land evaluation of a major group of soils. The general aim is to strengthen the state of knowledge on the world's soil resources, for application in the field of land management and agro-technology transfer.

The present paper is the result of a comparative study on the characteristics, genesis and analysis of a major group of similar soils, the podzols, with the aim to define classification criteria of universal validity. This study has been conducted in the framework of the ISM soil correlation programme by a visiting scientist from Michigan State University (USA) and a staff member of the Agricultural University of Wageningen.

ISM appreciates any comment on its publications and any suggestion for research needs. Individual soil scientists are welcome to join ISM as guest researcher, to prepare either a Soil Monograph or a Soil Monolith Paper.

Wageningen, July 1982

W.G. Sombroek
Director

Contents

List of tables

List of text figures

1 Introduction

The term 'podzol' which originated in Russia has been adopted in several soil classification systems and is now defined in various ways. The concept varies from country to country and with time in a single country.

Several processes play a role in the formation of podzols. Insight into the processes involved has changed with time, depending on the kind of information gathered. Variation in the information collected has depended, at least partially, on changes in the podzol concept.

The most important feature of Podzols or Spodosols is the presence of a horizon with an accumulation of amorphous organic matter and aluminum, with or without iron. Therefore, criteria for a podzol B horizon or spodic horizon have been based, at least partially, on the amounts of organic carbon, Al and Fe extracted by specific solutions from these horizons.

The objectives of this study were to 1. review the literature on the Podzols and Spodosols, the criteria for classifying Podzols and Spodosols, and the processes involved in podzolization; 2. study the processes of podzolization in profiles collected for this purpose in the Netherlands and Belgium and on other profiles existing in the International Soil Museum collection and 3. develop new chemical criteria for classifying Podzols and Spodosols and compare these with existing criteria.

2 Podzol and spodosol concepts

The term 'podzol' was first applied by Russian workers solely to the bleached horizon that occurred at or near the surface of soils (Muir, 1961). It has been generally assumed that 'podzol' was derived from the Russian terms 'pod' meaning under or beneath and 'zol' or 'zola' meaning ashes. According to Muir (1961), the Russian term 'pod' should have the same meaning as the German term 'Boden', the Greek term 'pedon', and the Latin term 'peda'; therefore the term podzol means ashy soil (in fact, the latin word is pes, pl. pedes). Ponomareva (1964) assumed that the term 'pod' originated from the fact that the gray or ashy layer of soil is usually found under some other layer or layers of soil materials. For a summary of the historical development of the podzol concept the reader is referred to Muir (1961).

Differences in the concept of a podzol have persisted between soil scientists from Russia and Western Europe. Podzols in Western Europe were

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* Throughout this report, when referring to literature, original horizon designations and classification terms are maintained; otherwise, horizon designations and classification terms of FAO (1974; 1977) will be used.

restricted to sandy soils while Russian podzols included clayey soils with clay illuviation. Early Western European soil scientists considered the translocation of materials from the eluvial horizon to the illuvial horizon to occur in solution. These scientists were reluctant to accept the mechanical translocation of clay as part of the podzolization process.

The Western European concept of podzols is reflected in the soil classification systems of the various countries. This concept was carried to the United States by Marbut (Muir, 1961). According to Byers et al. (1938) podzols had an illuvial horizon with an accumulation of humus, iron and aluminum and occurred only on coarser textured parent materials. This concept reflects the Western European concept, a reddish-brown horizon beneath a bleached horizon, rather than the Russian concept, only a bleached horizon.

The order Spodosol and diagnostic spodic horizon in the new soil classification system, Soil Taxonomy (Soil Survey Staff, 1975), also originated in the Western European concept of podzols. In the 7th Approximation (Soil Survey Staff, 1960) and in Soil Taxonomy, Spodosols were identified by the spodic horizon and not the albic horizon. The spodic horizon was defined as an illuvial accumulation of sesquioxides and organic matter. Later the spodic horizon was defined as one in which active amorphous materials, composed of organic matter and aluminum with or without iron, have precipitated (Soil Survey Staff, 1975). The term 'active' described material that had high cation exchange capacity, large surface area and high water retention.

In virgin areas the spodic horizon usually lies below an albic horizon (whitish or grayish eluvial horizon). Emphasis is not placed on the albic horizon for two reasons (Smith, 1965). First, the albic horizon may be thin and incorporated into the A horizon by plowing, pasturing or by earthworms. Second, it is related to an absence of free iron oxide coatings. This may result from soil genesis or from unique parent materials. In Florida white quartz sand dunes are forming over older brown sands and they could be considered Spodosols if emphasis is placed too strongly on the albic horizon. Spodosols include most of the Podzols, Brown Podzolic soils and Ground-Water Podzols of the 1938 U.S. soil classification system (Baldwin et al., 1938).

The podzolic B horizon of England and Canada is similar to the podzol B horizon. In the soil classification system of England and Wales (Avery, 1980), the podzolic B horizon is one in which organic matter and aluminum and/or iron have accumulated in amorphous forms. It usually underlies a bleached E horizon. Podzolic soils have a podzolic B horizon. Podzolic soils and Spodosols have similar concepts (Avery et al., 1977; Avery, 1980).

In the Canadian system of soil classification, soils in the Podzolic order have podzolic B horizons in which the dominant illuvial material is amorphous material composed mainly of organic matter with varying amounts of iron and aluminum (Canada Soil Survey Committee, 1978). The podzolic B horizon usually, but not always, underlies a light-colored eluvial horizon.

In the FAO-Unesco system (Food and Agriculture Organization, 1974) Podzol is used for soils with a spodic B horizon which has an illuvial accumulation of iron or organic matter, or both, but without clay skins on ped faces or in pores. A continuous albic horizon is not required above the spodic B horizon.

Except for the Russian concept, there appears to be much agreement among the definition of Podzols or Spodosols. The most important characteristic of Podzols is the translocation and accumulation of humus and/or sesquioxides. A grayish or whitish eluvial horizon is usually, but not always, present above the illuvial horizon. The translocation of humus and sesquioxides is not related to the translocation of silicate clays.

3 Environmental setting of podzols

Podzols (Spodosols) are only found in humic regions where precipitation exceeds evapotranspiration (Soil Survey Staff, 1960). They are not found in arid environments. However, they are found in Mediterranean climates which have long dry summers (Soil Survey Staff, 1975).

There appears to be no relationship between soil temperature and occurrence of podzols. They are found in cool to hot climates (Soil Survey Staff, 1975). Earlier American soil scientists (Baldwin et al., 1938) thought podzols were typically found in cool climates and that those which occur outside these climates result from special local conditions, e.g. siliceous parent materials.

In cold climates podzols tend to be shallow while in warmer climates they tend to be thicker. The eluvial horizon of podzols in tropical areas tend to be thick (Barshad and Rojas-Cruz, 1950; Bleackley and Khan, 1963; Klinge, 1965; Andriesse, 1969) while those in cold climates tend to be thin (Chandler, 1942; Kubota and Whittig, 1960; Stevens, 1963; Ponomareva, 1964).

Podzols have been described in many areas of the world. They are found in almost all countries in Europe, in all provinces of Canada (NCSS, NSSC and FAO, 1975), and in many states in the U.S.A. from Alaska to Florida (Soil Survey Staff, 1975). Podzols have been reported in the Amazon Basin (Klinge, 1965), British Guiana (Bleackley and Khan, 1963), Columbia, South America (Barshad and Rojas-Cruz, 1950), East Malaysia (Andriesse, 1969, 1970), Indonesia (Tan et al., 1970), and Zambia (Brammer, 1973).

Outside the cold climates podzols form, for the most part, in siliceous parent materials (Byers et al., 1938;Racz, 1968; Stace et al., 1968; Andriesse, 1969; Soil Survey Staff, 1975; Canada Soil Survey Committee, 1978, De Bakker, 1979). They are low in weatherable minerals. Some may have more than 95%

quartz, zircon, tourmaline, rutile, or other relatively insoluble crystalline minerals that do not weather to produce iron or aluminum. In the humid environments most of the bases are leached and therefore podzols have a low base saturation and pH.

In cool climates podzols have had a heath (Erica and Calluna) or a forest vegetation. Most have had a coniferous or oak forest. In forested areas podzols are more strongly developed under some species, such as hemlock (Tsuga canadensis) and kauri (Agathis australis), than under others. In warmer climates podzols occur under savannah, palms, and mixed forests. Podzols in Zambia developed under similar savannah forest as oxisols but on different parent materials (Brammer, 1973).

Podzols form both in well drained soils and in soils with a shallow, fluctuating watertable. If the water level is within the podzol B horizon for long periods, the B horizon may contain little or no iron. Podzols do not appear to form in soils that are permanently saturated with water and have strong reducing conditions.

4 The podzolization process

The podzolization process comprises the reactions and processes involved in the formation of a podzol B or a spodic horizon and the removal of sesquioxides and organic carbon from overlying layers. It involves the translocation of organic compounds, aluminum and iron. The mechanisms of podzolization must explain the release, mobilization, migration and immobilization of these materials.

Many studies have been conducted to obtain information on the mechanisms involved in the podzolization process. No attempt will be made to review each of these studies. Several authors have reviewed the literature concerning the major processes (Stobbe and Wright, 1959; Bloomfield, 1963; Wright and Schnitzer, 1963; Ponomareva, 1964; McKeague and St Arnaud, 1969; Petersen, 1976; McKeague et al., 1978; De Coninck, 1980; Flach et al., 1980). A summary of the conditions for and the processes of podzolization follows.

Processes of podzolization may be grouped as follows: accumulation of organic matter in and on the topsoil; leaching and acidification; weathering; translocation of organic compounds, aluminum and iron; immobilization of organo-metallic complexes; formation of humus pellets, and cementation.

The accumulation of organic matter in the O and Ah horizon results from the deposition of litter on the soil and the incorporation of its decay products into the mineral soil by fauna. Roots also contribute to organic matter in the Ah horizons. The major portion of the organic matter in soils consists of humic substances, of which the main components are humic and fulvic acids (Schnitzer and Kodama, 1977). Both humic and fulvic acids, like other organic acids, form complexes with bi- en trivalent cations. These complexes may be soluble in water when unsaturated with cations and insoluble when saturated. The leachate collected between the Ae and Bhf horizons of a Humic Podzol was primarily (87%) fulvic acid (Schnitzer and Desjardins, 1969). These acids are also active in mineral degradation (Ponomareva, 1964; Ponomareva and Ragim-Zade, 1969; Kodama and Schnitzer, 1972; Baker, 1973; Schnitzer and Kodama, 1976).

The order of stability of some fulvic acid-metal complexes at low pH (<3.5) was: $Fe^{3+} > Al^{3+} > Ca^{2+} > Mg^{2+}$ (Khanna and Stevenson, 1962; Khan, 1969; Schnitzer, 1969; Schnitzer and Hansen, 1970). The greater affinity of fulvic acid for Fe^{3+} than Al^{3+} may explain the greater dissolution of Fe-rich chlorites and micas than the Fe-poor minerals (Kodama and Schnitzer, 1972; Schnitzer and Kodama, 1976). According to Van Dijk (1971) at pH 5.0 there was no large difference in bond strength for humic acid-metal complexes involving Ca^{2+}, Mg^{2+} and Fe^{2+}. Fe^{3+} was more firmly bound while Al^{3+} formed a hydroxide. The above sequences differ from that based on bond stability: $Al^{3+} > Fe^{3+} > Mg^{2+} > Ca^{2+}$ (De Coninck, 1980). Thus, the preferences of the organic ligands for Al^{3+} and Fe^{3+} may change with pH.

The complexation properties of organic matter imply that before appreciable amounts of humus, aluminum and iron can be translocated, soluble salts, such as calcium carbonate, and most exchangeable bases, especially calcium, must be removed from the upper horizons. The calcium and other bases will form insoluble compounds with the water-soluble organic materials. Soils with a high clay content are likely to have low amounts of water-soluble organic compounds, because these soils will have readily available aluminum and iron in clay lattices, which can completely neutralize the negative charges. The soils which are most likely to become podzolized are sandy soils which contain small amounts of bases, aluminum and iron and which easily become acid. In these soils the water-soluble organic compounds take up small amounts of aluminum and iron in the A horizons where they are released during the weathering of primary minerals.

As the organo-metallic complexes migrate downward, they will take up more aluminum and iron. Immobilization may occur either when sufficient amounts of aluminum and iron are adsorbed to form large immobile, polymerized organo-metallic compounds, or through desiccation, or when a horizon with a different ionic concentration or acidity (hydrolys) is encountered. Finally, precipitation of sesquioxides may result from oxidation of the organic component of the complex.

Most of the organic matter of a podzol Bh horizon (Schnitzer, 1969) and an ironpan of a Humic Podzol (McKeague et al., 1967) was soluble in dilute alkali and acid, indicating it was predominantly fulvic acid (FA). In solutions of purified fulvic acid and $AlCl_3$ and $FeCl_3$ at pH 4.0, Fe^{3+}-fulvic acid and Al^{3+}-fulvic acid complexes were water soluble when the metal/FA molar ratio was one but insoluble when the ratio was six (Schnitzer and Skinner, 1963). The molecular weight of fulvic acid was taken as 670 (Schnitzer and Desjardins, 1962). In the ironpan of a Humic Podzol the Fe^{3+}/FA molar ratio was about six (McKeague et al., 1967). The B horizons of several Canadian podzols had ratios of pyrophosphate extractable iron plus aluminum to fulvic acid between six and nine while the Ae horizons had ratios of 3.5 and 5.0 (McKeague, 1968).

Molar ratios expressed as metal/fulvic acid or metal/humic acid are rather inaccurate because of the difficulties in determining the molecular weight of organic matter fractions. Various authors, therefore, chose to use atomic ratios with respect to elemental carbon.

In laboratory experiments, aluminum- and iron-fulvic acid complexes were soluble up to an Fe/C atomic ratio of 0.2 and Al/C atomic ratio of slightly greater than 0.2 (McKeague et al., 1971). In dilute HCl extracts of the B horizons of a Canadian podzol, the (Al+Fe)/C atomic ratio was 0.2 (Schnitzer and Skinner, 1964). Similar results were obtained for a Russian podzol: (Al+Fe)/C ratios for the A2 and the two B horizons were 0.26, 0.12 and 0.15, respectively (Kononova and Bel'chikova, 1970). In other investigations, ratios of pyrophosphate extractable sesquioxides to total carbon were higher. B horizons of Canadian podzols had $(Al+Fe)_p/C_t$ atomic ratios of 0.28 to 0.92, while ratios of sodium hydroxide-tetraborate extractable sesquioxides to total C, $(Al+Fe)_{ht}/C_t$, varied between 0.05 and 0.17 (McKeague and Sheldrick, 1977). A similar range of ratios were obtained for B horizons of Belgian podzols: $(Al+Fe)_p/C_t$ ratios between 0.03 and 0.42 and $(Al+Fe)_{ht}/C_t$ ratios between 0.03 and 0.11 (Higashi et al., 1981). In these Belgian soils, the range of $(Al+Fe)_p/C_p$ ratios was 0.05 to 0.60 and that of $(Al+Fe)_{ht}/C_{ht}$ atomic ratios was 0.04 to 0.27.

In a study of Danish podzols, Petersen (1976) used C/Al, C/½Fe and C/(Al+½Fe) weight ratios. Sesquioxides were extracted with sodium dithionite-EDTA. C/(Al+½Fe) ratios in B horizons varied from 0.7 to 17; in A2 horizons from 11 to 120. Petersen also carried out several titration experiments where extracts of Ah horizon organic matter were titrated with solutions of $AlCl_3$ and $FeCl_3$. Fifty percent of the dissolved organic matter was precipitated at a C/Al weight ratio of 7.5 and C/½Fe ratio of 5.0. These are equivalent to Al/C and Fe/C atomic ratios of 0.06 and 0.09, respectively.

Also Ponomareva (1964) found that precipitation of iron required less organic matter (fulvic acid) than that of aluminum. Other authors also found that fulvic acid has a greater affinity for Fe^{3+} than for Al^{3+} (Kodama and Schnitzer, 1972; Schnitzer and Kodama, 1976), although Al^{3+} more readily precipitates the acids. Such differences might be instrumental in the differentiation of iron and aluminum maxima in podzol B horizons. This affinity may also explain the Fe and Al distributions in some Welsh soils (Adams et al., 1980). Iron exhibited the typical pattern of eluviation and illuviation but Al rarely accumulated in B horizons enriched in Fe.

Although the metal-carbon ratios for precipitation of organic matter, obtained by various authors, vary considerably, they suggest that the distribution of organic matter in eluvial and illuvial horizons of podzols is regulated by the amount of sesquioxides bound to organic matter, that saturation of organic matter with sesquioxides leads to mutual precipitation and that the transport of sesquioxides is regulated by this process.

This is contrary to the theory recently proposed by Farmer et al. (1980) that the transport of aluminum in podzols is by means of proto-imogolite. Imogolite and/or proto-imogolite have been found in podzol B horizons (Tait et al., 1978; Ross and Kodama, 1979; Farmer et al., 1980; Ross, 1980a; 1980b; McKeague and Kodama, 1981). This mineral has not been observed in eluvial horizons and in the upper part of illuvial horizons (Tait et al., 1978; Farmer et al., 1980). According to these authors large amounts of humic substances may inhibit the formation of imogolite in Bh horizons.

When immobilization occurs, the organo-metallic compounds are still surrounded by water of hydration (De Coninck, 1980). Water molecules and cations are trapped inside voids during the formation of large particles. A gel state results rather than a solid state. Dehydration occurs gradually under the influence of different factors: 1) decrease in charge when reacting with cations, 2) increase in concentration of ions inside the voids, and/or 3) desiccation. The gel gradually loses its water and changes into a solid state.

Some podzol B horizons are cemented while others are not. Cemented and uncemented horizons may have similar chemical composition (McKeague and Wang, 1980). The cemented B horizons in some European podzols are dominated by polymorphic pellets and aggregates (De Coninck, 1980). The monomorphic coatings are strongly cracked, indicating the transition from the gel to solid state. Uncemented horizons have many features indicating much biological activity, such as, many roots, thorough mixing of organic matter with silt and clay, and pedotubules (Wang et al., 1978; De Coninck, 1980). In some Canadian podzols cemented and uncemented horizons had similar fabrics (McKeague and Wang, 1980). Ortstein, cracked coatings and dark pellets are morphological requirements for a spodic horizon (Soil Survey Staff, 1975).

Biological activity and translocation of organo-metallic compounds, occur simultaneously. The relative intensities of these two processes determine the kind of podzol B horizon that will form (De Coninck, 1980). If biological activity predominates, the horizon will be loose. If the accumulation of organo-metallic compounds predominates the horizon will gradually become cemented. The dominant cementing material in ortstein horizons from podzols in France (Righi and De Coninck, 1977) and Canada (Miles et al., 1979; McKeague and Wang, 1980) was Al-organic matter complex.

In early stages of podzolization sufficient aluminum and iron is present in the surface layer and immobilization will occur near the soil surface. The soil will have a shallow B horizon. With time the B horizon will move to greater depths. The aluminum and iron contents of the A horizons will become lower and lower. The soluble organic compounds will have smaller and smaller amounts of aluminum and iron when they reach the B horizon. These compounds will then remove from the upper portion of the B horizon some of the aluminum and iron from the organo-metallic compounds which were immobilized earlier. This will mobilize some of the organic matter which had originally precipitated. This organic matter will migrate downward and may be immobilized at greater depths. This process may repeat itself many times. This could explain the thin lamellae with humus coatings found in podzols in the Netherlands (Van den Broek, 1965; De Bakker, 1979) and Belgium (Higashi et al., 1981).

This review indicates that the major controversies as well as research needs are in the carbon/sesquioxide ratios, the extraction methods, the presence and role of imogolite, and the differentiation of material in the podzol-B horizon. This study will therefore further evaluate the use of carbon/sesquioxide atomic ratios for describing podzols and the podzolization process; check the presence and discuss the role of imogolite, and evaluate the significance of complexation behavior of organic matter relative to differentiation in the podzol B horizon.

If carbon/sesquioxide ratios can be used describing the podzolization process, they may also provide a better separation between iron-less Gleyic Podzols and well-drained Orthic and Humic Podzols that are low in iron.

Because the choice of extraction method for iron and aluminum is of utmost importance, four widely used methods will be discussed in the next chapter.

5 Extractions of C, Fe and Al relative to the podzolization process

5.1 ORGANIC CARBON

Extraction of organic C has been done with several kinds of solutions: water, aqueous solutions of neutral salts, organic solvents, acid solutions, alkaline solutions, and complexing agents (Petersen, 1976). Water usually dissolves small amounts of organic compounds. Water extracted larger amounts of organic carbon from the Ao-A1 and B1 (Bh) than from Bs and C horizons of Danish podzols (Petersen, 1976).

Aqueous solutions of neutral salts extracted only small amounts of organic carbon from the A1 and B21 horizons of a Canadian podzol (Schnitzer et al., 1958).

In general, organic solvents such as alcohols, ethers and benzene are not effective extractants for organic compounds found in soil (Petersen, 1976).

Various organic and inorganic acids have been used to extract organic carbon from soils. The kind and concentration of the acid and the conditions of extraction determine the amount of organic carbon extracted. The kind of horizon also influences the amount extracted. Relatively large amounts of organic carbon were extracted from a Canadian podzol B21 horizon but only small amounts were extracted from the Ao horizon by 0.5% HCl and 0.5% HF (Schnitzer et al., 1958).

Alkaline solutions can extract a portion of the organic carbon from soils. The amount of organic carbon extracted depends on the concentration and kind of base and the kind of soil horizon. Of the various alkaline solutions (NaOH, KOH, NH_4OH, Na_2CO_3), sodium hydroxide is the most frequently used (Hayes and Swift, 1978). From a podzol, Schnitzer et al. (1958) extracted 24.8% of the total organic carbon from the Ao horizon and 96.3% from the B21 horizon using 0.5N NaOH. Only small differences in composition and properties of organic matter were found in 0.5N NaOH extracts from a podzol Ao and Bh horizon under air and nitrogen (Wright and Schnitzer, 1959). No significant differences were found in the elemental composition and content of functional groups of organic matter extracted by 0.5N NaOH and 0.1N HCl from a podzol B horizon (Schnitzer and Skinner, 1968). According to Hayes et al. (1975), sodium hydroxide was the best reagent for extracting humic materials from a wide range of soil materials.

Several organic and inorganic compounds can form complexes with metal ions thereby making the organic matter soluble. Sodium pyrophosphate, sodium fluoride, and EDTA extracted similar amounts (in excess of 80%) of organic carbon as did sodium hydroxide from a podzol B21 horizon but not from the podzol Ao horizon (Schnitzer et al., 1958). From the Ao horizon less than 10% was extracted by the complexing compounds where as about 25% was extracted by sodium hydroxide.

Based on their solubility in alkali and acid, humic substances can be divided into three fractions: humic acid, fulvic acid, and humin. Humic acid is soluble in dilute alkali but is precipitated by acidification of the alkaline extract. Fulvic acid is soluble in dilute alkali and remains soluble when the alkaline extract is acidified. Humin is not soluble in dilute alkali and acid.

Structurally the three humic fractions are similar, but they differ in molecular weight, analytical characteristics, and functional group composition (Schnitzer and Kodama, 1977). Fulvic acid has a lower molecular weight than humic acid and humin. Elemental and functional group analyses of humic acid and humin are similar but they differ from those of fulvic acid. Humic acid and humin contain more C, H, N and S but less oxygen than fulvic acid. Fulvic acid has more oxygen-containing functional groups (COOH, OH, C=O) per unit weight than humic acid and humin. The COOH content of fulvic acid is about two times greater than that of the other two fractions. The ratio of COOH to phenolic OH groups in fulvic acid is about 3 and that in humic acid and humin is about 2. For a more detailed discussion of the chemical composition and physical properties of humic substances, the reader is directed to articles by Schnitzer and Khan (1972), Flaig et al. (1975), Schnitzer and Kodama (1977), Hayes and Swift (1978), and Schnitzer (1978).

The differing carbon content of fulvic and humic acids has repercussions as to the method of carbon *determination* that is suitable for the present investigation.

5.2 IRON AND ALUMINUM

Many methods have been employed to determine amorphous iron and/or aluminum in soils with the objective of relating them to soil forming processes and soil classification. Acids and complexing agents extract both Fe and Al, reducing agents extract primarily Fe compounds, and alkaline solutions extract primarily Al compounds from soils.

Dithionite

Sodium dithionite was used as a reducing agent to dissolve iron oxides from soils (Deb, 1950). Some silicate minerals, such as montmorillonite were attacked. Kilmer (1960) modified this method to permit extraction at room temperature. Mitchell and MacKenzie (1954) recommended using 0.05N HCl and dithionite to prevent the precipitation of ferrous sulfide in the dithionite extracts. Aguilera and Jackson (1953) modified Deb's dithionite method by adding sodium citrate as a complexing agent. Mehra and Jackson (1969) modified the dithionite-citrate method by adding sodium bicarbonate to buffer the mixture at pH 7.3. This method completely dissolved crystalline iron oxides. Coffin (1963) replaced the sodium bicarbonate buffer with a citrate buffer of pH 4.75. Coffin's method did not extract all crystalline iron oxides but did attack nontronite. Holmgren (1967) extracted iron oxides using dithionite and a large excess of sodium citrate at room temperature.

Dithionite-citrate-bicarbonate is considered to extract the crystalline, amorphous and organically bound Fe from soils (Schwertmann, 1964; McKeague and Day, 1966; Blume and Schwertmann, 1969). It also extracts Al from organic complexes and non-crystalline hydrous oxides (Wada and Greenland, 1970; Tokashiki and Wada, 1975).

Oxalate

An oxalate buffer, pH 3.2-3.3, was used to extract 'colloidal' Fe and Al (Tamm, 1922), but silicate minerals were partially destroyed by this extractant (Tamm, 1932). The amount of Fe extracted increased when the extraction was done in sunlight (Schofield, 1949; Deb, 1950). Schwertmann (1959, 1964) found ammonium oxalate extracted only amorphous oxides when the extraction was done in darkness. Ammonium oxalate dissolves some crystalline iron oxides (Baril and Britton, 1967; McKeague et al., 1971; Schwertmann, 1973; Borggaard, 1976).

Ammonium oxalate extracts most of the Fe and Al from amorphous materials but not much from crystalline oxides (Schwertmann, 1964; McKeague and Day, 1966; Blume and Schwertmann, 1969). It also extracts aluminum and silica from allophane-like materials and to a lesser extent from imogolite.

The ratio of oxalate extractable Fe (Fe_o) to dithionite extractable Fe (Fe_d), also called the 'activity ratio', has been used as a relative measure of the crystallinity and mobility of free iron oxides and to separate Bhir horizons from B2t horizons in some German soils (Blume and Schwertmann, 1969). The Bhir horizons had higher values than B2t horizons. The Fe_o/Fe_d ratio distinguished brown podzolic soils from podzols in England and Wales (Loveland and Bullock, 1976).

Pyrophosphate

A 0.1M sodium pyrophosphate solution was used to extract Fe and Al from soils (Aleksandrova, 1960). The dissolution is due to direct complexation of the Fe and Al (McKeague, 1967). Franzmeier, et al. (1965) used a pyrophosphate-dithionite reagent (pH 7.3) to extract Fe, Al and C from soils, especially spodic horizons. McKeague (1967) found that pyrophosphate-dithionite extracted not only the amorphous Fe but also some crystalline Fe. A 0.1M potassium pyrophosphate solution (pH 10) extracted very little Fe from crystalline Fe oxides but successfully extracted amorphous organic complexes of Fe and Al (Bascomb, 1968). Organic C was also determined in the potassium pyrophosphate extract.

Pyrophosphate extracts all organic-complexed Fe and Al, and minor amounts of the non-crystalline hydrous oxides (McKeague, 1967; Bascomb, 1968). Ball and Beaumont (1972) regarded the Fe extracted by pyrophosphate (Fe_p) as the mobile fraction and the Fe_o as the mobile plus stable amorphous fraction. The stable amorphous fraction represented the aged amorphous hydrous oxides accumulated in situ.

Tetraborate

Sodium hydroxide-tetraborate has been introduced (Nguyen Kha and Bruckert, 1972) to extract organic-complexed Fe from soils. The only function of the tetraborate is to buffer the solution at pH 9.5. This solution extracted less Al and Fe from some podzol B horizons than did pyrophosphate (McKeague and Sheldrick, 1977; Higashi et al., 1981). Bruckert and Souchier (1975) and Higashi et al. (1981) concluded tetraborate removed only the organic-bound Al and Fe and pyrophosphate also removed some Al and Fe not bound by organic matter. On the other hand, McKeague and Sheldrick (1977) found tetraborate did not remove all of the Al and Fe from synthetic Al- and Fe-fulvic acid complexes but pyrophosphate did and therefore concluded tetraborate was not suitable for extracting organically bound Fe and Al from spodic horizons. Higashi and Shinagawa (1981) concluded pyrophosphate was more effective extractant of Al- and Fe-humus complexes in A1 horizons of Dystrandepts than was tetraborate.

6 Present criteria for spodic or podzol B horizons

The criteria used to define the podzol B horizon or spodic horizon vary considerably. In some countries only morphological criteria are used, while in others both morphological and chemical criteria are used.

6.1 USSR

When Dokuchaiev first applied the term 'podzol', it referred to a group of soils with a bleached horizon (Muir, 1961). Later, Zakharov in 1906 advocated the recognition of an illuvial horizon as part of the podzolic profile. In the USSR podzols are subdivided based on the degree of podzolization (Ivanova and Rozov, 1960). Weakly, moderately, and strongly developed podzols are defined on the basis of the ratio of the thickness of the A1 horizon to that of the A2 horizon. If the ratio is greater than 1, the podzol is weakly developed, if equal to 1 it is moderately developed, and if less than 1 it is strongly developed (Tavernier, 1963).

6.2 FEDERAL REPUBLIC OF GERMANY

Early German workers recognized the bleached horizon and the "Ortstein"; Senft described such a podzol in 1862 (Muir, 1961). This concept of a bleached, eluvial horizon and an illuvial horizon, "Ortstein" or "Orterde", continues today. In the present German classification system (Arbeitsgemeinschaft Bodenkunde, 1971) a podzol is a soil with an O-Ah-Ae-B-C profile. Podzols are differentiated only on morphological properties, including:

1 Texture and parent material
2 Depth to lower boundary of B horizon

Solum < 5 cm	very shallow (Micropodzol)
Solum 5 - 20 cm	shallow (Shallow Podzol)
Solum 20 - 40 cm	medium (Medium Podzol)
Solum > 40 cm	deep (Deep Podzol)

3 Cementation of the B horizon
    Weakly cemented or no cementation (Orterde)
    Medium cemented ("firm" Orterde)
    Strongly cemented (Ortstein)
4 Thickness of the B horizon
5 Thickness and kind of raw humus layer (O horizon)
6 Thickness of the Ae horizon
7 Thickness and humus content of Ah horizon
8 Degree of erosion: Podzol with truncated profile.

<u>Subdivisions</u>:

Type	Subtype	Profile
Podzol	Iron-humus Podzol (Normaler Podsol = Eisenhumuspodsol)	O-Ah-Ae-Bhs-C
	Iron Podzol (Eisenpodsol)	O-A-Ae-Bs-C
	Humus Podzol (Humuspodsol)	O-Ah-Ae-Bh-C
	Ironpan Podzol (Bändchenpodsol)	
	Brown Earth Podzol (Braunerde-Podsol)	O-Ah-Ae-Bhs-Bv-C
	(Gray Wooded) Podzol (Parabraunerde-Podsol)	O-Ah-Ae-Bhs-Al-Bt-C
	Pseudogley Podzol (Pseudogley-Podsol)	O-Ah-Ae-Bhs-S
	Gley-Podzol (Gley-Podsol)	O-Ah-Ae-Bhs-G
	Peat-Podzol (Hochmoor-Podsol)	Hh-Ah-Ae-Bsh-Bv-C

6.3 NETHERLANDS

In the Netherlands the *podzol B horizon* is an illuvial horizon in which amorphous humus with or without sesquioxides have accumulated or sesquioxides with non-amorphous humus have accumulated (De Bakker and Schelling, 1966). The *prominent podzol B horizon* has the following characteristics below 20 cm depth:

1 a B2h horizon of at least 3 cm thickness with a color value of 2 or less and a chroma of 1.5 or less; and/or

2 a B2 horizon with color value differences between the B2 and the C horizon as follows:

<u>thickness of the B2</u>	<u>value difference</u>	
0 - 5 cm	> 3	
5 - 20 cm	> 2	
20 - 30 cm	> 1.5	
> 30 cm	> 1	;or:

3 a B horizon, which continues to a depth of 120 cm, with a color value of 5.5 or less; or:

4 a reworked B horizon with lumps of B2 differing more than 1.5 value from the C horizon.

A *prominent humuspodzol B horizon* is a prominent podzol B horizon with below 20 cm depth (1) a B2h horizon or (2) amorphous organic matter in at least the upper part of the B horizon. This horizon may or may not contain iron.
A *prominent moderpodzol B horizon* is a prominent podzol B horizon with below 20 cm depth (1) no B2h horizon and (2) non-amorphous organic matter, usually

moder, in the B horizon. This horizon must contain iron (De Bakker and Schelling, 1966).

Subdivisions

Order	Suborder	
Podzol	Moderpodzol	Organic C and Fe, not amorphous
	Hydropodzol	Organic C with little or no Fe and hydromorphic characteristics
	Xeropodzol	Organic C with little or no Fe

6.4 ENGLAND AND WALES

In England and Wales the *podzolic B horizon* was defined by the following characteristics (Avery, 1973; Avery et al., 1977):

1 usually underlies a bleached E horizon or a dark Ah, H or O horizon in which the mineral grains are uncoated;

2 begins within 1.5 m of the soil surface;

3 extends to at least 15 cm depth, excluding surface litter (L, F);

4 the following horizons can form all or part of a podzolic B horizon:

Bh at least 2.5 cm thick;
contains translocated organic matter and Al, or Fe and Al;
it is darker and has more organic C (0.6 percent) than an overlying E horizon, if present;
contains more Al_p* and Fe_p than an overlying E or A horizon;
if the Fe_d content exceeds 0.3 percent, both value and chroma are 3 or less.

Bs at least 5 cm thick;
contains Fe and Al with organic matter;
has organo-ferruginous coatings on mineral grains and/or sand or silt size, pelletlike, peds;
value and/or chroma are more than 3;
Fe_p plus Al_p exceed 0.3 percent;
Fe_p plus Al_p divided by percent clay is greater than 0.05.

Bf less than 5 mm thick;
black to dark brown;
brittle or cemented;
enriched in Fe_p and C_p.

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* Al_p, Fe_p and C_p are pyrophosphate extractable Al, Fe and C; Al_d and Fe_d are dithionite-citrate extractable Al and Fe; Al_o and Fe_o are ammonium oxalate extractable Al and Fe.

Ragg et al. (1978) proposed a ratio of Fe_p to Fe_d of greater than 0.36 for B horizons of podzols. This ratio was more effective in separating podzols from non-podzols in Scotland than $(Fe_p + Al_p) \div \text{clay} \geq 0.05$.

Recently the *podzolic B horizon* has been redefined as a B horizon in which amorphous materials containing C and Al, Fe, or both have accumulated, either by illuviation or by weathering *in situ* (Avery, 1980). the B horizon has the following requirements:

1 Qualifies as a Bh, Bs or Bf, or comprises some combinations of these horizons.

Bh - contains translocated organic matter with Al, or Al and Fe in coatings on sand and silt particles or in sand or silt-size aggregates;
- is darker and has more organic matter than an overlying eluvial horizon;
- contains more $Al_p + Fe_p$ than an overlying E or A horizon; may be cemented;
- has organic $C \geq 0.6\%$ and may or may not contain significant amounts of Fe;
- have value and chroma of 3 or less if $Fe_d > 0.3\%$.

Bs - has moist value and/or chroma of 4 or more;
- contains $Al_p + Fe_p > 0.3\%$;
- has $(Al_p + Fe_p) \div \text{clay} \geq 0.05$;
- reacts positively to the NaF test for reactive hydroxy-Al;
- contains sand or silt-size pellet-like aggregates, sesquioxidic coatings on mineral grains, or both.

Bf - is black to reddish brown;
- is brittle or cemented (ironpan);
- is < 10 mm thick;
- is enriched in Fe_p and C_p.

2 Moist chroma is greater than 3, or the value is 3 or less.

3 Begins within 120 cm depth;
underlies an E, A, H, or O horizon;
extends below 15 cm depth, excluded fresh or partially decomposed litter.

4 At least 10 cm thick if there is no overlying E horizon and it is composed only of a Bs horizon; or
at least 2.5 cm thick if it consists only of a Bh horizon lying below an E horizon.

In addition podzolic B horizons usually have the following associated properties:

a high pH dependent CEC; the difference between CE (pH 8) and CEC (soil pH) ≥ 8 meq/100 g soil.

b large water holding capacity relative to particle size distribution, when not cemented.

c $C_p \div C_t \geq 0.3$ (>0.5 in well-expressed horizons)
$Fe_p \div Fe_d > 0.3$ (>0.5 in well-expressed horizons).
d high P retention capacity.
e high fluoride reactivity.

Subdivisions

Major group	Group	
Podzolic soils	Brown podzolic soils	Bs horizon, no E horizon
	Humic cryptopodzols	thick, humose Bh horizon
	Podzols	E horizon and distinct Bh horizon
	Gley-podzols	E and Bh with gleying below B horizon
	Stagnopodzols	gleyed E over Bs horizon, or thin iron pan below peaty topsoil, E or Bh horizon

6.5 CANADA

The definition of the *podzolic B horizon* in Canada has been modified several times. In 1963 the National Soil Survey Committee of Canada defined a Bf horizon as a horizon enriched with Fe and having a chroma of 3 or more and redder than the horizon above or below (McKeague and Day, 1966) In 1966 McKeague and Day proposed Bf horizons be required to have $\Delta(Fe + Al)$* greater than 0.8 percent or have at least 1 percent more Fe_d than the C horizon.

Clark et al. (1966) proposed to use pH-dependent CEC as an additional means of defining podzolic B (spodic) horizons. A pH-dependent portion of the CEC of 8 meq/100 g soil was suggested as the lower limit for podzolic B horizons. The horizons were also required to meet the appropriate organic matter and free oxide limits: Bf must contain 0.5 to 5% organic matter and have $\Delta(Fe + Al) > 0.8\%$.

In 1974 the Canada Soil Survey Committee (1974) defined Podzolic Soils as soils with Podzolic B horizons (Bh, Bhf, Bfh or Bf horizons). The Bf, Bfh and Bhf horizons were required to have $\Delta(Fe + Al) > 0.8\%$. The Bh horizons usually had $\Delta(Fe + Al) < 0.8\%$. The organic matter content of the Bf is <5%, of the Bfh is 5-10% and of the Bhf is >10%. The Bh has >2% organic matter and a ratio of organic matter to Fe_o of 20 or more. The Bh has a color value and chroma of 3 or less when moist. McKeague (1967) found that horizons which had $\Delta(Fe + Al)$ greater than 0.8% also had Fe_p plus Al_p greater than 0.65%.

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* $\Delta(Fe + Al)$ = percentage oxalate-extractable Fe plus Al in a Bf horizon minus percentage oxalate-extractable Fe plus Al in the C horizon.

A limit of 0.6% Al_o gave good separation of podzolic B horizons from other horizons (McKeague and Day, 1969). Baril and Tran (1977) found Fe_p plus Al_p and its ratio over clay were useful to classify podzols. The limits proposed were $Fe_p + Al_p \geq 0.6\%$ and $(Fe_p + Al_p) \div \text{clay} \geq 0.05$. Podzolic horizons appeared to be separated from non-podzolic horizons using a value of 6 meq/100 g for the organic pH-dependent CEC (Clark and Nichol, 1968).

The Canada Soil Survey Committee (1978) defined a podzolic B horizon as having the following morphological and chemical properties:

Morphological:

1 at least 10 cm thick;
2 moist color is black or the hue is 7.5YR or redder or 10YR near the upper boundary and becomes yellower with depth. The chroma is greater than 3 or the value is 3 or less;
3 accumulation of amorphous material is indicated by brown to black coatings on some mineral grains or brown to black micro-aggregates. The material feels silty when rubbed wet, unless it is cemented;
4 texture is coarser than clay.

Chemical:

1 if it is a Bh subhorizon very low in Fe, it must be at least 10 cm thick and have organic C > 1%, $Fe_p < 0.3\%$, and organic $C/Fe_p \geq 20$;
2 if it is a Bf or Bhf subhorizon with appreciable Fe and Al, it must be at least 10 cm thick and have organic C > 0.5%, $Al_p + Fe_p > 0.6\%$ if finer than sand, $Al_p + Fe_p \geq 0.4\%$ if sand, $(Al_p + Fe_p)/\text{clay} > 0.05$, and $Fe \geq 0.3\%$ and/or organic $C/Fe_p < 20$.
Several ortstein horizons in Canadian podzols did not have the required organic C or extractable Al and Fe contents of the podzolic B horizon (Wang et al., 1978; Miles et al., 1979; McKeague and Wang, 1980).

Subdivisions

Order	Great Groups	
Podzolic	Humic Podzol	High organic C relative to Fe, usually associated with wetness
	Ferro-Humic Podzol	High organic C with Fe and Al
	Humo-Ferric Podzol	Low organic C with Fe and Al

6.6 FRANCE

While soil classification in France is not based on diagnostic horizons, the general criteria used for the distinction of the B horizon of 'sols podzolisés' are virtually identical to those in other countries, i.e. (CPCS, 1967):

- a high content of 'free' sesquioxides with respect to the parent material
- a high content of organic matter (> 0.5%) with a C/N ratio > 14, and a higher content of organic matter than the A_2 horizon.
- presence of coatings of iron and organic matter on mineral grains
- presence of silt size iron oxide and organic matter pellets.

The degree of development of the 'sols podzolisés' is related to the intensity of the ashy color of the A_2 horizon (Tavernier, 1963), but the subdivisions of the classification are based on climate and hydrology (CPCS, 1967). Bruckert (1979) proposed using the Fe/Al ratio from buffered tetraborate extracts (pH 9.5) to classify brown soils (sols bruns) and podzolized soils (sols podzolisés). Podzolized soils had a ratio greater than 1 and brown soils a ratio less than 1.

<u>Subdivisions</u>

Classe : Sols podzolisés (podzolized soils)

Sous classe : Sols podzolisés de climat tempéré (podzolized soils of temperate climates)

Groupe : Podzols

Sous groupes
Podzols humiques (humic podzols; Bh, no Bfe)
: Podzols ferrugineux (iron podzols; Bfe, no Bh)
: Podzols humo-ferrugineux (humus-iron podzols; Bh & Bfe)
: Sols humo-cendreux (humic ashy soils; A2, but no B)
: Podzols de hydromorphie profonde (podzols with deep hydro-morphism; gley in or below B)

Groupe : Sols podzoliques ('podzolic' soils)
No Bh horizon, but distinct Bfe; well developed but not ashy A_2. Contains five subgroups.

Groupe : Sols ocre-podzoliques (ochreous podzolic soils)
A_2 horizon discontinuous or absent; Bfe with strong color. Contains two subgroups

Groupe : Sols cryptopodzoliques (cryptopodzolic soils)
No A_2 horizon. Podzolization apparent in thin sections and chemical analyses only. Reddish brown B horizon. Contains two subgroups.

Sous classe : Podzols de climat froid (podzols of cold climates)
Thinner A_2 horizon; higher base saturation. Contains two groups.

Sous classe : Sols podzolisés hydromorphes (hydromorphic podzolized soils)

Groupe	: Podzols à gley (gley podzols) With gley phenomena very close to the surface. Contains two subgroups.
Groupe	: Molken podzols Profile: A_0, g, B,C. Permanent water table.
Groupe	: Podzols de nappe tropicaux: (tropical groundwater podzols) Very thick A_2 and concretionary B horizon.

6.7 AUSTRALIA

In Australia podzols are defined as acid, sandy soils with a gray A1 horizon, a thick whitish sand A2 and a B horizon with an accumulation of organic matter and/or sesquioxides (Stace et al., 1968). Australian podzols seldom have a continuous O horizon.

6.8 NEW ZEALAND

In New Zealand Podzol soils are called Podiform soils and have a prominent O horizon; an ash-gray, structureless, silica-rich A2 horizon; and usually, but not always, a humus and iron enriched illuvial horizon (Taylor and Pohlen, 1968). The A2 horizon is the main differentiating characteristic.

6.9 UNITED STATES

In the 1938 soil classification system (Byers et al., 1938) the B2 horizon of Podzols was defined as having an accumulation of humus, iron and aluminum and a clay content that was not unusually high. The *spodic horizon* is basically the same concept as the original concept of the Podzol B horizon (Soil Survey Staff, 1960). A spodic horizon had the following properties:

1 amorphous coatings of humus and allophane or of humus, allophane, and free sesquioxides on particles of sand or silt; or rounded to subangular pellets of humus or of humus and sesquioxides between 20 and 50 μm in diameter; or both.
2 more than 0.29% organic C or 1% free sesquioxides in some part.
3 no clay skins; under crossed polarizers coatings in thin sections show slight or no birefringence and no extinction on rotation, which indicates substance forming the coatings are not both crystalline and oriented.
4 no structure; or structure other than blocklike; or blocklike structure only if the grade of structure is weak.
5 C/N ratio of more than 14, if profile is virgin.
6 SiO_2/R_2O_3 ratio in clay fraction less than that in clay fraction of overlying A2 or albic horizon and less than that in clay fraction of parent material.

Horizons are not considered to be spodic if they are so thin, are so near the surface, and are so weakly expressed that the cutting of a forest and plowing a few times to a depth of 6 to 7 in. obliterates all traces.

Franzmeier et al. (1965) proposed the following criteria for the spodic horizon:

1 $\frac{CEC_{moist} - CEC_{240°C}}{CEC_{moist}} \times 100 > 30$

2 $(C + Fe + Al)^* \div clay > 0.15$

In the 1967 supplement (Soil Survey Staff, 1967) to the 7th Approximation the spodic horizon criteria were revised:

1 If an O, A, Al, or albic horizon overlies the spodic horizon, the spodic horizon has:
  a a 15-bar water content of less than 20%;
  b less than 60% volcanic ash, pumice and other pyroclastic materials in the 20-200 μm fraction;
  c enough amorphous material that $\frac{(C + Fe + Al)^*}{Clay} \geq 0.15$;
  d a thickness of 1 cm or more, either as a continuous horizon or as a sum of lamallae;
  e moist colors of 7.5YR or redder and moist values of 3 or less in some continuous part of the horizon or in any one subhorizon that is at least 1 cm thick and hues as red or redder than the underlying horizon, or $(C + Fe + Al)^* = 1\%$;
  f enough depth that the horizon is not obliterated by plowing to 18 cm or enough degree of expression that the horizon after mixing to 18 cm meets criteria under 2.

2 If an Ap is present and is not underlain by a diagnostic subsurface horizon other than a fragipan, with or without an albic horizon, the Ap is considered a spodic horizon if it has the following properties:
  a contains more than 3% organic matter (1.7% organic C);
  b $(C + Fe + Al)^* \div clay \geq 0.20$;
  c fragments of amorphous coatings or pellets can be clearly identified;
  d the hue is redder than 10YR and the moist color value less than 3, or the chroma is 3 or more in hues of 10YR or redder;
  e a 15-bar water content of < 20%;
  f less than 60% volcanic ash, pumice, or other pyroclastic material in the 20-200 μm fraction.

When Soil Taxonomy (Soil Survey Staff, 1975) was published, the criteria for the spodic horizon had been revised again. A spodic horizon is normally a subsurface horizon that underlies an O, Al, Ap or A2 horizon. It may, however, meet the definition of an ochric or umbric epipedon. A spodic horizon

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* Pyrophosphate-dithionite extractable.

has the morphological or the chemical and physical characteristics that are listed below, and its hue and chroma remain constant with increasing depth or the subhorizon that has the reddest hue or the highest chroma is near the top of the horizon. The color changes within 50 cm from the top of the horizon. A thin black horizon that has a color value of 2 or less may overlie this horizon. If the soil temperature regime is frigid or warmer, some part of the spodic horizon must meet one or more of the following requirements below a depth of 12.5 cm or below any Ap horizon that is present. If the soil temperature regime is cryic or pergelic, there is no requirement for depth. In addition, the spodic horizon must meet one or more of the following requirements:

1 Have a subhorizon 2.5 cm thick that is continuously cemented by some combination of organic matter with iron or aluminum or both;

2 have a particle-size class that is sandy or coarse loamy, and sand grains are covered with cracked coatings or there are distinct pellets of coarse-silt size, or both; or

3 have one or more subhorizons in which,

   a If there is 0.1% or more extractable Fe,
   $$\frac{\%\ Fe_p + Al_p \text{ at pH } 10}{\%\ \text{clay}} \geq 0.2,$$ or if there is < 0.1% extractable Fe,
   $$\frac{\%\ Al_p + C_p}{\%\ \text{clay}} \geq 0.2,$$ and

   b $$\frac{\%\ Fe_p + Al_p}{\%\ Fe_d + Al_d} \geq 0.5,$$ and

   c The combined index of accumulation of amorphous material must be 65 or more. The index for each subhorizon is calculated by subtracting half of the clay percentage from CEC at pH 8.2 and multiplying the remainder by the thickness of the subhorizon in centimeters. The results for all subhorizons are then added and the total must be 65 or more.

Subdivisions

Order	Suborder	Criteria
Spodosol	Aquods	Wet
	Ferrods	High percentage of Fe relative to organic C
	Humods	High percentage of organic C relative to Fe
	Orthods	About equal amounts of Fe and C

6.10 FAO-UNESCO

The FAO-Unesco system (Food and Agriculture Organization, 1974), defines the spodic B horizon similar to that in Soil Taxonomy. A spodic B horizon must have one or more of the requirements (1, 2 or 3 above) below a depth of 12.5 cm, or, when present, below an Ap horizon.

Subdivision

Unit	Subunit	
Podzols	Placic Podzols	thin ironpan in or over B horizon
	Gleyic Podzols	hydromorphic properties within 50 cm
	Humic Podzols	contains humus, little or no Fe
	Ferric Podzols	% free Fe/% organic C ≥ 6
	Leptic Podzols	thin or no E horizon, no B horizon enriched with carbon
	Orthic Podzols	other Podzols

The soil classification systems of Canada, England and Wales, FAO-Unesco and United States all use the ratio of $(Al_p + Fe_p) \div clay$, but the limiting value varies. Both the Canadian and English systems use 0.05 as the critical value while the FAO-Unesco and U.S. systems use 0.20. Several researchers (De Kimpe and Martel, 1976; Baril and Tran, 1977; Avery et al., 1977; Singer et al., 1978; Knuteson and Harpstead, 1980; Stanley and Ciolkosz, 1980) have found soils which morphologically appear to be Spodosols or Podzols but do not have $(Al_p + Fe_p) \div clay \geq 0.20$. Avery et al. (1977) and Adams et al. (1980) found some soils which did not appear morphologically to be Spodosols or Podzols did have $(Al_p + Fe_p) \div clay \geq 0.05$. De Kimpe and Martel (1976) proposed a critical value of 0.10 be used to define the spodic horizon or podzol B horizon.

All values have an empirical rather than a theoretical background. The differences are due to the populations of podzols that occur within a given country.

However, values of chemical characteristics that are derived from processes that play a role in podzolization might be more generally applicable. This thought is pursued in the present investigation.

7 Methods

Soil samples were air dried and crushed to pass through a 2 mm sieve. After removal of organic matter with H_2O_2 and washing free of salts, particle size distribution was determined by sieving the greater than 50 µm fraction and by pipette method for the less than 50 µm fraction (Kilmer and Alexander, 1949). Soil pH was determined using a 1:2.5 soil:water ratio and using a 1:2.5 soil:1 N KCl ratio.

For some profiles (Table 1) CEC was determined at pH of the soil and pH 8.2 by saturating with $BaCl_2$, exchanging with Mg and titrating excess Mg (Bascomb, 1964). For the other profiles CEC was determined at pH 7.0 by leaching with NaOAc and NH_4OAc (modified from USDA, 1972). Air-dried soil was saturated with Na by leaching the samples with 1 N NaOAc (pH 7.0). Excess Na was removed by washing with 95% ethanol. Adsorbed Na was replaced by leaching with 1 N NH_4OAc (pH 7.0). Na in the leachate was determined by atomic absorption spectrophotometry.

Total organic carbon (Ct) was determined using wet combustion. Organic carbon was estimated for some profiles (Table 1) using rapid titration (Walkley and Black, 1934). For the other profiles total organic carbon was measured by potentiometry (Van Oostrum and Mokma, this volume). Organic carbon was also measured in 0.5 N NaOH using a 1:10 soil:solution ratio (Ch) (Schnitzer et al., 1958; Schnitzer and Skinner, 1968; Chen et al., 1978). Organic carbon in the supernatant was determined potentiometrically (Van Oostrum and Mokma, this volume).

Al and Fe were determined in sodium dithionite-citrate, ammonium oxalate and sodium pyrophosphate extracts (Al_d and Fe_d; Al_o an Fe_o; Al_p and Fe_p, respectively) (USDA, 1972). All three extracts of the same soil sample were made during the same 24 hr period. A reference sample was extracted with each batch. Al and Fe were determined by atomic absorption spectrophotometry (Perkin Elmer model 460) on the same day as the extracts were made. C was determined using a carbon auto analyzer (Beckman model 915B) on the same day as the extracts were made. Standard deviations and means of the analyses on the reference sample are reported in Table 2.

To examine for the presence of imogolite with an electron microscope, the air-dry, < 2 mm material was treated with H_2O_2 to remove organic matter and then was adjusted to pH 4. The < 2 µm fraction was separated by sedimentation and the < 0.2 µm fraction was separated by centrifugation. Electron microscope examination was made with a Philips EM 400 transmission electron microscope on specimens prepared by allowing a drop of dilute clay suspension to dry at room temperature on a carbon-coated, copper grid.

Table 1 Soil profiles in this study and the methods used for their CEC and organic C determinations

CEC		Organic C	
$BaCl_2$	NH_4OAc	Potentiometry	Rapid Titration
NL-101	CDN-13	NL-101	CDN-13
NL-102	CDN-14	NL-102	CDN-24
NL-103	CDN-24	NL-103	D-11
NL-104	D-11	NL-104	F-2
NL-105	F-2	NL-105	IRL-9
NL-106	F-10	NL-106	N-1
NL-107	IRL-1	NL-107	N-2
NL-108	IRL-9	NL-108	NL-2
NL-109	N-1	NL-109	S-2
NL-110	N-2	NL-110	S-9
B-101	NL-2	B-101	S-10
B-102	S-2	B-102	S-14
B-103	S-9	B-103	S-15
B-104	S-10	B-104	S-16
B-105	S-14	B-105	SF-4
B-106	S-15	B-106	SK-3
	S-16	USA-1	SK-4
	S-17	GMC-4	
	SF-4	GMC-6	
	SK-2	GMC-7	
	SK-3	GMC-8	
	SK-4	GMC-13	
	GMC-4	CDN-14	
	GMC-6	F-10	
	GMC-7	IRL-1	
	GMC-8	S-17	
	GMC-13	SK-2	
	USA-1		

Table 2 Mean and standard deviation of Al, Fe and C extractions from the reference sample, a B21ir horizon of Becket soil series.

Extractant	Element	Mean(%)	Standard deviation	Number of determination
Dithionite-citrate	Al	0.48	0.05	26
	Fe	0.77	0.05	27
Oxalate	Al	1.03	0.07	28
	Fe	0.38	0.03	30
Pyrophosphate	Al	0.38	0.02	27
	Fe	0.17	0.01	27
	C	1.22	0.08	24
Hydroxide	C	1.39	0.11	11
Total C	C	1.90	0.04	15

8 Materials

For this study soil samples were obtained from three sources:

1) ten soil profiles in the Netherlands; six soil profiles in Belgium and one soil profile in Michigan, U.S.A. described and collected by the authors;
2) 23 soil monoliths in the International Soil Museum collection and
3) five soil monoliths collected by Russian soil scientists for the First International Congress of Soil Science held in 1927 (section 8.1).

Soil profiles were described according to FAO Guidelines (FAO, 1977). Detailed profile descriptions of the Dutch, Belgian and Michigan profiles collected by the authors as well as of the Russian profiles are given in Appendices 1 and 2. Descriptions of the profiles from the museum collection can be obtained from ISM. A large number of the profiles used in this study have been selected for photographic representation on the colour plate "Podzols and related soils", which is issued as a separate sheet.

8.1 USSR PODZOL MONOLITHS

Russian soil scientists prepared many soil monoliths for display at the First International Congress of Soil Science held in Washington D.C. in 1927. The monoliths did not arrive in time for display at the Congress (Truog, 1928). The U.S. Department of Agriculture received custody of them and placed them in storage (Bailey, 1980). In 1954 or 1955 Roy W. Simonson and C.C. Nikiforoff placed many of the monoliths on display at the Beltsville Agricultural Research Centre. In an attempt to preserve the collection, the monoliths were treated with poured vinyl resin (laminac thinned with styrene). They were on display until 1961 and then returned to storage. In 1979 the monolith collection was donated to the International Soil Museum and is now known as the "Glinka Memorial Collection". Soil samples from some of the monoliths were removed and stored with the U.S. National Soil Survey Laboratory. A tentative placement in the U.S. soil taxonomic system was also made. After the monoliths arrived at the International Soil Museum in 1980, those monoliths which had been tentatively classified as Spodosols were selected for study (Monolith numbers 4, 6, 7, 8 and 13 assigned by C.C. Nikiforoff and numbers 24, 26, 27, 28 and 33 assigned by Russian soil scientists for the Congress).

Brief descriptions of the five monoliths as they were given in the original publication (Anonymous, 1927) follow.

Monolith 24 - Peaty - podzolized - gley soil on sandy loam. Pine-forest with an undergrowth of Vaccinium myrtillus and moss-cover. Leningrad - Okhta forestry.

Monolith 26 - Podzolized soil with ortstein on heavy loam. Forest meadows. Plain south of Pskov gvt. Velikiye Luki district.

Monolith 27 - Podzolized soil without ortstein on boulder loam. Skirt of deciduous forest. Leningrad gvt. Leningrad district.

Monolith 28 - Sandy-loamy podzol. Meadow over the terrace of Slavianka River. Leningrad gvt. Trotsk district.

Monolith 33 - Sandy-loamy podzol. Fir-forests with moss-cover. Over a slope towards a swamp. Tver gvt. Rzhev district.

Brief descriptions of the five monoliths as prepared by C.C. Nikiforoff (Bailey, 1980) follow (number in parenthesis are those assigned in the original publication).

Monolith GMC* 4 (24) - Podzolized peaty-gley soil with a distinct bleached G horizon. Developed under poorly drained, predominantly coniferous forest (spruce, pine, with birch). Okhta forest, near Leningrad (about 60°N, 30°E).

Monolith GMC 6 (26) - Podzolic soil with ortstein from Velikiye Luki region (about 56°N, 30°E).

Monolith GMC 7 (27) - Podzolic soil without ortstein developed from glacial drift (boulder loam). Sablino, near Leningrad (about 60°N, 30°E).

Monolith GMC 8 (28) - Sandy podzol on the terrace of Slavianka River, Gatchina district, near Leningrad.

Monolith GMC 13 (33) - Sandy podzol under spruce forest with hypnum moss. Nearly flat area near the sphagnum peat-bog in the Rzher district of Kalinin oblast.

* (GMC denotes Glinka Memorial Collection)

Because vinyl resin had been poured on the front of the monoliths, soil samples for chemical and physical analyses could not be taken from the front side. To obtain samples which were not affected by the vinyl resin, it was decided to remove material from the back of the monoliths. To obtain the samples, 2.5 cm thick styrofoam was cut to fit inside the monolith box and placed on the front of the monolith. The front of the box was replaced and the back of the box was removed. The styrofoam expanded and pushed the monolith out the back of the box 1 to 1.5 cm. The horizons were identified and described. Because some of the vinyl resin may have run along the sides of the box when it was poured on the front of the monolith, about 1 cm thickness of the soil which extended beyond the sides of the box was removed and discarded. The remaining soil which extended beyond the box was then removed for laboratory analysis.

Classification of the soils studied according to the FAO-Unesco System (FAO, 1974) and Soil Taxonomy (Soil Survey Staff, 1975) is given in Table 3.

Table 3 Classification of the soils investigated.

Profile Number	Country	FAO-Unesco	Soil Taxonomy
NL-101	Netherlands	Orthic Podzol	Typic Haplohumod
NL-102	Netherlands	Gleyic Podzol	Aeric Haplaquod
NL-103	Netherlands	Gleyic Podzol	Aeric Haplaquod
NL-104	Netherlands	Orthic Podzol	Typic Haplohumod
NL-105	Netherlands	Orthic Podzol	Typic Haplorthod/Haplohumod
NL-106	Netherlands	Cambic Arenosol	Spodic Udipsamment
NL-107	Netherlands	Orthic Podzol	Plaggeptic Haplohumod
NL-108	Netherlands	Humic Podzol	Typic Haplohumod
NL-109	Netherlands	Orthic Podzol	Aquic Haplorthod
NL-110	Netherlands	Humic Podzol	Typic Haplohumod
B-101	Belgium	Orthic Podzol	Typic Haplorthod
B-102	Belgium	Gleyic Podzol	Aeric Haplaquod
B-103	Belgium	Gleyic Podzol	Aeric Haplaquod
B-104	Belgium	Gleyic Podzol	Typic Haplaquod
B-105	Belgium	Gleyic Podzol	Aeric Haplaquod
B-106	Belgium	Gleyic Podzol	Typic Haplaquod
SER-3	Switzerland	Ranker	Lithic Cryumbrept
SER-10	Switzerland	Dystric Cambisol	Typic Dystrochrept
CDN-13	Canada	Dystric Cambisol	Typic Fragiochrept
CDN-14	Canada	Gleyic Podzol	Typic Haplaquod
CDN-24	Canada	Dystric Cambisol	Dystric Cryochrept
D-11	Germany	Dystric Cambisol	Typic Dystrochrept
F-2	France	Dystric Cambisol	Typic Dystrochrept
F-10	France	Cambic Arenosol	Spodic Udipsamment
IRL-1	Ireland	Cambic Arenosol	Spodic Udipsamment
IRL-9	Ireland	Placic Podzol	Typic Placohumod
N-1	Norway	Calcaric Regosol	Typic Cryorthent
N-2	Norway	Gleyic Podzol	Placic Haplaquod
NL-2	Netherlands	Cambic Arenosol	Typic Udipsamment
S-2	Sweden	Dystric Cambisol	Typic Dystrochrept
S-9	Sweden	Orthic Podzol	Tupic Cryorthod
S-10	Sweden	Orthic Podzol	Typic Cryohumod
S-14	Sweden	Cambic Arenosol	Typic Cryopsamment
S-15	Sweden	Humic Podzol	Typic Cryohumod
S-16	Sweden	Dystric Cambisol	Dystric Cryochrept
S-17	Sweden	Orthic Podzol	Typic Cryorthod
SF-4	Finland	Cambic Arenosol/ Orthic Podzol	Spodic Udipsamment/ Typic Cryorthod
SK-2	Sarawak (Mal.)	Humic Podzol	Tropohumod
SK-3	Sarawak (Mal.)	Cambic Arenosol	Typic Tropopsamment
SK-4	Sarawak (Mal.)	Cambic Arenosol	Typic Tropopsamment
GMC-4	Soviet Union	Gleyic Podzol	Typic Cryaquod
GMC-6	Soviet Union	Orthic Luvisol	Typic Glossoboralf
GMC-7	Soviet Union	Orthic Luvisol	Aquic Cryoboralf
GMC-8	Soviet Union	Orthic Podzol	Typic Haplorthod
GMC-13	Soviet Union	Gleyic Acrisol	Aquic Hapludalf
USA-1	United States	Orthic Podzol	Typic Haplorthod

9 Results and discussion

9.1 PARTICLE SIZE DISTRIBUTION

The particle size distribution of the soils is given in Appendix 3. The moist color of the horizons of the profiles not described previously are included in Appendix 3. The soils from the Netherlands and Belgium were all sandy or the profile was developed in the sandy portion.

In the Soviet Union profiles, podzols developed in sandy materials and argillic horizons developed in finer materials. Spodic horizons tended to develop in coarser textured material, while non-spodic horizons tended to develop in finer textured material.

9.2 CARBON AND SESQUIOXIDES

Selected chemical properties of the soils studied are given in Appendix 4.

With the exception of the Sarawak soils, dithionite-citrate extracted the most iron and pyrophosphate extracted the least from a given sample. This agrees with the general theory that dithionite-citrate extracts crystalline and amorphous forms of iron, oxalate extracts some crystalline and all amorphous iron and pyrophosphate extracts the iron which is organically bound. The three extractants, pyrophosphate excepted, are not as specific for aluminum.

In most of the soils there is little difference between the Al_o and Al_p contents. This indicates that in these there is little amorphous Al which is not organically bound. In the Dutch and Belgian soils the Al_d, Al_o and Al_p contents are similar. In several of the other soils Al_d contents are significantly lower than Al_o contents. This is not surprising since Al is not affected by reducing agents.

In A horizons and some E horizons pyrophosphate did not extract all of the organic C. Roots present in these horizons are not extracted by pyrophosphate. In most B horizons of podzols the C_t and C_p contents were similar indicating there is relatively little contribution of organic C from roots.

Carbon/aluminum, carbon/iron and carbon/sesquioxides atomic ratios have been calculated using total carbon, sodium hydroxide-extractable carbon, pyrophosphate-extractable carbon and sesquioxides extracted by dithionite, oxalate and pyrophosphate (Appendix 4 and Figures 1 to 8).

The C/Al, C/Fe and C/Ses atomic ratios are combined in graphs that show both variation with depth and within horizons. C/Al graphs are given in detail because the C/Al ratios proved most useful for distinction between eluvial and illuvial horizons. In case of ratios with respect to pyrophosphate-extractable matter, B horizons are split up in detail, while for the other extractants B horizons have been grouped into one bar for the Bh and one for the Bs horizon. C/Fe and C/Ses graphs have been condensed in this way, and C_h/Fe and C_h/Ses ratios are not shown in the graphs. Orthic/Humic and Gleyic Podzols are treated separately for C/Al and C/Ses ratios, while they have been combined in the C/Fe graphs in order to allow distinction between these groups on the basis of C/Fe ratio. Some atomic ratios are less accurate than others because the values for Al or Fe are near the detection limit. For example, ratios for B horizons tend to be more accurate than those for E horizons. In the figures the ratios obtained with sesquioxide contents of 0.02% and lower have been underlined.

9.2.1 Carbon/aluminum ratios

The C/Al atomic ratios for the three organic carbon fractions (C_t, C_h, C_p) and the three aluminum extractions (Al_d, Al_o, Al_p) all decrease with depth, i.e. from Ah to C horizons (figures 1 to 4). This trend holds for all podzols in this study.

Pyrophosphate aluminum

In the Humic and Orthic Podzols from the Netherlands and Belgium, a C_t/Al_p ratio of about 45 gives an almost perfect separation between eluvial and illuvial horizons. Ah and E horizons have ratios higher than 45, while all B horizons have ratios below 45. There is only one E horizon sample with a value less than 45 that overlaps with those of the B horizons. This horizon is from profile NL-108 and may have had some B horizon material mixed in it.

C_h/Al_p ratios do not give as good a separation between eluvial and illuvial horizons; the ratios of E and B horizons overlap between the values 18 and 35. All B horizons have C_h/Al_p ratios less than 35 but four E horizons also have values less than 35. Two of these E horizons are from profile NL-108 and a third has less than 0.02% Al.

C_p/Al_p ratios give good separation between eluvial and illuvial horizons. The ratios for B horizons were all less than 40 but three E horizons also had ratios less than 40. Two of these E horizons were from profile NL-108 and the other has only 0.01% Al.

In the Dutch and Belgian Gleyic Podzols, the C_t/Al_p ratio also gives good separation of eluvial and illuvial horizons, at a ratio of approximately 40. Only the Ah and E horizons of profile NL-103 have ratios less than 40, but these horizons have been covered by more recent wind-blown sand and may have received some illuvial sesquioxides from this sand cover, where podzolization is also active.

The C_h/Al_p ratio does not give a good separation in the Gleyic Podzol profiles. Many Ah and E horizons have ratios in the same range as the B horizons.

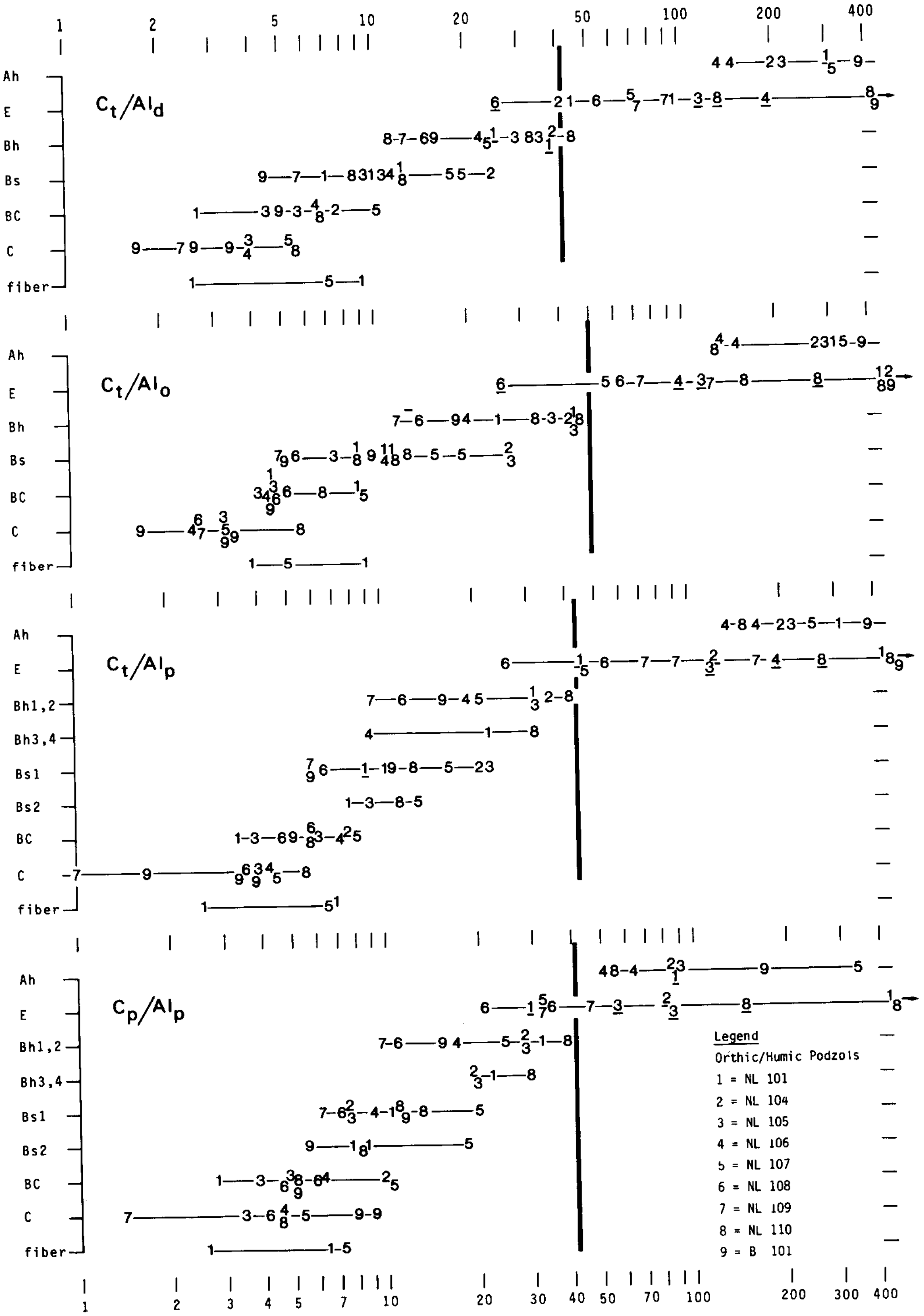

Figure 1. C/Al ratios of Orthic and Humic Podzols

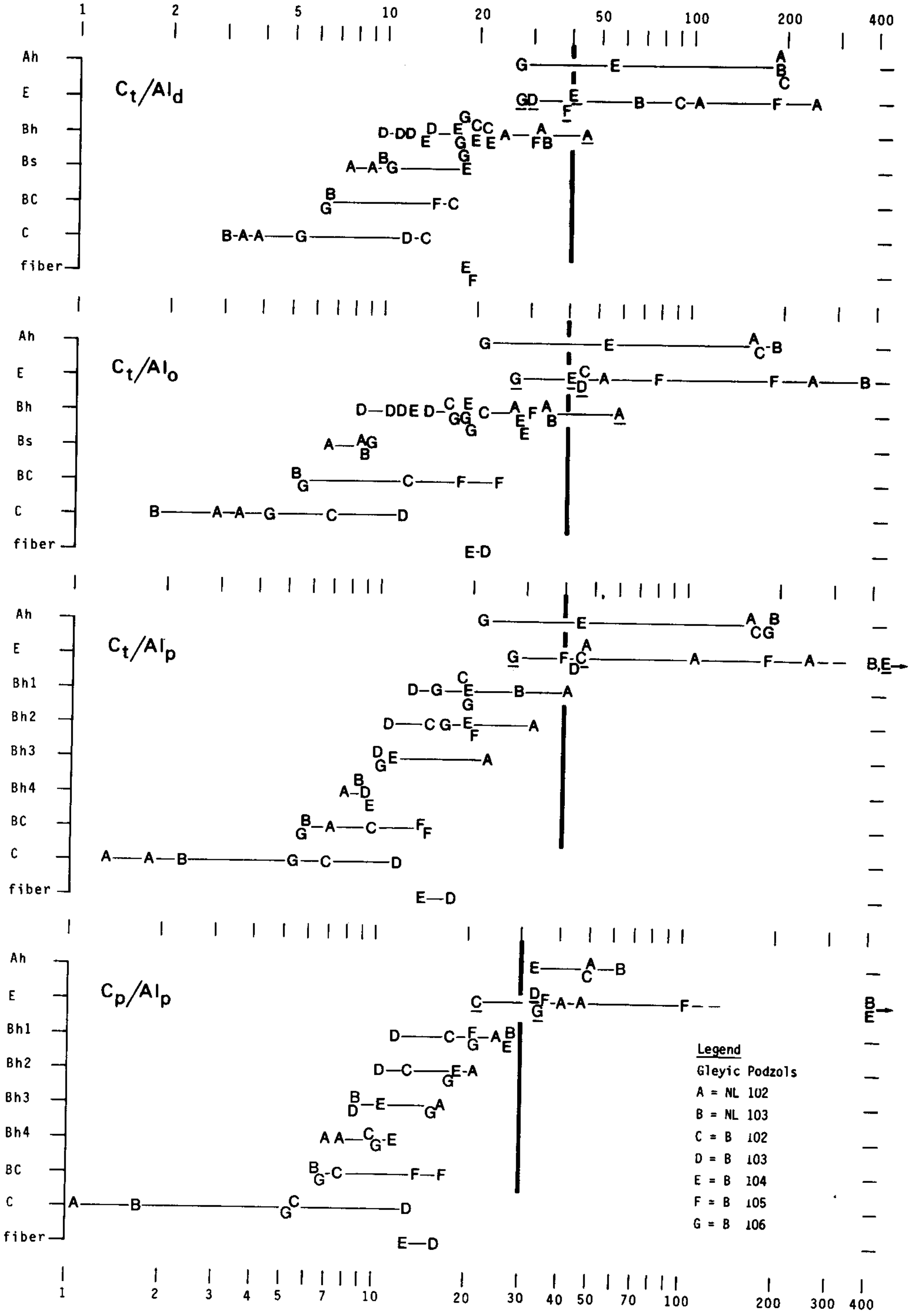

Figure 2. C/Al ratios of Gleyic Podzols

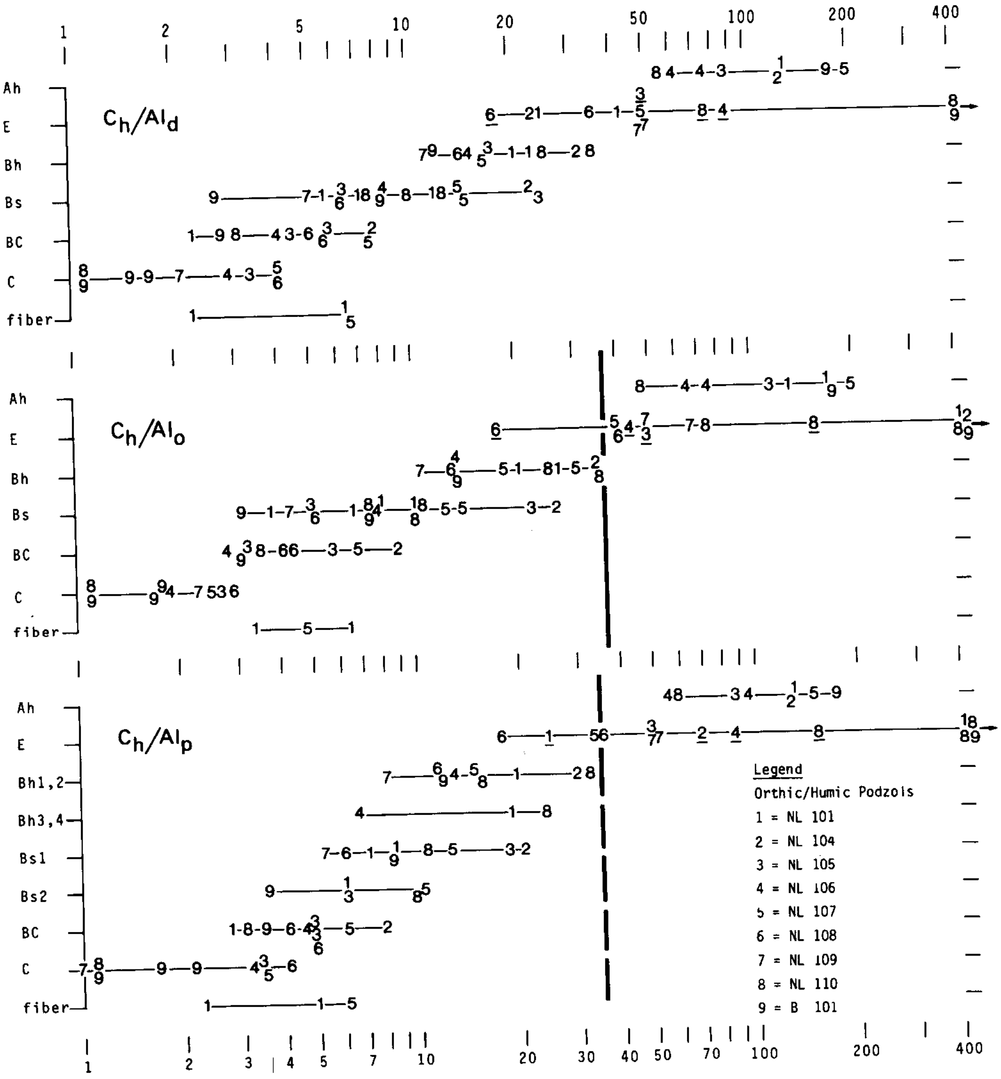

Figure 3. C_h/Al ratios of Orthic and Humic Podzols

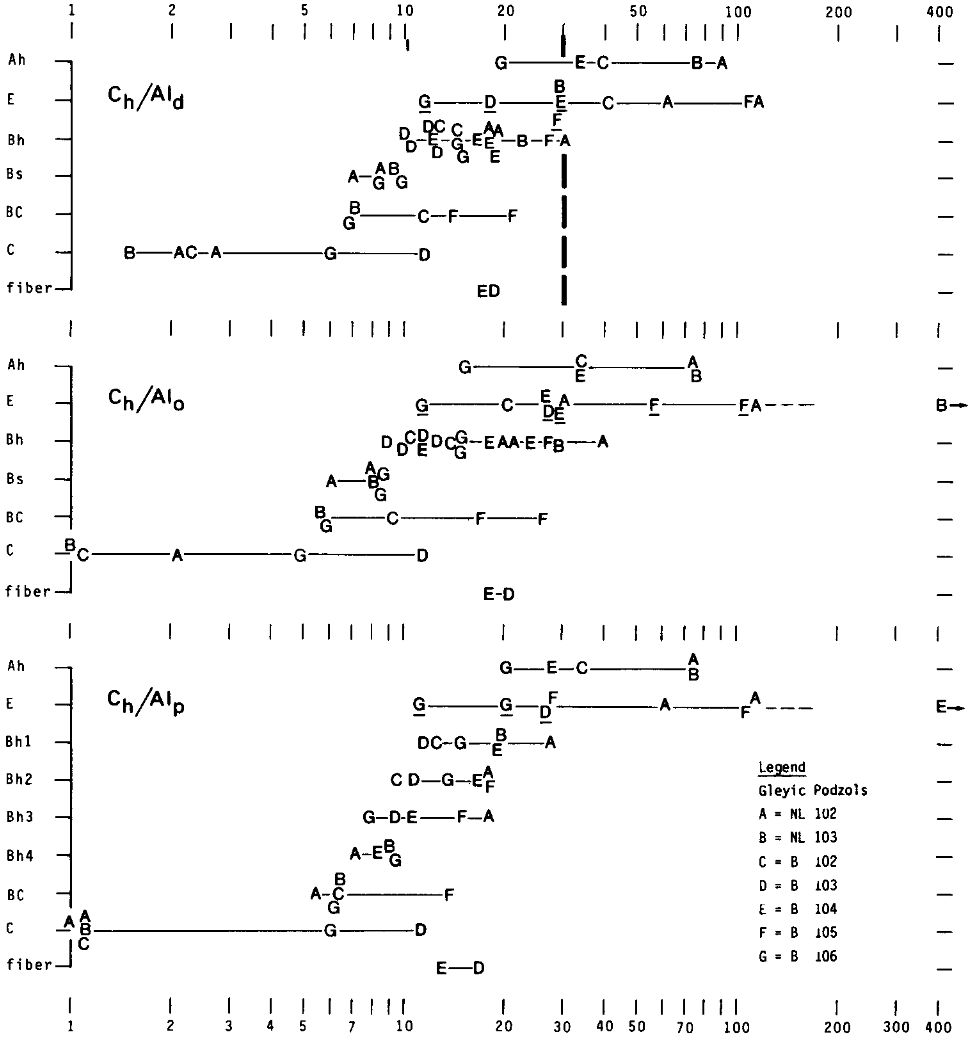

Figure 4. C_h/Al ratios of Gleyic Podzols

The C_p/Al_p ratios, however, give good separation with only one overlapping value but in this E horizon the Al_p content was 0.02%. The ratio for separating E and B horizons is about 30.

Dithionite aluminum

In Humic and Orthic Podzols from The Netherlands and Belgium, C_t/Al_d ratios give a fairly accurate separation between E and B horizons. The break is at a ratio of about 40-45. The C_h/Al_d ratio, however, gives a broad overlap between illuvial and eluvial horizons.

In Gleyic Podzols, the separation is not as good as in the dryer profiles. Only after elimination of less accurate C_t/Al_d ratios, is a separation value of about 40 obtained. The same holds true for the C_h/Al_d ratios. After elimination of less accurate ratios, the separation value can be set at the highest ratio found in the B horizons, 30.

Oxalate aluminum

In the Dutch and Belgian Humic and Orthic Podzols, C_t/Al_o gives a good separation between E and B horizons at values between 45 and 55. As mentioned earlier, the only overlapping E horizon sample probably has admixtures of B horizon material. The C_h/Al_o ratios also give a good separation, at values 35-40.

The oxalate aluminum in Gleyic Podzol profiles shows the same problems as with dithionite aluminum. C_t/Al_o give a fairly good separation at values between 30-35, which is improved after elimination of less accurate ratios. The C_h/Al_o ratios on the other hand do not give very good results. The highest accurate value in the B horizon is 40 but there are many Ah and E horizons with values lower than this.

The C_t/Al ratios are slightly higher than C_h/Al and C_p/Al ratios. The C_t/Al_p ratio gives good separation in both Humic/Orthic Podzols and Gleyic Podzols. Moreover, the separation values are similar for both groups studied. The C_p/Al_p ratio also gives fair to good separation but the separation value is 40 for the Humic/Orthic Podzols and 30 for the Gleyic Podzols.

9.2.2 Carbon/iron ratios

The C/Fe atomic ratios for the three organic C fractions and the three iron extractions all tend to decrease with depth, i.e. from the Ah to the C horizons for the Humic, Orthic and Placic Podzols but not the Gleyic Podzols (Appendix 4 and Figure 5). None of the C/Fe ratios gives a good separation between eluvial and illuvial horizons in the Dutch and Belgian soils. The ratios behave erratically, but in some soils there is clear separation between E and Bs horizons.

The Gleyic Podzols without gley mottles have higher C/Fe ratios than the Humic and Orthic Podzols. Therefore, these ratios may be used to distinguish between those Gleyic Podzols that have no mottles of iron compounds below the B horizons and have very low iron contents, and Humods and Orthods which lack a distinct Bs horizon. The C_p/Fe_p ratios of B horizons give the best separation between these two groups of Podzols. A C_p/Fe_p ratio of 150 can be used to distinguish between the Gleyic Podzols (higher ratios) and the Humic and Orthic Podzols (lower ratios). There are ratios from only three profiles which overlap, two are Gleyic Podzols and the other is a Humic Podzol. The samples from two of the profiles have low iron contents, 0.03% or less. The third profile is a Gleyic Podzol which is intergrading to Humic Podzol.

All Gleyic Podzols in the ISM monolith collection had C_p/Fe_p atomic ratios of B horizons greater than 150. Only one of the Humic and Orthic Podzols had a C_p/Fe_p ratio of B horizon greater than 150. The ratio of the Bh1 horizon was 159 but that of the Bh2 was only 24.6. Consequently, Gleyic Podzols without gley mottles might be defined as having ratios higher than 150 in all subhorizons of the B, while Orthic and Humic Podzols have a ratio lower than 150 in at least one subhorizon.

The other C/Fe ratios give separation between Gleyic Podzols and Humic and Orthic Podzols at values of 110 to 150. There is some overlap, especially in the Bh horizons.

9.2.3 Carbon/sesquioxide ratios

The C/Ses atomic ratios for the three organic C fractions and the three aluminum and iron extractions all decrease with depth, i.e. from the Ah to the C horizons (Appendix 4a,4b and Figures 6-8). This trend holds for all Podzols included in this study. $C_h/Ses_{d,o}$ ratios have not been included in the figures. For values, the reader is referred to Appendix 4.

Pyrophosphate sesquioxides

None of the C/Ses_p atomic ratios gives a good separation between eluvial and illuvial horizons in the Dutch and Belgian soils. In the Humic and Orthic Podzols the C_t/Ses_p ratio gives separation between the eluvial and illuvial horizons at values of 25-35. The highest ratio in the B horizon is 35 and the lowest in the E horizon is 25. The C_h/Ses_p ratio shows an overlap of values for E and B horizons. Also the C_p/Ses_p ratios show some overlap of values for Ah and E horizons with B horizons.

In the Gleyic Podzols C_t/Ses_p ratios give fair separation at a value of 35. The overlapping values from the E horizons are for samples with very low, less than 0.02%, Al and Fe contents. The overlapping values for Ah horizons are from profiles NL-103 and B-103, which have sand covers and the Ah horizons

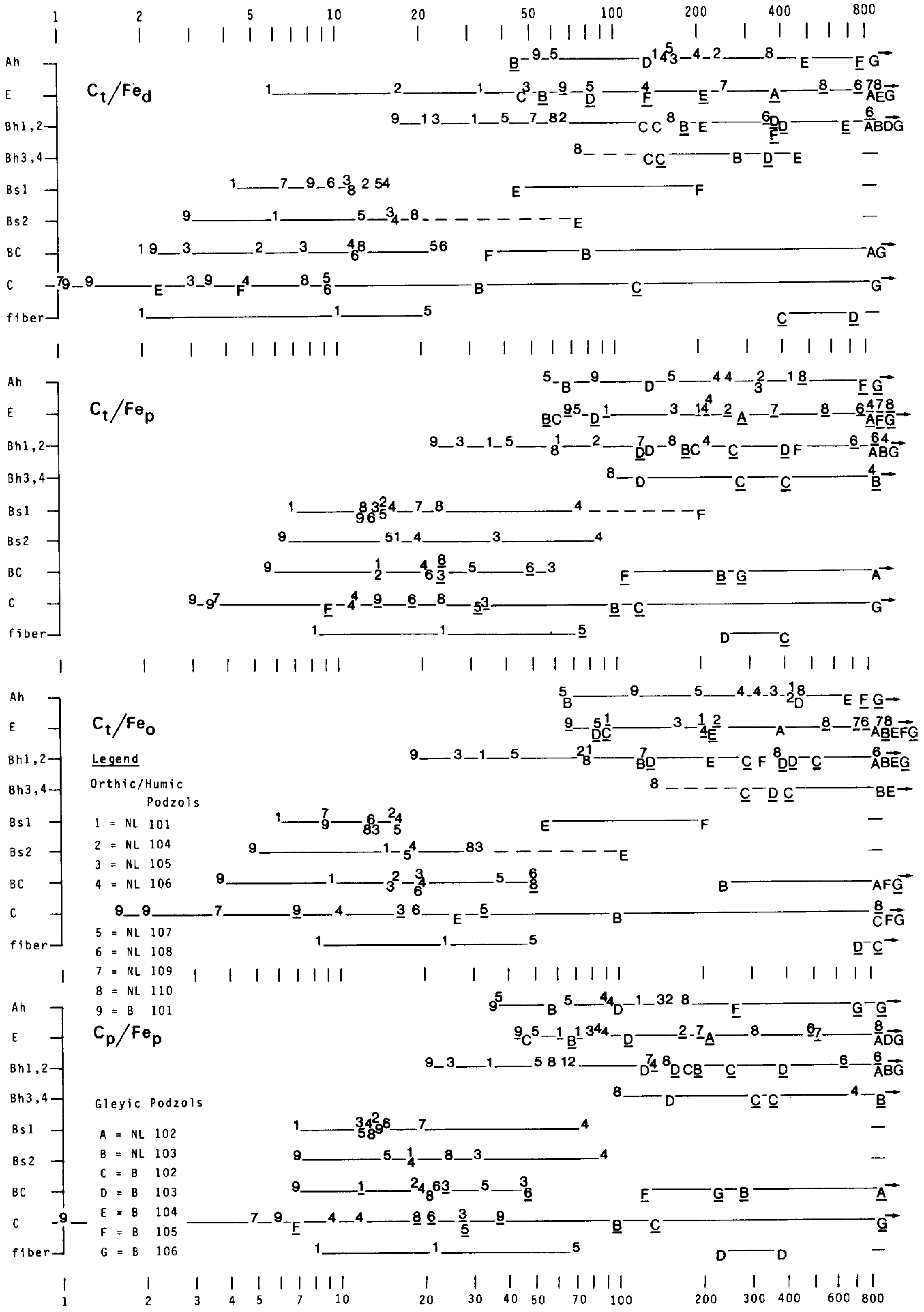

Figure 5. C/Fe ratios of Orthic/Humic and Gleyic Podzols

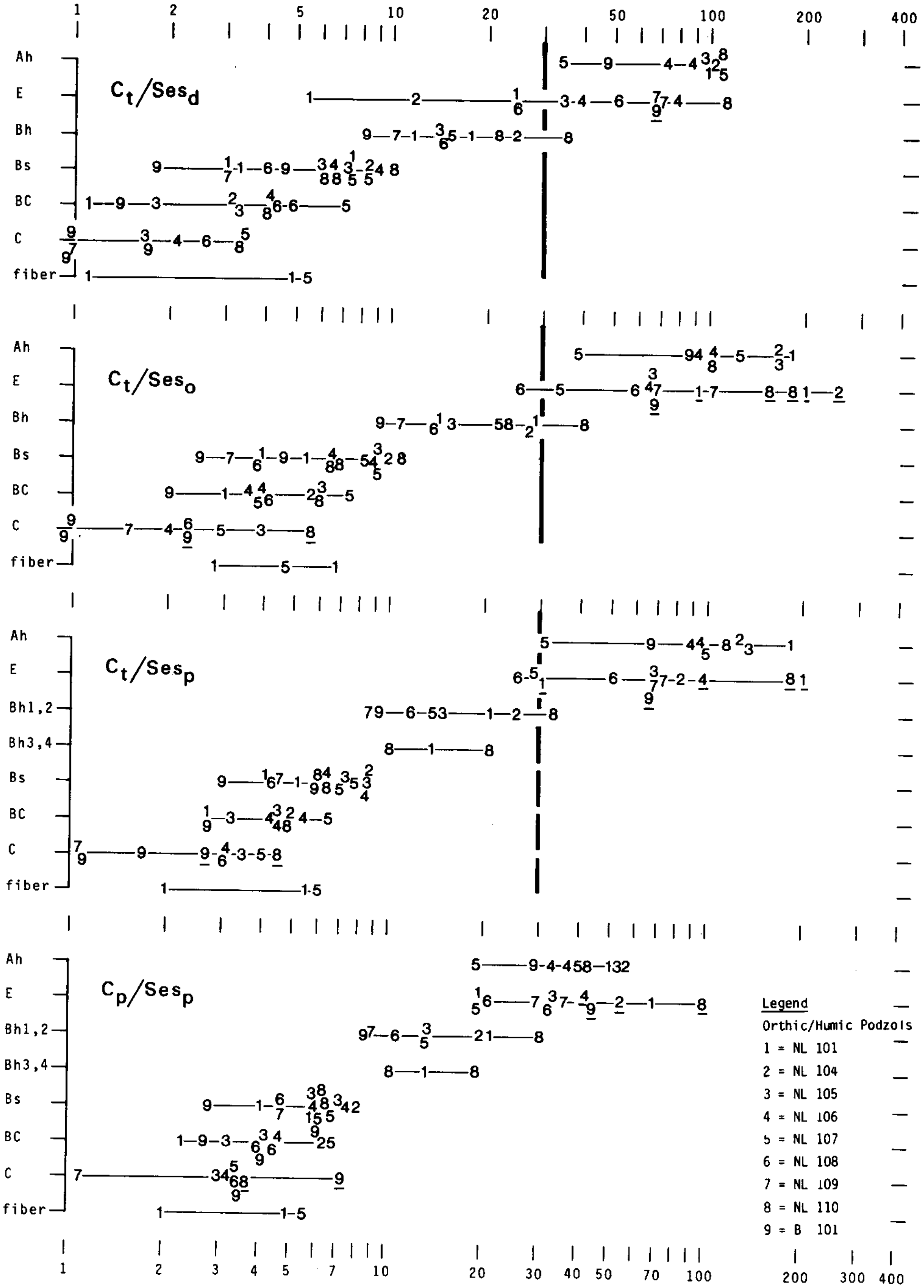

Figure 6. C/Ses ratios of Orthic and Humic Podzols

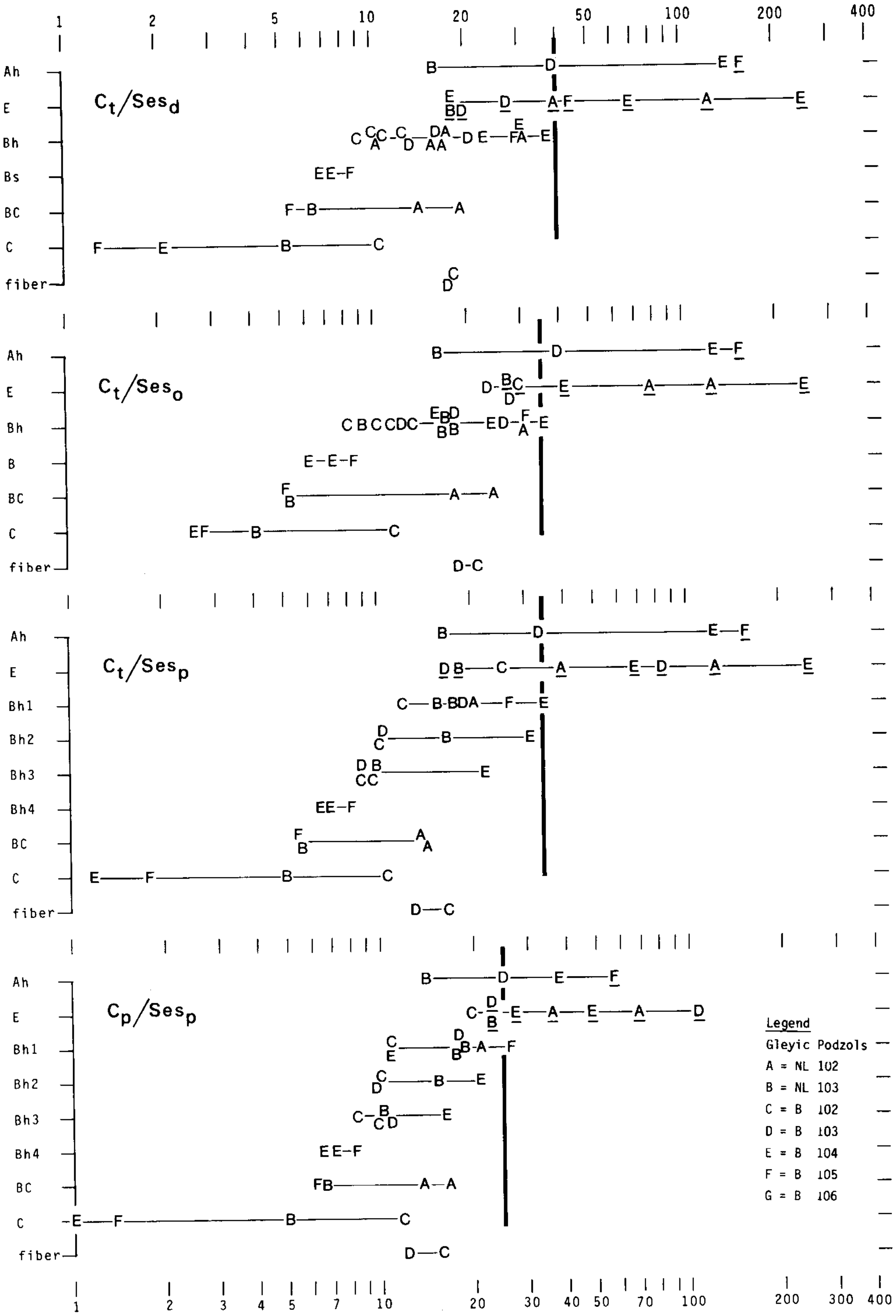

Figure 7. C/Ses ratios of Gleyic Podzols

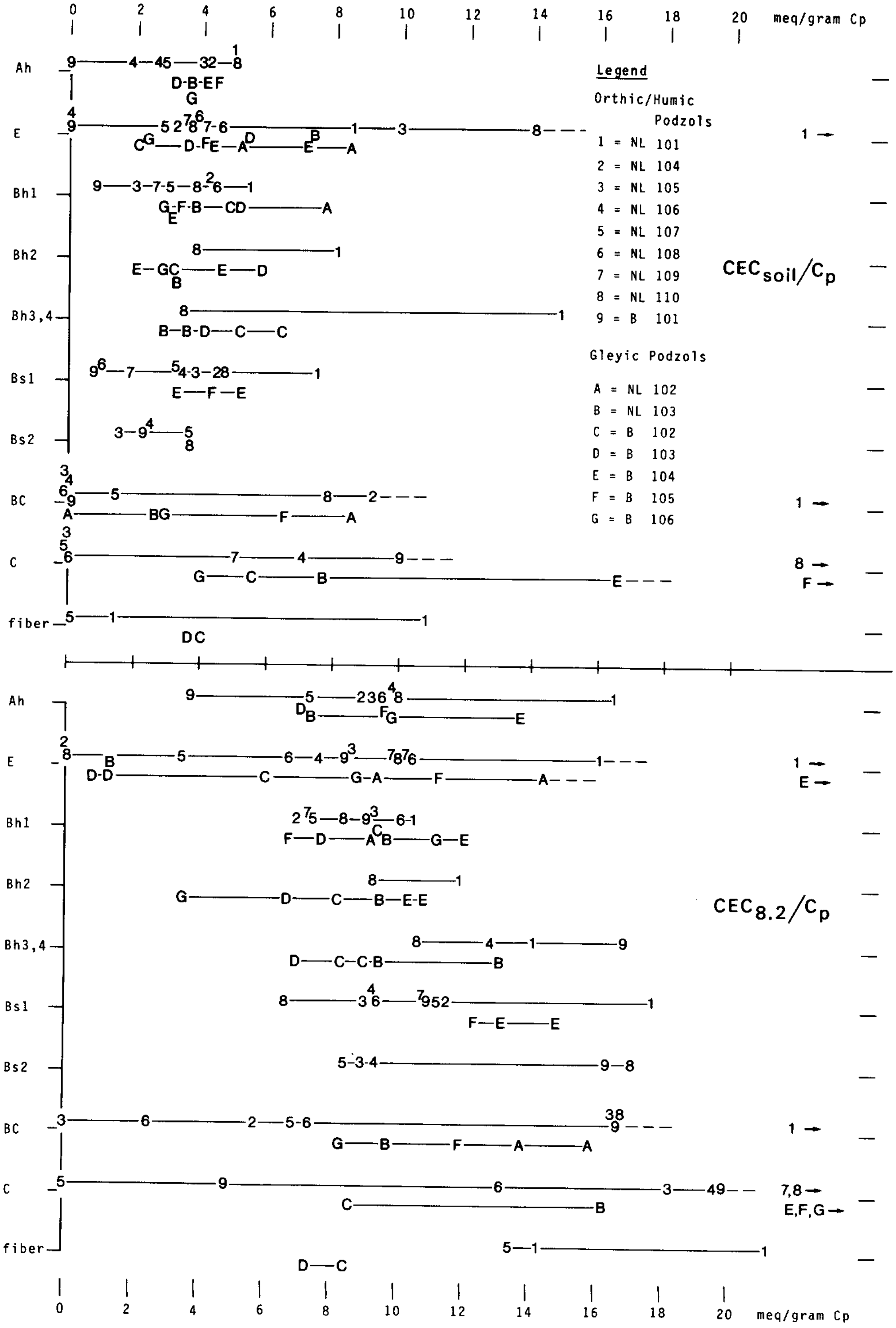

Figure 8. Depth functions of CEC$_{soil}$ and CEC$_{8.2}$

may have received some illuvial sesquioxides from this material. The C_h/Ses_p ratio gives separation at a value of 25 after eliminating less accurate values. The C_p/Ses_p ratio gives separation at approximately the same value after eliminating the less accurate values.

Dithionite sesquioxides

There is considerable overlap of C/Ses_d ratios between the Ah, E and B horizons. In the Humic and Orthic Podzols the C_t/Ses_d and C_h/Ses_d ratios give poor separation at values of 25-30. With both ratios there is considerable overlap of values in the E and B horizons.

In the Gleyic Podzols similar results were obtained. Both the C_t/Ses_d ratio and the C_h/Ses_d ratio give poor separation.

Oxalate sesquioxides

In the Humic and Orthic Podzols the C_t/Ses_o ratio gives fair separation at values of ± 30. The overlap of values from Ah and E horizons with those from B horizons occurs in two profiles: NL-107 and NL-108. Profile NL-107 has a plaggen epipedon and some sesquioxides may have eluviated from above and accumulated in the E horizon. The E horizon of profile NL-108 may have had some admixture of B horizon material. The C_h/Ses_o ratio gives fair separation at values of 25-30. Most of the overlapping values from the Ah and E horizons are less accurate.

In the Gleyic Podzols the C_t/Ses_o ratios give fair separation of eluvial and illuvial horizons at values of about 35. The E horizons with values which overlap the B horizon range have either low aluminum and iron contents or have a sand cover. The Ah horizon with a ratio which overlaps with the B horizon range also has a sand cover. The C_h/Ses_o ratios give poor separation. Most of the overlapping values are from profiles with low aluminum and iron contents in the E horizon or with a sand cover.

9.2.4 Discussion carbon/metal ratios

The separation values for all carbon fractions and all sesquioxide extractions found in Dutch and Belgian soils also hold true for most of the podzols in the ISM monolith collection (Appendix 4b) and for several reported in literature (Appendix 5). For the soils that do not fit the above separation, the C/Al ratios in the B horizons do not exceed the separation values, but the C/Al ratios of the E horizons are lower than these values. Profile F-10 is the only profile where C/Al ratios of the B horizon exceed the separation value. Roots in the B horizon may have caused the high C_t/Al ratio.

It is likely that the highest atomic ratios in the B horizon, or the separation values, indicate the minimum amount of sesquioxides necessary for the precipitation of the complex. In the Humic and Orthic Podzols the C/Al separation values are about 45 for C_t/Al, about 35 for C_h/Al and about 40 for C_p/Al. In the Gleyic Podzols the C/Al separation values are about 40 for C_t/Al, 30 for C_h/Al and about 30 for C_p/Al.

C/Al and C/Ses ratios in E and B horizons tend to increase with podzol development. For the E horizons it indicates a net removal of sesquioxides; for the B horizons it is accompanied by a clearer separation of Bh and Bs horizons. Because not all sesquioxides in the Bs horizon are bound to organic matter (compare dithionite and pyrophosphate extractions) this implies that the C/Al and C/Ses ratios in the upper Bh horizons of well-developed profiles are more characteristic for the minimum amount of sesquioxides required to precipitate organic matter than ratios obtained from B horizons of less strongly differentiated profiles. Consequently, the *highest* ratios in the B-horizon should be used to set it off against the E horizon.

The *lowest* C_p/Ses_p atomic ratios in the B horizon should indicate the maximum amount of sesquioxides that organic matter can bind, provided that pyrophosphate does not extract sesquioxides that are inorganically bound, such as Fe in oxyhydrates and Al in allophanic compounds. In the Gleyic Podzols from the Netherlands and Belgium all B horizons had ratios greater than 6.0. In the Humic and Orthic Podzols only four Bh, Bhs and Bs horizons had C_p/Ses_p ratios below 5.8 (Appendix 4a, b). Most of the B horizons of the non-podzols reported in literature (Appendix 5) had C_p/Ses_p ratios below 5.8. This would indicate that a C_p/Ses_p ratio of 5.8 reflects about the maximum amount of sesquioxides that organic matter in podzol B horizons can bind.

Two profiles with fibers (NL-101 and NL-107) have low C_p/Ses_p ratios in the Bs horizons (Figure 6). In profile NL-101 the ratios for the Bs and BC horizons are below 5.8 and in profile NL-107 both the Bhs and the BC horizon have a ratio of 6.8.

Higashi et al. (1981), however, assumed that it is impossible for organic matter to bind metallic ions in metal/C atomic ratios higher than 0.12, which is equivalent to a C/Ses ratio of about 8.5. However, these authors did not prove that a value of 0.12 is more accurate than the value of 0.16 (or C/Ses = 6) they arrived at after provisional calculations. The latter value is in accordance with the assumptions made in this paper.

C/Al ratios behave regularly and provide a good separation between eluvial and illuvial horizons; C/Fe ratios behave erratically, and C/Ses ratios behave regularly but separation is not as good as with C/Al ratios. This, and the near absence of iron in Gleyic Podzols supports the earlier assumption that aluminum rather than iron regulates the precipitation of organic matter.

In podzols, the B horizon moves downward with time and the E horizon becomes thicker (De Coninck, 1980). One of the mechanisms used to explain this process is the oxidation of organic matter from the complexes that have precipitated and further transport of the sesquioxides by fresh organic matter from above. This theory does not explain why one chelate would be more resistant to oxidation than another, nor does it explain that in many podzols the maxima of organic matter, aluminum and iron do not coincide.

If one accepts the theory that organic matter is immobilized by absorption of a certain amount of sesquioxides, it is also possible that a once precipitated chelate can be remobilized by the addition of fresh, undersaturated organic ligands from above or from decomposition of roots in the B horizon. This redissolution process, together with a pH-dependent preferent Fe to Al complexation (Schnitzer and Skinner, 1963) may be the key to the diverging iron and aluminum maxima.

In early stages of podzolization, sufficient iron and aluminum is present in the surface layer, and immobilization will occur near the surface layer. The soil will have a shallow B horizon. Further eluviation results in dissolution of the upper part of the B horizon; the solubilized complexes are redeposited in the lower part of the same horizon. As mentioned previously, fulvic acids preferentially complex Fe^{3+} at the prevailing pH. This causes a gradual depletion of iron in the upper part of the B horizon, and consequently an enrichment in the lower part while the precipitation of organic matter in the upper part of the B horizon is more dependent on aluminum. Thus, instead of the Bh horizon forming *on top* of a Bhs horizon, it may form *by differentiation* of the Bhs horizon.

Differences in pH or in organic matter composition may cause differences in preferential complexation, so that the places of aluminum and iron maxima are exchanged. In the well-drained podzols of this investigation, however, a Bh horizon always has less iron than the underlying Bhs.

The formation of lamellae or fibres with humus and sesquioxides below Bh and Bs horizons is not explained by the precipitation of humus upon increasing saturation with sesquioxides. Because the C_p/Ses_p ratios of the fibers are lower than those in the E and Bh horizons (Table 4, Figure 6,7) of the same profiles, it is likely that either a different mechanism is involved in the precipitation of the fibers, or the composition of the organic matter in the fibers is different and has different complexation properties. Possibly, this organic matter is not primarily precipitated by sesquioxides, but immobilized physically. Organic matter may have percolated through the soil with water, and come to a stand still with the water front. When the soil dries out, the soluble substances are precipitated. This would explain the irregular shape of humus fibers in homogeneous sediments, and the tendency to accumulate at textural changes, slips, and other unconformities that hamper percolation of water.

Tabel 4 Carbon/aluminum atomic ratios for separating eluvial and illuvial horizons in Orthic/Humic and Gleyic Podzols.

Ratio	Orthic/Humic		Gleyic	
	Separation	Value	Separation	Value
C_t/Al_p	good	± 45	good	± 40
C_h/Al_p	fair	± 35	poor	-
C_p/Al_p	good	± 40	good	± 30
C_t/Al_d	fair	40-45	fair	± 40
C_t/Al_o	good	45-55	good	± 40
C_h/Al_d	poor	-	fair	± 30
C_h/Al_o	good	35-40	poor	-

Table 5 Linear regression and correlation between C_t and C_p and C_t and C_h.

	n		r^2
A) for all A-horizons and E-horizons	39	$C_p = 0.35 + 0.18C_t$	0.80
B) for all B- and C-horizons	81	$C_p = 0.08 + 0.86C_t$	0.96
C) for all A- and E-horizons	39	$C_h = 0.14 + 0.42C_t$	0.81
D) for all B- and C-horizons	81	$C_h = 0.06 + 0.73C_t$	0.93

Table 6 Linear regression and correlation between $CEC_{8.2}$ and carbon contents.

	n		r^2
A) for all profiles and all horizons	120	$CEC_{8.2} = 0.81 + 8.80\ C_p$	0.86
	120	$CEC_{8.2} = 2.98 + 4.76\ C_t$	0.61
	120	$CEC_{8.2} = 1.50 + 8.83\ C_h$	0.76
B) as for A) less all A-horizons	102	$CEC_{8.2} = 0.64 + 8.27\ C_t$	0.87
C) for dry podzols only and all horizons	70	$CEC_{8.2} = 0.89 + 8.53\ C_p$	0.87

9.3 CEC-ORGANIC CARBON RELATIONS

Since the podzols investigated are very low in clay content, it is assumed that the CEC in these soils is mainly due to organic matter and sesquioxides. In horizons where Ses_p equals Ses_d, which is the case in the E and B horizons of Gleyic Podzols, and in some of the E and B horizons of Orthic and Humic Podzols from the Netherlands and Belgium, the CEC can be fully attributed to organic matter alone. Both CEC at soil pH and CEC at pH 8.2 were determined (CEC_{soil}, resp. $CEC_{8.2}$).

To decide which organic carbon fraction would most likely be highly correlated with CEC, correlations between (C_t and C_p) and (C_t and C_h) were calculated (Table 5). Any relation between C_p and C_h was considered to originate from the preceding relations and was therefore not calculated.

All correlations are significant at the 0.01% probability level. Both in the C_p-C_t regression correlation and in the C_h-C_t regression correlation, correlations are better for the B and C horizons than for A and E horizons, which is probably due to a relatively high and variable root content in A and E horizons. In the B and C horizons, the C_p-C_t correlation is better than the C_h-C_t. Pyrophosphate extracts more organic matter from these horizons than hydroxide.

Regression of cation exchange capacities with C_t, C_h and C_p respectively showed that CEC_{soil} had a much lower correlation than $CEC_{8.2}$ (Table 6, only regressions between $CEC_{8.2}$ and carbon contents are shown). Intra-profile correlations for CEC_{soil} were higher than the correlation over all profiles. The facts that 1) contents of sesquioxides vary more strongly within profiles than between profiles and 2) sesquioxides have a higher negative charge at high pH suggest that sesquioxides are of minor importance for the CEC of the podzols investigated. This is corroborated by an estimate of the maximum contribution of sesquioxides to the $CEC_{8.2}$: maximum amounts of sesquioxides encountered in the B horizons of any profile is about 1%. If no sesquioxides were bound by organic matter they might account for a maximum CEC of about 0.35 me/100 g (Parfitt, 1980). This is negligible compared to the CEC determined in these horizons. The variations in CEC_{soil} and its relatively low correlation with organic carbon content should therefore probably be explained by the variation of te charge of organic matter with pH (the soil-pH varies per sample, viz. pH-KCl). Of the $CEC_{8.2}$-C regressions, $CEC_{8.2}$-C_p gives the best correlation (Table 6). The $CEC_{8.2}$-C_t correlation is significantly lower but becomes much better when A horizons are excluded. This again points to the inclusion of inactive organic material in the C_t determination. As correlation with C_p is better than with C_h it is concluded that C_p more closely represents the active organic fraction than does C_h.

From the high correlation between C_p and $CEC_{8.2}$ it can be concluded that throughout the podzol profile and between various podzol profiles, the organic matter has a fairly constant $CEC_{8.2}$ per gram C. Trends with depth

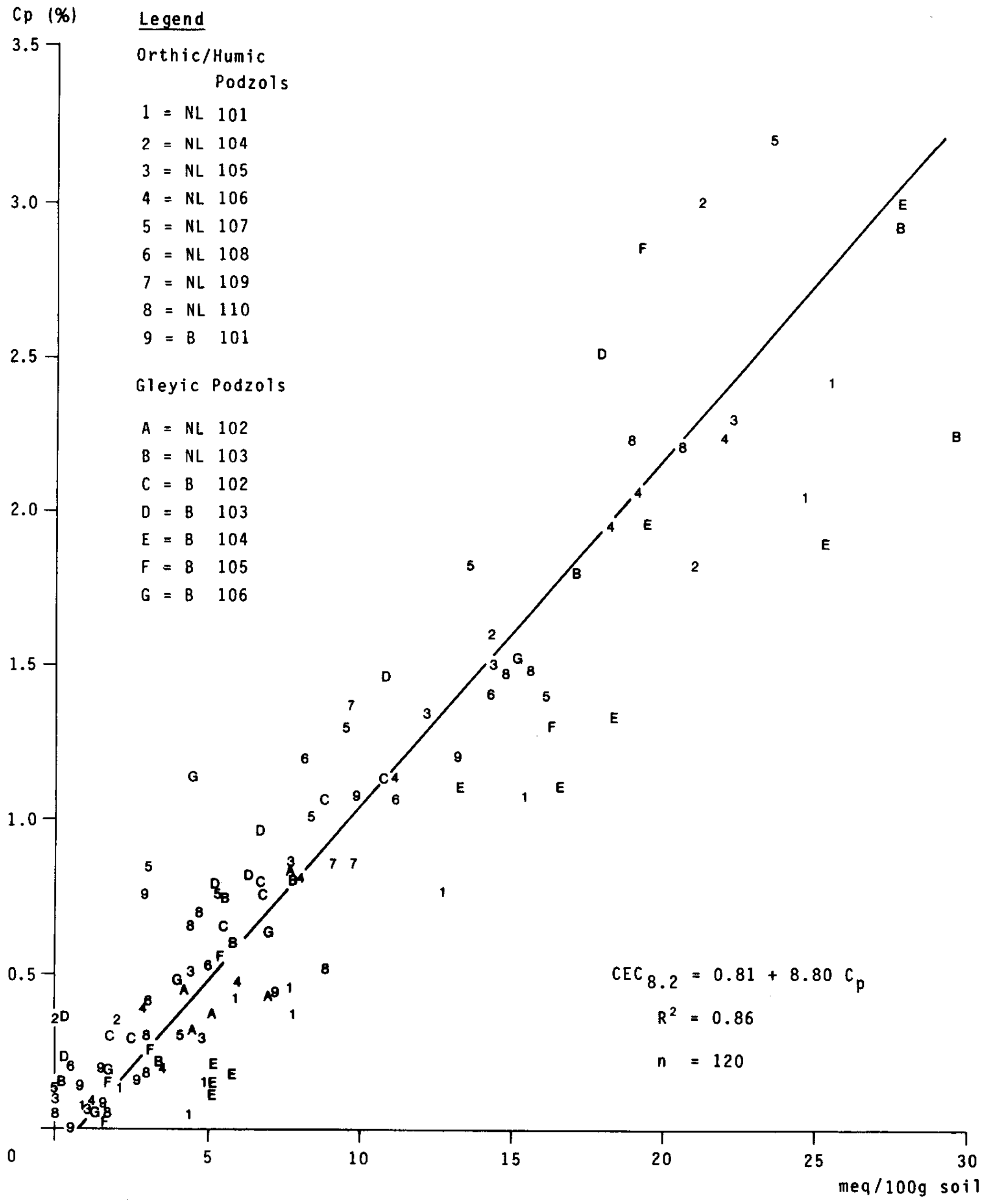

Figure 9. Regression of $CEC_{8.2}$ with C_p for all samples

are illustrated in Figure 8 for both CEC_{soil} and $CEC_{8.2}$. Mean values are 3-4 meq/g C_p at soil pH and 8-10 me/g C_p at pH 8.2. There is no distinct trend of CEC with depth, although fibers tend to have a higher CEC/C than the horizon in which they are found. No differences are found between Humic and Orthic Podzols on one hand and Gleyic Podzols on the other. Extremely high CEC/C values occur when both CEC and C figures are low. Such ratios are therefore less reliable. The regression between $CEC_{8.2}$ and C_p is illustrated in Figure 9.

9.4 IMOGOLITE

Imogolite was not detected in the fine clay and clay fractions of the samples examined. This is in contrast to the imogolite found in spodic horizons in Scotland and Canada (Tait et al., 1978; Ross and Kodama, 1979; Farmer et al., 1980; Ross, 1980; McKeague and Kodama, 1981). Possible explanations for this difference are the occurrence of imogolite in the parent material, the addition of volcanic ash to the soils, and the formation of imogolite after transport of aluminum to the B horizons. In the Scottish soils studied by Farmer et al. (1980) imogolite was present in the C horizon or in the deepest horizon samples in the three profiles with imogolite in the B horizons. In the profile without imogolite in the C horizon, no imogolite was found in the B horizon. In the Scottish soils studied by Tait et al. (1978) one podzol had no imogolite in the B horizon and no C horizons were examined. The soils in the Canadian studies were from British Columbia and only B horizons were examined (Ross and Kodama, 1979; Ross, 1980; McKeague and Kodama, 1981). Volcanic ash was detected in the sand fraction of the two soils studied by Ross and Kodama (1979).

Another contrast between the soils of this study and those reported in literature is in the Al_o content. In only six soils was the Al_o content of the B horizons greater than 1% and in two of these soils the Al_p content was also relatively high. The B horizons of these six soils also have relatively high organic carbon contents which may inhibit the formation of imogolite (Tait et al., 1978). This indicates that the B horizons of most of these soils do not have much amorphous Al which is not organically bound. In the Canadian and some of the Scottish soils the Al_o contents were high, greater than 1% (Tait et al., 1978; Ross and Kodama, 1979; Ross, 1980; McKeague and Kodama, 1981). Farmer et al. (1980) found acetic acid extracted much more Al than did EDTA. This indicates that most of the Canadian and Scottish soils have large amounts of amorphous Al.

It is possible that the imogolite formed in those B horions after the Al had been deposited and released from the organic matter complex. This would explain the absence of imogolite in any of the eluvial horizons and in the upper B horizons of several of the soils. On the other hand, if volcanic ash or its weathering products allophane and/or imogolite had been present in the parent material, these would certainly have been removed from the eluvial horizons by the podzolization process, and thus result in an absence of allophane in the eluvial and a presence in the illuvial and lower horizons. Certainly, in soils containing volcanic ash particles in the sand fraction, an explanation for the presence of imogolite should not be sought in the podzolization process. Furthermore, the present authors feel that the transport of aluminum as a silicate complex would not explain the co-precipitation of aluminum and organic matter. Nor is it likely that the transport mechanism for iron would be different from that for aluminum. The transport of iron would not be explained by the imogolite model.

9.5 IRON CONTENT AND COLOR AFTER IGNITION

Both the content of 'free' iron and color after ignition have been used to separate Gleyic Podzols from well-drained Podzols. Most classifications do not state a minimum iron content for well-drained podzols, nor are any definite criteria available for the amount of color change after ignition that should be present to call a sample 'redder'. In order to solve both problems and arrive at suitable criteria for the iron content and color for Gleyic Podzols and well-drained podzols, an effort was made to correlate both properties.

For this purpose it was necessary to attribute numerical values to Munsell color codes. This was done by attributing the value 1 to the color 2.5Y 8/1 (the strongest white color found in ignited samples) and adding 1 for the distance of one unit, both in horizontal (chroma) and vertical direction (value). Numerical values then read 1, 2, 3, 4, 6, 8 for 2.5Y 8/1, 8/2, 8/3, 8/4, 8/6 and 8/8 respectively and for 8/1, 7/1, 6/1, 5/1, 3/1 and 1/1 respectively. Values within the matrix were obtained by multiplying the respective row and column values, e.g. the numerical value for 2.5Y 4/5 is 4 x 4 = 16. These values were multiplied by 2 for each redder hue. The resulting matrices are given in Table 7. Each numerical value can be otbained by several colors, e.g. the numerical value 96 stands for 7.5YR 6/8 and 5/6; 5YR 7/6, 6/4 and 5/3; 2.5YR 8/6, 7/3 and 6/2; and 10YR 8/3 and 6/1. Not all colors of the matrices occur in ignited samples. Those colors encountered are printed in italics.

Dithionite-citrate extractable iron plotted against the numerical color value of the ignited sample gives a population that can be divided into two subpopulations (Figure 10). One set of B horizon samples has numerical color values below 100 and free iron contents of less than 0.125%. The second set of samples has color values above 100 and iron contents above 0.135%. The population with the low contents contains B horizons of Podzols that have been classified in the field as 'Gleyic Podzols' and Bhl horizons of well-drained profiles. Color values of over 1000 are reached with iron contents as low as 0.5% in Bhs and Bs horizons.

Table 7 Numerical values assigned to Munsell color codes.

Hue 2.5Y

	/1	/2	/3	/4	/6	/8
8/	*1*	*2*	3	4	6	8
7/	2	4	6	8	12	16
6/	3	6	9	12	18	24
5/	4	8	12	16	24	32
4/	5	10	15	20	30	40

Hue 10YR

	/1	/2	/3	/4	/6	/8
8/	*2*	*4*	*6*	*8*	*12*	16
7/	4	8	*12*	*16*	*24*	*32*
6/	6	12	*18*	*24*	*36*	*48*
5/	8	16	24	32	*48*	*64*
4/	10	20	30	40	*60*	*80*

Hue 7.5YR

	/1	/2	/3	/4	/6	/8
8/	4	8	*12*	*16*	*24*	32
7/	8	*16*	24	*32*	*48*	64
6/	12	24	*36*	48	*72*	96
5/	16	32	48	64	*96*	128
4/	20	40	60	80	120	160

Hue 5YR

	/1	/2	/3	/4	/6	/8
8/	8	16	24	*32*	48	64
7/	16	32	*48*	*64*	*96*	*128*
6/	24	48	72	*96*	*144*	*192*
5/	32	64	96	128	*192*	*256*
4/	40	80	120	160	240	320

Hue 2.5YR

	/1	/2	/3	/4	/6	/8
8/	16	32	48	64	96	128
7/	32	64	96	128	*192*	256
6/	48	96	144	*192*	*288*	*384*
5/	64	128	192	256	*384*	*512*
4/	80	160	240	320	*480*	*640*

Hue 10R

	/1	/2	/3	/4	/6	/8
8/	32	64	96	128	192	256
7/	64	128	192	256	384	512
6/	96	192	288	384	*576*	*768*
5/	128	256	384	*512*	*768*	*1024*
4/	160	320	480	640	960	*1280*

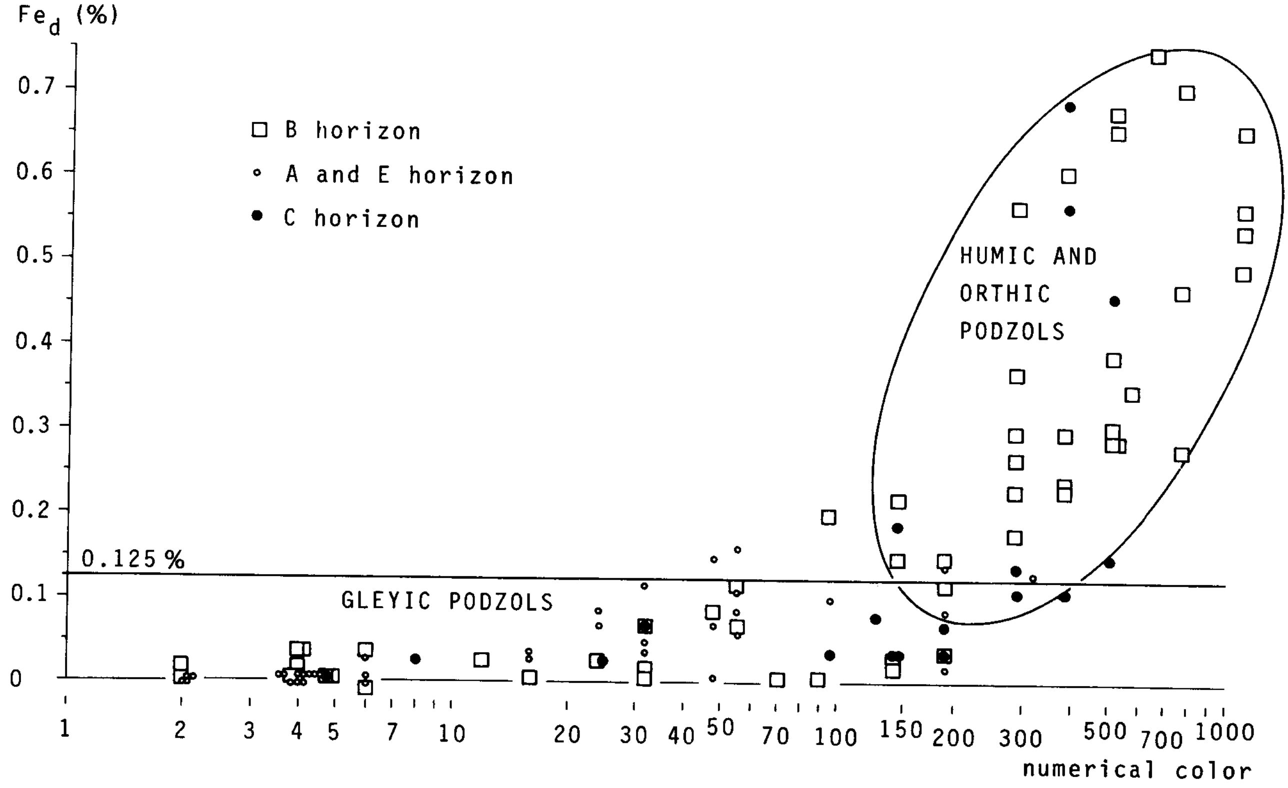

Figure 10. Color after ignition and Fe$_d$ content of Orthic/Humic and Gleyic Podzols

It appears that color after ignition and iron content of the sample are well-correlated and that either a free iron content of $< 0.12\%$ or a numerical color value of less than 150 would serve to define the Gleyic Podzol profiles 'that lack iron coatings'.

9.6 SPODIC HORIZON CRITERIA

Tables 8, 9 and 10 summerize the data used to classify the soils into the FAO-Unesco system (FAO-Unesco, 1974) and Soil Taxonomy (Soil Survey Staff, 1975). Most of the soils studied had the morphology of a Spodosol or a Podzol; however, several soils did not classify as Spodosol or Podzols according to these systems.

Because the spodic horizon is considered as a horizon having an illuvial accumulation of organic matter and aluminum, with or without iron, it was decided to concentrate on these three properties to develop new criteria with which to define the spodic horizon. Pyrophosphate is generally considered to extract Al and Fe bound to organic matter. By complexing Al and Fe pyrophosphate makes the organic matter soluble. Therefore it was concluded that pyrophosphate extractable C, Al and Fe would be the best properties on which to define the spodic horizon.

The chemical criteria for defining the spodic horizon were developed based on the data collected from the soils sampled in the Netherlands, Belgium and Switzerland (Table 8). It was assumed that a B horizon with a 7.5YR 4/4 color would morphologically qualify as a spodic horizon, a B horizon with a 10YR 4/4 color would sometimes qualify as a spodic horizon, a B horizon with a 5/4 color or lighter would not qualify. B horizons with a 7.5YR 4/4 color had $C_p + Al_p + Fe_p \geq 0.50$ and B and C horizons with a 10YR 5/4 color or lighter and no mottles had $C_p + Al_p + Fe_p \leq 0.42$. Two BC horizons with 10YR 4/4 color had $C_p + Al_p + Fe_p$ of 0.76 and 0.36.
From this it was concluded the minimal value of $C_p + Al_p + Fe_p$ for a spodic horizon should be 0.50.

In Gleyic Podzols without mottling, B horizons have C_p/Fe_p atomic ratios greater than 150 and in Humic and Orthic Podzols B horizons have ratios less than 150. The $C_p/(Al_p + Fe_p)$ atomic ratios of B horizons in Gleyic Podzols were less than 30.0 and those of B horizons in Humic and Orthic Podzols were less than 26.0.

The amount and distribution of amorphous material varies greatly in spodic horizons. Some horizons have large amounts in thin horizons and others have small amounts in thick horizons. Therefore a minimum accumulation of amorphous materials must be defined. The minimum $C_p/(Al_p + Fe_p)$ atomic ratio was taken as 5.8, which is the value between the highest $C_p/(Al_p + Fe_p)$ atomic ratios in the two Swiss soils, one having the morphology of a Spodosol or Podzol and the other not (Table 8). Also, the minimum $C_p/(Al_p + Fe_p)$ atomic ratio in most subhorizons of the B horizons was 5.8. The minimal thickness

Table 8 Selected properties and classification of Dutch, Belgian, and Swiss soils

Soil Profile No.	Morph. Char.*	Lowest	Highest			Accum.** Index	FAO Class.*	Highest			Σ**	Soil Class.‡
		$\frac{Fe_d}{C_t}$	Fe_p %	$\frac{Al_p+Fe_p}{clay}$	$\frac{Al_p+Fe_p}{Al_d+Fe_d}$			$C_p+Al_p+Fe_p$	Atomic Ratio $\frac{C_p}{Fe_p}$	Atomic Ratio $\frac{C_p}{Al_p+Fe_p}$		
NL-101	P	0.15	.31	.41	.74	214	P	2.78	63.	21.3	112.0	P
NL-102	P	0	.00	.47+	1.50	294	P	.93	-	21.0	759.5	P
NL-103	P	<.01	.02	3.43+	1.09	242	P	3.44	1424.	18.4	315.1	P
NL-104	P	.07	.62	-	.93	294	P	4.05	80.	23.7	351.9	P
NL-105	P	.20	.54	-	.90	434	P	3.05	25.	13.3	215.4	P
NL-106	P	.29	.66	.17	1.02	0	N	3.10	14.	7.6	89.8	P
NL-107	P	.11	.56	.80	1.07	168	P	3.94	40.	13.4	225.0	P
NL-108	P	.01	.17	-	1.20	186	P	1.94	763.	12.5	100.0	P
NL-109	P	.09	.19	.25	1.06	233	P	1.74	128.	9.0	63.0	P
NL-110	P	.03	.25	.12	1.05	132	P	2.57	149.	19.4	142.5	P
B-101	P	.28	.41	.53	.83	177	P	1.86	21.	8.8	88.4	P
B-102	P	.03	.03	.38+	1.04	411	P	1.74	231.	14.3	494.9	P
B-103	P	.01	.03	1.09+	1.67	412	P	1.28	461.	21.3	365.7	P
B-104	P	.01	.12	.21	1.08	669	P	3.43	129.	20.9	365.9	P
B-105	P	.01	.03	.87+	1.12	193	P	3.12	444.	20.8	189.6	P
B-106	P	0	.00	.34+	1.33	101	P	1.34	-	12.8	364.5	P
SER-3	N	1.78	.13	.06	.28	n.d.#	N	.58	125.	5.7	0	N
SER-10	P	.87	1.24	.37	.40	n.d.	N	6.38	16.	5.9	76.7	P

* morphological characteristics or classification: P = Podzol; N = Non-podzol

**Σ = thickness of horizon × $C_p/(Al_p+Fe_p)$ atomic ratio for B horizons with $C_p+Al_p+Fe_p$ ≥0.50% and $C_p/(Al_p+Fe_p)$ = 5.8-25.0 if C_p/Fe_p atomic ratio <150 or $C_p/(Al_p+Fe_p)$ = 5.8-22.0 if C_p/Fe_p atomic ratio >150

+ (C_p+Al_p)/clay

‡ classification using new criteria: P = Podzol; N = Non-podzol

\# n.d. = not determined

++CEC at pH 7 used to calculate Accumulation Index

Table 9 Selected properties and classification of soils in the monolith collection of the International Soil Museum

Soil Profile No.	Morph. Char.*	Lowest	Highest			Accum. Index.‡	FAO Class.*	Highest			Σ^{**}	Soil Class.#
		$\frac{Fe_d}{C_t}$	Fe_p %	$\frac{Al_p+Fe_p}{clay}$	$\frac{Al_p+Fe_p}{Al_d+Fe_d}$			$C_p+Al_p+Fe_p$	Atomic Ratio $\frac{C_p}{Fe_p}$	Atomic Ratio $\frac{C_p}{Al_p+Fe_p}$		
CDN-13	N	.97	.46	.16	.41	0	N	2.57	15.	3.8	0	N
CDN-14	P	<.01	.01	$.23^+$	1.21	335	P	4.25	1466.	17.7	384	P
CDN-24	P	.32	.48	.12	.73	0	N	3.53	77.	7.6	246	P
D-11	N	1.36	.57	.03	.33	0	N	1.80	7.	3.4	40	N
F-2	N	.33	.88	.18	.90	0	N	3.62	10.	5.6	0	N
F-10	P	.26	.17	.06	.71	0	N	.75	19.	13.4	187	P
IRL-1	P	.57	.22	.20	.74	51	N	.90	13	7.2	72.0	P
IRL-9++	P	.06	.11	.08	.94	35	N	.48	31.	16.9	225.	P
N-1	N	.09	.04	$.37^+$	.37	0	N	.78	340.	48.8	0	N
N-2	P	.17	.87	1.53	1.01	759	P	7.93	33.	10.5	160	P
NL-2	N/P	.30	.14	.09	.58	0	N	.96	21.	6.2	93.0	P
S-2	N/P	.37	.77	.10	.58	0	N	2.28	41.	8.4	350.	P
S-9	P	.54	.39	.27	.60	133	P	.56	65.	9.8	174	P
S-10	P	.04	.13	.55	1.02	240	P	5.53	159.	9.7	67.9	P
S-14	N	.78	.04	$.30^+$	.27	0	N	.63	88	5.8	40.6	N
S-15	P	.03	.83	.41	1.09	1024	P	7.35	32.	18.4	555	P
S-16	N/P	1.06	.04	50^+	16	0	N	1.04	76.	5.5	0	N
S-17	P	.26	1.32	-	.88	1444	P	10.00	36.	8.4	220	P
SF-4	P	.40	.41	.14	.46	0	N	3.34	130.	7.2	72.0	P
SK-2	P	.03	.04	$-^+$	1.15	262	P	2.05	200.	24.3	357	P
SK-3	N	3.53	1.22	.17	.34	0	N	2.29	6	4.8	0	N

Table 9 (ctd.)

SK-4	N	5.77	.23	.07	.15	0	N	.48	4	3.1	0	N
GMC-4	P	<.01	.06	3.26$^+$	1.13	208	P	3.30	1275.	14.2	295	P
GMC-6	N	6.18	.07	.01$^+$	.06	0	N	.43	15.	9.8	0	N
GMC-7	N	4.85	.26	.04	.51	0	N	1.33	15.	6.9	0	N
GMC-8	P	.22	.47	.22	1.23	333	P	2.49	21.	9.6	76.8	P
GMC-13	N	.54	.07	.06$^+$	.67	0	N	.49	18.	3.3	0	N
USA-1	P	.16	.34	.14	.91	80	P	1.77	29.	7.2	122.2	P

* morphological characteristics or classification: P = Podzol; N = Non-podzol; N/P = Podzol characteristics are weakly developed

**Σ = thickness of horizon × $C_p/(Al_p+Fe_p)$ atomic ratio for B horizons with $C_p+Al_p+Fe \geq 0.50\%$ and $C_p/(Al_p+Fe_p)$ = 5.8–25.0 if C_p/Fe_p atomic ratio <150 or $C_p/(Al_p+Fe_p)$ = 5.8–22.0 if C_p/Fe_p atomic ratio >150

‡ CEC at pH 7.0 used to calculate Accumulation Index

$^+$ (C_p+Al_p)/clay

\# classification using new criteria: P = Podzol; N = Non-podzol

Table 10 Selected properties and classification of soils

Soil	Soil Classification	Highest						Σ*	Soil Class$^+$.	Reference
		Fe_p	$\frac{Al_p+Fe_p}{clay}$	$\frac{Al_p+Fe_p}{Al_d+Fe_d}$	$C_p+Al_p+Fe_p$	Atomic Ratio $\frac{C_p}{Fe_p}$	Atomic Ratio $\frac{C_p}{Al_p+Fe_p}$			
Charr	Histic Placaquept	.81	.14	nd	2.42	11.2	3.2	0	N	Ragg and Clayden, 1973
Insch	Typic Cryochrept	.04	$.06^{++}$	nd	.88	54.9	2.7	0	N	
Linhope	Dystric Cryochrept	1.00	.07	nd	3.02	8.2	5.3	0	N	
Dunsford	Typic Fragiochrept	.73	.05	nd	1.84	4.6	2.2	0	N	
Tarves	Typic Fragiochrept	.17	.05	nd	1.45	22.2	3.3	0	N	
Denbigh	Andic Dystrochrept	1.17	.07	nd	2.86	10.9	4.2	0	N	
Dod-Minchmoor	Typic Placaquod	.26	.21	nd	5.66	86.5	15.4	123.2	P	
Telegraph	Typic Placaquod	.24	.04	nd	.67	23.8	10.6	116.6	P	
Holden	Alfic Sideraquod	.07	$.17^{++}$	nd	2.55	151.	21.0	84.0	P	
Minchmoor	Haplic Cryohumod	.95	.14	nd	4.67	321.	18.3	91.5	P	
Merrick	(Cryic)Fragihumod	.81	.27	nd	7.72	35.3	11.7	117.0	P	
Shirrel	Ferrudalfic Haplohumod	.68	.12	nd	2.05	35.6	9.9	158.4	P	
Moretonhampstead	Typic Fragiorthod	.75	.10	nd	1.44	35.8	4.5	0	N	
Countesswells	Typic Fragiorthod	.55	.09	nd	4.32	25.9	7.0	63	P	
Fondland	Cryic Fragiorthod	.59	.19	nd	4.23	36.5	10.3	30.9	N	
Merrick	Cryic Fragiorthod	3.07	.66	nd	11.35	11.2	7.0	70.0	P	
Crannymoor	Typic Haplorthod	.57	.07	nd	2.30	27.8	9.3	65.1	P	
Crannymoor	Typic Haplorthod	.07	$.20^{++}$	nd	1.65	98.0	23.0	324.0	P	
Leon	Aeric Haplaquod	<.01	$.30^{++}$	1.00	1.12	-	20.2	291.8	P	Brandon et al., 1977
Leon	Aeric Haplaquod	<.01	$.51^{++}$	1.67	1.44	-	20.9	721.6	P	
Leon	Aeric Haplaquod	<.01	$.33^{++}$	.75	.56	-	37.5	0	N	

Table 10 (ctd.)

-	Humic Haplorthod	1.52	1.54	nd	8.36	18.9	12.6	274.3	P	Coen and Arnold, 1972
-	Typic Sideraquod	1.10	.51	nd	3.17	47.4	33.1	207.5	P	
-	(Cryic)Fragihumod	1.34	.56	nd	8.96	31.9	24.0	467.3	P	
-	Typic Haploquod	tr	2.79[++]	2.50	2.79	-	17.1	5082.	P	Holzhey et al., 1975
-	Cryandept	.7	.13	1.1	8.0	36.0	5.4	0	N	Singer et al., 1978
Pedon 108‡	Aeric Haploquod	tr	1.83[++]	.54	3.11	-	5.4	0	P	Soil Survey Staff, 1975
76	Typic Haplaquod	.01	1.29	1.00	1.27	1271.	13.9	567.5	P	Higashi et al., 1981
78	Aquic Haplohumod	.06	1.25	.91	1.87	389.	22.1	420.0	P	
74	Aquic Haplohumod	.05	1.08	1.00	1.70	395.	13.1	265.4	P	
75	Typic Placohumod	1.39	2.07	1.00	2.73	271.	12.5	62.5	P	

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* Σ = thickness of horizon × $C_p/(Al_p+Fe_p)$ atomic ratio for B horizons with $C_p+Al_p+Fe_p \geqslant 0.50\%$ and $C_p/(Al_p+Fe_p)$ = 5.8-25.0 if C_p/Fe_p atomic ratio <150 or $C_p/(Al_p+Fe_p)$ = 5.8-22.0 if C_p/Fe_p atomic ratio >150

‡ Ortstein present

\+ classification using new criteria: P = Podzol; N = Non-podzol

++ (Al_p+C_p)/clay

of a spodic horizon was taken to be 10 cm which is used in the Canadian (Canada Soil Survey Committee, 1978) and English (Avery, 1980) systems. Therefore the sum of the products $C_p/(Al_p + Fe_p)$ atomic ratio and horizon thickness must exceed 58.

In summary, the proposed chemical requirements for a spodic horizon are:

1. $C_p/(Al_p + Fe_p) \geq 0.50\%$;
2. $C_p/(Al_p + Fe_p)$ atomic ratio = 5.8 to 30.0 if C_p/Fe_p atomic ratio > 150,

or

5.8 to 26.0 if C_p/Fe_p atomic ratio < 150;

and

3. Sum of horizon thickness x $C_p/(Al_p + Fe_p)$ atomic ratio $\geq$ 58, for B horizons with 1 and 2 above.

All soils in Table 8 with podzol morphology meet these requirements and the one soil without podzol morphology did not meet these requirements.

The criteria were tested by applying them to the soils in the ISM monolith collection (Table 9). All soils with definite podzol morphology meet the requirements and two of the three soils with weak podzol morphology meet the requirements. Soils that did not have a podzol morphology did not meet the requirements.

The criteria were further tested by applying them to soils which have been reported in literature (Table 10). The soils were limited to those which had been classified according to Soil Taxonomy and had been analyzed for C_p, Al_p and Fe_p. Of the 24 soils classified as Spodosols by the authors eight did not have $(Al_p + Fe_p)$/clay or $(C_p + Al_p)$/clay equal to or greater than 0.20 and should not have been classified as Spodosols. *When using the proposed criteria* only four soils fail to meet the chemical criteria for spodic horizon and one of these soils has an ortstein which is sufficient to classify it as a Spodosol. None of the Inceptisols, including the Cryandept, meet the *proposed* criteria for spodic horizon.

Note that the present proposal does not use the ratios of amorphous matter to clay.

10 Conclusions

1. Precipitation of organic matter in the B horizon in both Orthic/Humic and in Gleyic Podzols is regulated by aluminum rather than iron.

2. Total carbon is not an appropriate measure for the active organic matter in podzols. Pyrophosphate extractable carbon (C_p) gave better correlations with CEC than either total carbon or sodium hydroxide extractable carbon. Therefore, C_p is considered to represent more closely the chemically active fraction.

3. Carbon/metal atomic ratios can be used to separate illuvial and eluvial horizons in podzols. Of C/Al, C/Fe and C/Sesquioxide atomic ratios, the C/Al ratios and, more specifically, the C_p/Al_p (pyrophosphate extractable carbon to pyrophosphate extractable aluminum) and C_t/Al_p (total carbon to C_p) atomic ratios are most suitable for this separation. The presence of roots in the B horizon appears not to influence these ratios. Pelletal humus formed from decaying roots in the B horizon appears to have the same chemical characteristics as organic matter in organans.

4. Organic matter in podzols is mobile at C_p/Al_p atomic ratios above 30 (Gleyic Podzols) or 40 (Orthic/Humic Podzols), and immobilized at lower ratios.

5. C/Fe atomic ratios do not provide a good separation between illuvial and eluvial horizons in either Orthic/Humic or Gleyic Podzols. Humic/Orthic Podzols can be separated from Gleyic Podzols that are poor in iron (no mottles) by a C_p/Fe_p atomic ratio of 150. In Gleyic Podzols all subhorizons in the B horizons have ratios above 150; in Humic/Orthic Podzols, at least some subhorizon of the B has a ratio lower than 150.

   An iron content of more than 0.12% (dithionite extractable) was found to suffice for the sample to turn redder upon ignition.

6. Although C/Sesquioxide ratios are less suitable for separating illuvial and eluvial horizons than are C/Al ratios, the C_p/Ses_p ratio is useful for identifying a spodic horizon. A minimum C_p/Ses_p ratio of 5.8 in the B horizon, which represents an estimate of the maximum amount of metal bound per unit C, can be used to define an accumulation index. The proposed criteria for a spodic horizon are as follows:

   a. $C_p + Al_p + Fe_p: \geq 0.50\%$
   b. Cp/Sesp atomic ratio is higher than 5.8 but lower than 40 in at least one subhorizon of the B (spodic horizon)
   c. The accumulation index should exceed 58. The accumulation index is defined as thickness (cm) x C_p/Ses_p atomic ratio.

7. The gradual deepening of the podzol profile and the differentiation of the B horizon into Bh and Bs can be explained by redissolution of the upper part of the B horizon by added unsaturated organic compounds, and a preference of these compounds for Fe, while precipitation is regulated by Al. The Bh and Bs horizons thus form by differentiation within the B horizon and not because the Bh precipitated on top of the Bs horizon.
8. Fibers below the B horizon are not precipitated at the same C/metal ratios as the organic matter in the B horizon and saturation with metals may not play a crucial role in the precipitation of amorphous matter in fibers.
9. Imogolite does not play an essential part in the podzolization process. Although imogolite might be formed in B horizons, it is not instrumental in the transport of aluminum.

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APPENDIX 1. DESCRIPTION OF THE DUTCH AND BELGIAN PROFILES

PROFILE NO.: NL-101 (Plate)

Location	: Galgenberg, Province of Limburg, Netherlands 51°31'13" N; 6°07'52" E

Profile description

O	3 - 0 cm	Very dark gray (10YR 3/1) decomposed needle litter; very friable; abrupt wavy boundary.
Ah	0 - 5 cm	Very dark gray (10YR 3/1) and light brownish gray (10YR 6/2) sand; weak medium granular structure; very friable; abrupt wavy boundary; pH 4.0.
E1	5 - 24 cm	Dark brown (7.5YR 4/2) sand with common coarse distinct pinkish gray (7.5YR 6/2) mottles; single grained; loose; abrupt wavy boundary; pH 4.2
E2	24 - 41 cm	Dark brown (7.5YR 4/2) sand with many coarse distinct pinkish gray (7.5YR 6/2) mottles; single grained; loose; abrupt wavy boundary; pH 4.2.
Bh1	41 - 45 cm	Black (7.5YR 2/0) sand; weak medium subangular blocky to massive structure; friable; abrupt wavy boundary; pH 3.8.
Bh2	45 - 47 cm	Black (5YR 2.5/1) sand; weak medium subangular blocky to massive structure; very friable; abrupt wavy boundary; pH 3.8.
Bs1	47 - 53 cm	Strong brown (7.5YR 5/8) sand; single grained; loose; clear wavy boundary; pH 4.1.
Bs2	53 - 82 cm	Dark brown (7.5YR 3/2) sand; single grained; loose; clear wavy boundary; pH 4.4; contains tongues of Bh and Bs materials.
C/B	82 -150 cm	Yellowish brown (10YR 5/4) sand, single grained, loose, C part; dark brown (7.5YR 3/2) sand, massive, very friable, B part as thin regularly spaced humus lamellae; pH 4.6.

PROFILE NO.: NL-102 (Plate)

Location : Swolgender Heide, Province of Limburg, Netherlands
51°31'01" N; 6°07'51" E.

Profile description

0	5 - 0 cm	Undecomposed roots; abrupt smooth boundary.
E1	0 - 19 cm	Light gray (10YR 6/1) and gray (10YR 5/1) fine sand; single grained; loose; clear wavy boundary; pH 4.2.
E2	19 - 39 cm	Light brownish gray (10YR 6/2) fine sand; single grained; loose; many fine vertical root casts; few vertical humus lamellae; abrupt wavy boundary; pH 4.0.
Bh	39 - 44 cm	Dark brown (7.5YR 3/2) and brown (7.5YR 4/2) fine sand; massive; friable; composed of lamellae; clear wavy boundary; pH 4.1.
BC1	44 - 89 cm	Brown (7.5YR 4/4) fine sand; single grained; loose; clear wavy boundary; common fine vertical root casts; pH 4.4.
BC2	89 -150 cm	Yellowish brown (10YR 5/4) fine sand; single grained; loose; few fine vertical root casts; lamellae at 100 cm; pH 4.4.

PROFILE NO.: NL-103 (Plate)

Location : Swolgender Heide, Province of Limburg, Netherlands
51°31'01" N, 6°07'51" E

Profile description

	0 - 55 cm	Wind blown fine sand.
Ahb	55 - 59 cm	Dark gray (10YR 4/1) fine sand; loose; very friable; abrupt smooth boundary; pH 4.4.
Eb	59 - 73 cm	Light gray (10YR 7/1) fine sand; single grained; loose; abrupt wavy boundary; pH 5.0.
BEb	73 - 76 cm	Gray (10YR 5/1) fine sand; single grained; loose; abrupt wavy boundary; pH 4.5.
Bh1b	76 - 80 cm	Black (7.5YR 2/0) fine sand; weak medium subangular blocky structure to massive; very friable; abrupt wavy boundary; pH 4.3.
Bh2b	80 - 82 cm	Black (5YR 2.5/1) fine sand; weak medium subangular blocky structure; very friable; abrupt wavy boundary; pH 4.2.

Bh3b	82 - 86 cm	Dark reddish brown (5YR 3/2) fine sand; weak medium subangular blocky to platy structure; very friable; abrupt wavy boundary; pH 4.3.
BCb	86 -102 cm	Yellowish brown (10YR 5/6) fine sand; single grained; loose; clear wavy boundary; pH 4.5.
C	102 -150 cm	Pale yellow (2.5Y 7/4) fine sand; single grained; loose; pH 4.6.

PROFILE NO.: NL-104 (Plate)

Location : Wellerlooi, Province of Limburg, Netherlands
51°32'42" N, 6°07'44" E

Profile description

O	7 - 0 cm	Decomposed needle litter and roots; very friable; abrupt smooth boundary.
Ah	0 - 18 cm	Very dark gray (10YR 3/1) sand; weak medium granular structure; very friable; clear wavy boundary; pH 3.7.
E	18 - 38 cm	Dark gray (10YR 4/1) sand; few fine gravels; single graines; loose; abrupt wavy boundary; pH 4.2.
Bhm	38 - 47 cm	Black (7.5YR 2/0) sand; weak medium subangular blocky structure; very firm; strongly cemented; clear wavy boundary; pH 3.8.
Bhs	47 - 61 cm	Very dark gray (5YR 3/1) sand; weak medium subangular blocky structure; very friable; abrupt wavy boundary; pH 3.8.
BC	61 -120 cm	Brown (10YR 4/3) sand; single grained; loose; pH 4.2.

PROFILE NO.: NL-105 (plate)

Location : Renderklippen, Province of Gelderland, Netherlands
52°22'32" N, 5°59'10" E

Profile description

O	3 - 0 cm	Decomposed leaf an needle litter; very friable; abrupt smooth boundary.
Ah	0 - 7 cm	Black (7.5YR 2/0) sand; weak medium granular structure; very friable; abrupt smooth boundary; pH 3.8.

E	7 - 16 cm	Brown (7.5YR 5/2) fine sand; single grained; loose; abrupt wavy boundary; pH 4.0.
Bh	16 - 22 cm	Black (7.5YR 2/0) sand; weak medium subangular blocky structure; very friable; abrupt wavy boundary; pH 3.9.
Bhs1	22 - 30 cm	Dark reddish brown (5YR 2.5/2) sand with many coarse distinct strong brown (7.5YR 4/6) mottles; single grained; loose; clear wavy boundary; pH 4.0.
Bhs2	30 - 43 cm	Dark brown (7.5YR 3/4) sand with many coarse distinct yellowish brown (10YR 5/6) mottles; single grained; loose; clear wavy boundary; pH 4.6.
BC1	43 - 61 cm	Yellowish brown (10YR 5/6) gravelly sand; single grained; loose; clear wavy boundary; pH 4.7.
BC2	61 - 88 cm	Brownish yellow (10YR 6/6) gravelly sand; single grained; loose; clear wavy boundary; pH 4.7.
C	88 -150 cm	Light yellowish brown (10YR 6/4) fine sand; single grained; cryoturbate with streaks of iron accumulation and bleaching; pH 5.0.

PROFILE NO.: NL-106 (Plate)

Location : Havelterberg, Province of Drente, Netherlands.
52°47'19" N, 6°13'05" E.

Profile description

O	5 - 0 cm	Decomposed leaf litter; very friable; abrupt smooth boundary.
Ah1	0 - 6 cm	Very dark gray (10YR 3/1) loamy fine sand; weak medium granular structure; very friable; abrupt wavy boundary; pH 4.0.
Ah2	6 - 11 cm	Black (5YR 2.5/1) loamy fine sand; weak medium granular structure; very friable; abrupt wavy boundary; pH 4.0.
E	11 - 22 cm	Pinkish gray (7.5YR 6/2 and 7.5YR 5/2) loamy fine sand; massive; very friable; abrupt irregular boundary; pH 4.4.
Bhs1	22 - 29 cm	Dark reddish brown (5YR 2.5/2) loamy fine sand; weak medium subangular blocky structure; very friable; abrupt wavy boundary; pH 4.3.
Bhs2	29 - 35 cm	Dark brown (7.5YR 4/4) loamy fine sand; weak medium subangular blocky structure; very friable; clear wavy boundary; pH 4.4.

2BC	35 - 45 cm	Dark yellowish brown (10YR 4/4) loam; weak medium subangular blocky structure; friable; abrupt wavy boundary; pH 4.5.
2Cg	45 - 65 cm	Pale yellow (2.5Y 7/4) loam; weak medium subangular blocky structure; black (5YR 2.5/1) Fe-Mn concretions; friable; clear wavy boundary; pH 4.6.

PROFILE No.: NL-107

Location : Paasloo, Province of Friesland, Netherlands
52°49'06" N, 5°59'47" E

Profile description

0	7 - 0 cm	Undecomposed leaf litter; abrupt wavy boundary.
Ah	0 - 10 cm	Very dark gray (10YR 3/1) fine sand; weak medium granular structure; friable; abrupt wavy boundary; pH 3.6.
Aan	10 - 45 cm	Very dark gray (10YR 3/1) fine sand; weak medium granular structure; very friable; abrupt wavy boundary; pH 3.9.
E	45 - 49 cm	Dark gray (10YR 4/1) fine sand; single grained; loose; abrupt broken boundary; pH 4.2.
Bh	49 - 52 cm	Black (10YR 2/1) fine sand; weak medium subangular blocky structure; very friable; abrupt wavy boundary; pH 4.1.
Bhs1	52 - 57 cm	Dark reddish brown (5YR 2.5/2) fine sand; weak medium subangular blocky structure; very friable; abrupt wavy boundary; pH 4.2.
Bhs2	57 - 60 cm	Dark reddish brown (5YR 3/2) fine sand; single grained; loose; clear wavy boundary; pH 4.3.
BC	60 - 78 cm	Brown (7.5YR 4/4) fine sand; single grained; loose; clear wavy boundary; irregularly spaced humus lamellae; pH 4.4.
C	78 -150 cm	Light yellowish brown (10YR 6/4) fine sand; single grained; loose; pH 4.6.

PROFILE NO.: NL-108 (Plate)

Location : Winterswijk, Province of Gelderland, Netherlands
51°57'57" N, 6°46'44" E

Profile description

O	4 - 0 cm	Very dark brown (10YR 2/2) decomposed leaf litter; very friable; abrupt wavy boundary.
E1	0 - 22 cm	Gray (10YR 5/1) fine sand; single grained; loose; clear wavy boundary; pH 4.4.
E2	22 - 29 cm	Gray (10YR 5/1) and very dark gray (10YR 3/1) fine sand; single grained; loose; abrupt wavy boundary; pH 4.5.
Bh	29 - 37 cm	Dark reddish brown (5YR 3/2) fine sand; weak medium subangular blocky structure; very friable; abrupt wavy boundary; pH 4.6.
Bsm	37 - 53 cm	Strong brown (7.5YR 5/6) fine sand with thin light yellowish brown (10YR 6/4) bands, massive; very firm; very strongly cemented; abrupt wavy boundary; pH 4.6.
BC1	53 - 82 cm	Yellowish brown (10YR 4/6) fine sand; massive; very firm; strongly cemented; clear wavy boundary; pH 4.6.
BC2	82 -109 cm	Light yellowish brown (10YR 6/4) fine sand; single grained; loose; clear wavy boundary; pH 4.6.
C	109-150 cm	Very pale brown (10YR 7/4) fine sand; single grained; loose; pH 4.6.

PROFILE NO.: NL-109 (Plate)

Location : Winterswijk, Province of Gelderland, Netherlands
51°57'57" N, 6°45'16" E

Profile description

O	5 - 0 cm	Very dark gray (10YR 3/1) decomposed leaf litter; very friable; abrupt smooth boundary.
E1	0 - 18 cm	Light brownish gray (10YR 6/2) loamy fine sand; 5% coarse gravel; weak medium subangular blocky structure; very friable; clear wavy boundary; pH 3.6.
E2	18 - 22 cm	Light gray (10YR 7/2) and very dark gray (10YR 3/1) gravelly loamy fine sand; 20% coarse gravel; weak medium subangular blocky structure; very friable; abrupt wavy boundary; pH 3.4.

Bh	22 - 29 cm	Dark reddish brown (5YR 3/2) gravelly fine sandy loam; weak coarse subangular blocky structure; friable; abrupt wavy boundary; pH 3.9.
Bhs	29 - 52 cm	Dark brown (7.5YR 4/4) loamy fine sand with many medium faint light gray (10YR 7/2) and many coarse distinct strong brown (7.5YR 4/6) mottles; weak medium subangular blocky structure; very friable; abrupt wavy boundary; pH 4.2.
2Cr	52 -100 cm	Light gray (2.5Y 7/2) fine sandy loam with many medium prominent strong brown (7.5YR 5/8) mottles; pseudogley; massive; firm; pH 4.0.

PROFILE NO.: NL-110 (Plate)

Location : Brunssumerheide, Province of Limburg, Netherlands
50°55'49" N, 6°0'35" E

Profile description

0	5 - 0 cm	Undecomposed leaf and needle litter; abrupt smooth boundary.
Ah	0 - 9 cm	Very dark gray (10YR 3/1) fine sand; weak medium granular structure; very friable; clear wavy boundary; pH 3.8.
E1	9 - 20 cm	Gray (10YR 5/1) gravelly fine sand; single grained; loose; abrupt wavy boundary; pH 4.2.
Fiber	20 cm	Very dark gray (10YR 3/1) fine sand; weak fine subangular blocky structure; very friable; abrupt wavy boundary; pH 4.0.
E2	20 - 70 cm	Light gray (10YR 7/1) fine sand; single grained; loose; abrupt irregular boundary; concentration of gravel at lower boundary; pH 4.6.
Bh1	70 - 72 cm	Black (7.5YR 2/0) fine sand; weak medium subangular blocky structure to massive; very friable; abrupt wavy boundary; pH 3.9.
Bh2	72 - 75 cm	Black (5YR 2.5/1) fine sand; weak medium subangular blocky structure to massive; very friable; abrupt wavy boundary; pH 4.0.
Bhs	75 - 80 cm	Dark reddish brown (5YR 3/2) fine sand with many coarse distinct yellowish red (5YR 5/6) mottles; weak medium subangular blocky structure; clear wavy boundary; pH 4.2.

Bs	80 - 85 cm	Dark reddish brown (5YR 3/3) fine sand with many coarse distinct strong brown (7.5YR 4/6) mottles; single grained; loose; clear irregular boundary; pH 4.5.
Bh3	85 - 87 cm	Black (5YR 2.5/2) fine sand; weak medium subangular structure; very friable; abrupt irregular boundary; pH 4.5.
BC	87 -100 cm	Very pale brown (10YR 7/4) fine sand; single grained; loose; clear broken boundary; many lamellae along joints, vertical and horizontal; pH 4.6.
C	100-150 cm	Pale yellow (2.5Y 8/4) fine sand; single grained; loose; pH 4.9.

PROFILE NO.: B-101 (Plate)

Location : Meerhout, Province of Antwerpen, Belgium
51°09'02" N, 5°03'51" E

<u>Profile description</u>

O	8 - 0 cm	Undecomposed needle litter; abrupt smooth boundary.
Ah	0 - 5 cm	Dark gray (10YR 4/1) fine sand; weak medium granular structure; very friable; abrupt smooth boundary; pH 3.6.
E	5 - 15 cm	Light gray (10YR 7/1) and light brownish gray (10YR 6/2) fine sand; single grained; loose; abrupt smooth boundary; pH 4.1.
Bh	15 - 18 cm	Black (5YR 2.5/1) fine sand; weak medium subangular blocky structure; very friable; clear wavy boundary; pH 4.1.
Bhs	18 - 28 cm	Dark brown (7.5YR 3/2), yellowish brown (10YR 5/4) and strong brown (7.5YR 4/6) fine sand; single grained; loose; clear wavy boundary; pH 4.2.
Bs	28 - 37 cm	Dark reddish brown (2.5YR 3/4) and light yellowish brown (10YR 6/4) fine sand; single grained; loose; clear wavy boundary; pH 4.2.
B/C	37 - 59 cm	Pale brown (10YR 6/3), brownish yellow (10YR 6/6) and strong brown (7.5YR 5/8) fine sand, B part; light gray (2.5Y 7/2) fine sand, C part; single grained; loose; clear wavy boundary; pH 4.3.
Cr	59 - 89 cm	Light gray (2.5Y 7/2) and yellowish red (5YR 5/6 and 5YR 4/6) fine sand; single grained; loose; abrupt irregular boundary; pH 4.5.

Cg	89 -120 cm	Brownish yellow (10YR 6/6) and strong brown (7.5YR 5/8) fine sand; single grained; loose; pH 4.3.
C	120-150 cm	Pale olive (5Y 6/3) fine sand; single grained; loose; pH 4.3.

PROFILE No.: B-102 (Plate)

Location : Meerhout, Province of Antwerpen, Belgium
51°09'17" N, 5°04'17" E

<u>Profile description</u>

O	3 - 0 cm	Decomposed needle litter; very friable, abrupt smooth boundary.
Ep	0 - 29 cm	Light gray (10YR 6/1) fine sand; single grained; loose; abrupt wavy boundary; pH 4.4.
Bhm1	29 - 47 cm	Dark reddish brown (2.5YR 2.5/2) fine sand, massive; very strongly cemented; very firm, clear wavy boundary; pH 4.4.
Bhm2	47 - 62 cm	Dark reddish brown (5YR 3/2) fine sand; massive; very strongly cemented; very firm; clear wavy boundary; pH 4.4.
Bhm3	62 - 77 cm	Dark brown (7.5YR 3/4) fine sand; massive; very strongly cemented; very firm; clear wavy boundary; pH 4.6.
B	77 - 92 cm	Brown (10YR 4/3) and dark brown (7.5YR 3/4) fine sand; single grained; loose; abrupt wavy boundary; pH 4.6.
Bhm4	92 -110 cm	Dark reddish brown (5YR 3/3) fine sand; massive; very firm; abrupt wavy boundary; lamellae of varying thickness; pH 4.5.
C	110-150 cm	Light yellowish brown (10YR 6/4) fine sand; single grained; loose; pH 4.7.

PROFILE NO.: B-103 (Plate)

Location : Meerhout, province of Antwerpen, Belgium
51°09'17" N, 5°04'17" E

Profile description

	0 - 23 cm	Wind blown sand.
Ahb	23 - 30 cm	Very dark gray (10YR 3/1) fine sand; weak medium granular structure; very friable; abrupt smooth boundary; pH 4.3.
Eb	30 - 58 cm	Light gray (10YR 7/1) fine sand; single grained; loose; abrupt wavy boundary; pH 4.7.
EBb	58 - 85 cm	Grayish brown (10YR 5/2) fine sand; single grained; loose; clear wavy boundary; pH 4.6.
Bh1b	85 -103 cm	Dark reddish brown (5YR 3/3) fine sand; weak medium subangular blocky structure; very friable; clear wavy boundary; pH 4.6.
Bh2b	103-125 cm	Dark reddish brown (5YR 3/3) fine sand; weak medium subangular blocky structure; very friable; clear wavy boundary; pH 4.5.
Bh3b	125-155 cm	Dark reddish brown (5YR 3/4) fine sand; single grained; loose; abrupt wavy boundary; pH 4.5.
Bhmb	155-170 cm	Black (5YR 2.5/1) fine sand; weak coarse subangular blocky structure to massive; strongly cemented; very firm; abrupt wavy boundary; pH 4.6.

PROFILE NO.: B-104 (Plate)

Location : Opgrimbie, Province of Limburg, Belgium
50°57'10" N, 5°38'03" E

Profile description

01	2 - 1 cm	Undecomposed needle litter; abrupt smooth boundary.
02	1 - 0 cm	Black (7.5YR 2/0) well decomposed needle litter; very friable; abrupt smooth boundary.
Ah	0 - 5 cm	Very dark gray (10YR 3/1) loamy fine sand; weak medium granular structure; very friable; abrupt wavy boundary; pH 3.8.
E1	5 - 18 cm	Grayish brown (10YR 5/2) gravelly fine sand; weak medium subangular blocky structure; very friable; clear wavy boundary; pH 4.1.
E2	18 - 33 cm	Brown (7.5YR 5/2) gravelly fine sand; weak medium subangular blocky structure; very friable; abrupt wavy boundary; pH 4.1.

Bh1	33 - 36 cm	Black (10YR 2/1) slightly gravelly loamy fine sand; weak medium subangular blocky structure; very friable; abrupt wavy boundary; pH 3.9.
Bh2	36 - 40 cm	Black (5YR 2.5/1) gravelly loamy fine sand; weak medium subangular blocky to platy structure; very friable; abrupt wavy boundary; pH 3.9.
Bh3	40 - 42 cm	Dark reddish brown (5YR 2.5/1) gravelly fine sand; weak medium subangular blocky to platy structure; very friable; wavy boundary; pH 4.1.
Bhs1	42 - 53 cm	Dark reddish brown (5YR 3/3) gravelly fine sand; weak medium subangular blocky to platy structure; very friable clear wavy boundary; pH 4.3.
Bhs2	53 - 70 cm	Dark brown (7.5YR 4/4) gravelly fine sand; weak medium subangular blocky structure; very friable; clear wavy boundary; pH 4.4.
2Cg	70 -100 cm	Light reddish brown (5YR 6/3) with many coarse prominent strong brown (7.5YR 5/6) mottles and yellowish brown (10YR 5/6) with many coarse prominent dark brown (7.5YR 4/4) mottles; loamy fine sand; massive; friable; pH 4.3.

PROFILE NO.: B-105 (Plate)

Location : Opgrimbie, Province of Limburg, Belgium
50°57'23" N, 5°38'34" E

Profile description

O	2 - 0 cm	Decomposed needle litter; very friable; abrupt smooth boundary.
Ah	0 - 8 cm	Very dark gray (10YR 3/1) fine sand; weak medium granular blocky structure; very friable; abrupt smooth boundary; pH 4.3.
E	8 - 23 cm	Light gray (10YR 6/1) fine sand; single grained; loose; abrupt wavy boundary; pH 4.6.
Bh	23 - 30 cm	Very dark gray (10YR 3/1) fine sand; weak medium subangular blocky structure; very friable; clear wavy boundary; pH 3.9.
Bhs	30 - 35 cm	Dark reddish brown (5YR 2.5/2) fine sand; weak medium subangular blocky structure; very friable; clear wavy boundary: pH 4.1.

BC	35 - 91 cm	Dark yellowish brown (10YR 4/4) fine sand; single grained; loose; abrupt smooth boundary; many thin horizontal lamellae, irregularly spaced; pH 4.6.
C	91 -150 cm	Light gray (2.5Y 7/2) and pale yellow (2.5Y 7/4) fine sand; single grained; loose; pH 4.6.

PROFILE NO.: B-106 (Plate)

Location : Opgrimbie, Province of Limburg, Belgium
50°57'23" N, 5°38'34" E

<u>Profile description</u>

O	7 - 0 cm	Very dark gray (10YR 3/1) decomposed leaf litter; very friable; abrupt; smooth boundary.
Ah	0 - 15 cm	Very dark gray (10YR 3/1) fine sand; weak medium subangular blocky structure; very friable; clear smooth boundary; pH 3.6.
E	15 - 31 cm	Light brownish gray (10YR 6/2) fine sand; single grained; loose; clear smooth boundary; many fine root casts; pH 4.2.
BE	31 - 40 cm	Brown (7.5YR 4/2) fine sand; weak medium subangular blocky structure; very friable; clear smooth boundary; common fine root casts; pH 4.2.
Bh	40 - 49 cm	Dark brown (7.5YR 3/4) fine sand; weak medium subangular blocky structure; very friable; clear smooth boundary; common fine root casts; pH 4.2.
BC	49 - 61 cm	Dark brown (7.5YR 4/4) upper 2 cm and brown (10YR 4/3) fine sand; single grained; loose abrupt wavy boundary; common fine root casts; pH 4.4.
C	61 -150 cm	Light gray (10YR 7/2) fine sand; single grained; loose; common fine root casts; pH 4.5.

ISM PROFILE NO.: USA-1 (Plate)

Location : Emmet County, Michigan, United States of America
40°27'52" N, 84°43'53" W

<u>Profile description</u>

O	5 - 0 cm	Black (10YR 2/1) well decomposed leaf litter containing a large amount of mineral soil; weak medium granular structure; very friable; abrupt smooth boundary.

E	0 - 23 cm	Light brownish gray (10YR 6/2) sand; single grained; loose; abrupt irregular boundary; pH 5.0.
Bh	23 - 32 cm	Dark reddish brown (5YR 2/2) sand; weak medium subangular blocky structure; very friable; some fragments of strongly cemented ortstein; abrupt irregular boundary; pH 4.7.
Bhs	32 - 50 cm	Brown (7.5YR 4/4) sand; weak medium subangular blocky structure; very friable; some fragments of strongly cemented ortstein; clear irregular boundary; pH 4.9.
BC	50 - 88 cm	Yellowish brown (10YR 5/6) sand; weak coarse subangular blocky structure; very friable; some fragments of weakly cemented ortstein; gradual wavy boundary; pH 5.1.
C	88 -130 cm	Yellowish brown (10YR 5/4) sand; single grained; loose; pH 5.8.

APPENDIX 2. DESCRIPTIONS OF THE RUSSIAN PROFILES

ISM PROFILE NO.: GMC-4 (Plate)

Location : Near Leningrad, Soviet Union
About 60° N, 30° E

Profile description

O	5 - 0 cm	Black (10YR 2/1) decomposed leaf litter; weak medium platy structure; friable; abrupt smooth boundary.
E1	0 - 12 cm	Pinkish gray (7.5YR 6/2) loamy very fine sand; single grained; loose; clear wavy boundary; pH 3.7.
E2	12 - 19 cm	Light brownish gray (10YR 6/2) loamy very fine sand; single grained; loose; abrupt wavy boundary; pH 4.1.
BE	19 - 23 cm	Dark brown (7.5YR 4/2) very fine sand; weak fine subangular blocky structure; very friable; clear wavy boundary; pH 4.3.
Bh	23 - 30 cm	Dark reddish brown (5YR 3/4) loamy very fine sand; weak fine subangular blocky structure; friable; abrupt smooth boundary; pH 4.2.
Bhs	30 - 36 cm	Dark brown (7.5YR 3/4) very fine sand; weak medium subangular blocky structure; very friable; clear wavy boundary; pH 4.3.
Bs	36 - 42 cm	Dark yellowish brown (10YR 4/4) loamy very fine sand; weak fine subangular blocky structure; very friable; abrupt smooth boundary; pH 5.2.

2Cg	42 - 58 cm	Pale brown (10YR 6/3) very fine sandy loam with many coarse prominent strong brown (7.5YR 5/6) mottles; weak coarse subangular blocky structure; friable; clear smooth boundary; pH 5.0.
2Cr1	58 - 75 cm	Light gray (2.5Y 7/2) very fine sandy loam with many coarse prominent dark brown (7.5YR 4/4) mottles; moderate very coarse subangular blocky structure; friable; clear smooth boundary; pH 5.6.
2Cr2	75 - 95 cm	Light gray (2.5Y 7/2) very fine sandy loam with many coarse prominent dark yellowish brown (10YR 4/4) mottles; weak medium subangular blocky structure; friable; pH 6.4.

ISM PROFILE NO.: GMC-6

Location : Velikiye Luki Region, Soviet Union
About 56° N, 30° E

Profile description

Ap	0 - 12 cm	Dark grayish brown (10YR 4/2) clay loam; weak medium subangular blocky structure; firm; abrupt smooth boundary; pH 6.5.
E/B	12 - 21 cm	Pale brown (10YR 6/3) A part; dark brown (7.5YR 4/4) B part; silty clay loam; weak medium subangular blocky structure; firm; clear wavy boundary; pH 5.4.
B/E	21 - 30 cm	Reddish brown (5YR 4/4) B part; light yellowish brown (10YR 6/4) A part; silty clay; weak fine subangular blocky structure; very firm; clear wavy boundary; pH 5.1.
Bt	30 - 57 cm	Reddish brown (5YR 4/4) silty clay; moderate very fine angular blocky structure; very firm; abrupt wavy boundary; pH 5.0.
2Cr	57 - 66 cm	Gray (10YR 6/1) clay with common medium prominent strong brown (7.5YR 4/6) mottles; weak fine angular blocky structure, very firm; abrupt wavy boundary; pH 4.9.
2C1	66 - 73 cm	Dark brown (7.5YR 4/4) clay with common fine distinct yellowish brown (10YR 5/6) and gray (5Y 6/1) mottles; weak medium subangular blocky structure; very firm; abrupt wavy boundary; pH 5.0.

2C2	73 - 85 cm	Dark brown (7.5YR 4/4) sandy clay loam; moderate medium subangular blocky structure; firm; clear wavy boundary; pH 5.0.
2C3	85 - 92 cm	Light olive gray (5Y 6/2) sandy clay loam with common medium prominent strong brown (7.5YR 5/8) mottles; weak medium subangular blocky structure; firm; abrupt wavy boundary; pH 5.4.
3C	92 -100 cm	Dark brown (7.5YR 4/4) sandy loam with many coarse prominent gray (5Y 6/1) and yellowish brown (10YR 5/8) mottles; weak coarse subangular blocky structure; friable; pH 5.4.

ISM PROFILE NO.: GMC-7

Location : Near Leningrad, Soviet Union
About 60° N, 30° E

<u>Profile description</u>

Ah	0 - 5 cm	Very dark grayish brown (10YR 3/2) loam; weak medium granular structure; friable; clear smooth boundary.
Bs	5 - 13 cm	Yellowish brown (10YR 5/4) loam; weak medium subangular blocky structure; friable; clear smooth boundary; pH 4.8.
E	13 - 25 cm	Light brownish gray (2.5Y 6/2) loam; very weak fine subangular blocky structure; friable; abrupt irregular boundary; pH 4.9.
Bt1	25 - 54 cm	Dark yellowish brown (10YR 4/4) loam; weak medium subangular blocky structure; friable; clear wavy boundary; pH 5.1.
Bt2	54 - 69 cm	Yellowish brown (10YR 5/4) loam with coarse medium distinct strong brown (7.5YR 5/6) mottles; weak medium subangular blocky structure; friable; clear smooth boundary; pH 5.8.
BCr	69 - 85 cm	Grayish brown (2.5Y 5/2) loam with coarse medium prominent yellowish brown (10YR 5/6) mottles; weak coarse platy to weak fine subangular blocky structure; friable; clear smooth boundary; pH 5.8.
C	85 - 100 cm	Light olive brown (2.5Y 5/4) loam with many coarse distinct olive gray (5Y 5/2) mottles; weak coarse platy to weak medium subangular blocky structure; friable; pH 5.3.

ISM PROFILE NO.: GMC-8 (Plate)

Location : Near Leningrad, Soviet Union
About 60° N, 30° E

Profile description

Ah	0 - 17 cm	Very dark grayish brown (10YR 3/2) fine sandy loam; weak medium granular structure; friable; abrupt smooth boundary; pH 6.1.
E	17 - 32 cm	Light gray (10YR 7/2) loamy fine sand; single grained; loose; clear wavy boundary; pH 6.3.
EB	32 - 37 cm	Grayish brown (10YR 5/2) loamy fine sand; weak fine subangular blocky structure; very friable, abrupt wavy boundary; pH 5.6.
Bhm1	37 - 49 cm	Dark reddish brown (5YR 3/2) fine sand; strong coarse subangular blocky structure to massive; very firm; clear wavy boundary; pH 4.7.
Bhm2	49 - 64 cm	Dark brown (7.5YR 4/4) fine sand; strong coarse subangular blocky structure to massive; very firm; clear wavy boundary; pH 4.5.
Bs	64 - 78 cm	Dark brown (7.5YR 4/4) fine sand; weak medium subangular blocky structure; very friable; clear wavy boundary; pH 4.6.
BC	78 - 93 cm	Yellowish brown (10YR 5/4) fine sand; single grained; loose; pH 4.7.
2C	93 -100 cm	Pale brown (10YR 6/3) fine sandy loam; weak coarse subangular blocky structure; friable; pH 4.7.

ISM PROFILE NO.: GMC-13

Location : Rzhev District of Kaolin Oblast, Soviet Union
About 56° N, 35° E

Profile description

O	4 - 0 cm	Black (10YR 2/1) charred twigs; abrupt smooth boundary.
Ah	0 - 10 cm	Grayish brown (10YR 5/2) sandy loam; weak medium subangular blocky structure; friable; clear wavy boundary; pH 4.0.
E1	10 - 19 cm	Light gray (10YR 7/2) sandy loam, weak medium subangular blocky structure; friable; abrupt smooth boundary; pH 4.8.

Bs	19 - 32 cm	Yellowish brown (10YR 5/4) sandy loam; weak medium subangular blocky structure; friable; clear wavy boundary; pH 5.2.
E2	32 - 46 cm	Light yellowish brown (10YR 6/4) sandy loam; weak medium subangular blocky structure; friable; abrupt wavy boundary; pH 5.7.
2Bt1	46 - 68 cm	Light yellowish brown (10YR 6/4) loam with common coarse distinct strong brown (7.5YR 5/6), dark brown (7.5YR 4/4) and pale brown (10YR 6/3) mottles; weak medium subangular blocky structure; friable; abrupt smooth boundary; pH 4.5.
2Bt2	68 - 96 cm	Brown (7.5YR 5/4) sandy loam with common medium distinct reddish brown (5YR 5/4) and light brown (7.5YR 6/4) mottles; moderate medium subangular blocky structure; friable; pH 4.6.

APPENDIX 3 PARTICLE SIZE DISTRIBUTION OF ALL PROFILES AND MOIST COLOR OF SOME PROFILES

Horizon	Depth	Particle Size (µm)							
	cm	2000-1000 %	1000-500 %	500-250 %	250-100 %	100-50 %	50-20 %	20-2 %	<2 %
NL-101									
O	3- 0								
Ah	0- 5	2	21	54	17	1	2	3	1
E1	5- 24	2	18	55	21	0	0	1	3
E2	24- 41	2	17	58	19	1	0	1	3
Bh1	41- 45	1	16	55	19	1	1	1	6
Bh2	45- 47	2	19	65	21	1	1	0	7
Bs1	47- 53	1	15	58	22	1	0	1	1
Bs2	53- 82	2	19	58	21	1	0	0	0
C/B	82-150	1	19	64	15	0	0	0	0
fiber	95	2	20	57	19	0	0	0	1
fiber	150	1	16	61	20	0	1	0	1
B2h root hole		1	18	57	19	0	0	0	1
NL-102									
O	5- 0								
E1	0- 19	0	1	12	72	12	2	1	0
E2	19- 39	0	1	11	71	14	1	1	1
Bh	39- 44	0	1	12	70	14	2	0	2
BC1	44- 89	0	1	15	68	12	2	0	2
BC2	89-150	0	1	15	62	14	6	1	1
NL-103									
Cover	0- 55								
Ahb	55- 59	0	1	8	64	19	5	0	3
Eb	59- 73	0	1	10	72	15	1	1	0
BEb	73- 76	0	1	12	75	10	1	1	1
Bh1b	76- 80	0	1	13	75	8	1	1	1
Bh2b	80- 82	0	1	14	76	5	1	1	1
Bh3b	82- 86	0	1	13	77	6	1	1	1
BCb	86-102	0	1	10	77	10	1	0	1
C	102-150	0	1	7	79	11	2	0	0
NL-104									
O	7- 0								
Ah	0- 18	0	6	47	42	1	1	1	1
E	18- 38	0	4	42	51	1	0	1	1
Bhm	38- 47	0	4	41	49	1	0	1	3
Bhs	47- 61	0	4	43	49	1	1	1	0
BC	61-120	0	4	35	56	3	1	1	1
NL-105									
O	3- 0								
Ah	0- 7	3	14	35	29	8	8	3	0
E	7- 16	1	11	34	29	11	9	2	2
Bh	16- 22	3	15	35	28	8	5	2	3
Bhs1	22- 30	3	15	35	28	7	6	3	2
Bhs2	30- 43	2	13	36	29	10	5	4	0
BC1	43- 61	2	11	31	33	13	7	2	0
BC2	61- 88	1	6	34	43	10	4	1	1
C	88-150	1	6	26	61	4	2	1	0
NL-106									
O	5- 3								
Ah1	0- 6	0	1	8	49	22	11	4	4
Ah2	6- 11	1	1	11	43	26	11	5	2
E	11- 22	1	2	12	49	20	10	5	1
Bhs1	22- 29	1	2	12	47	16	9	5	8
Bhs2	29- 35	1	2	12	53	13	8	5	6
2BC	35- 45	1	3	12	52	12	9	7	4
2Cg	45- 65	1	4	13	50	13	7	8	4
NL-107									
O	7- 0								
Ah	0- 10	0	1	17	62	11	5	2	2
Aan	10- 45	0	1	15	59	15	5	3	2
E	45- 49	0	1	17	57	16	6	2	1
Bh	49- 52	0	1	17	57	15	5	1	2
Bhs1	52- 57	0	1	16	58	17	5	2	1
Bhs2	57- 60	0	1	16	59	16	6	1	2
BC	60- 78	0	1	16	61	16	5	0	0
C	78-150	0	0	9	67	19	4	0	0
fiber		0	0	10	69	16	4	0	0
NL-108									
O	4- 0								
E1	0- 22	0	4	24	56	8	2	3	2
E2	22- 29	0	4	24	56	9	3	3	1
Bh	29- 37	0	3	25	60	8	1	2	2
Bsm1	37- 53	0	3	20	64	11	2	0	0
Bsm2	53- 82	0	2	17	69	11	1	0	0
BC	82-109	0	3	20	61	13	2	0	0
C	109-150	0	1	17	67	13	2	0	0

Horizon	Depth cm	2000-1000 %	1000-500 %	500-250 %	250-100 %	100-50 %	50-20 %	20-2 %	<2 %
		Particle Size (µm)							
NL-109									
O	5- 0								
E1	0- 18	2	6	17	42	17	9	2	5
E2	18- 22	2	5	17	44	17	8	5	2
Bh	22- 29	2	5	11	40	26	8	3	4
Bhs	29- 52	3	6	11	40	24	9	4	2
2Cr	52-100	1	4	13	39	11	8	7	17
NL-110									
O	5- 0								
Ah	0- 9	1	3	19	64	3	3	3	4
E1	9- 20	1	2	12	75	5	4	1	0
fiber	20	1	2	12	73	6	4	3	0
E2	20- 70	1	1	2	88	4	2	2	0
Bh1	70- 72	0	1	12	68	8	2	5	3
Bh2	72- 75	0	1	11	78	0	2	3	4
Bhs	75- 80	0	1	7	81	4	2	1	4
Bs	80- 85	0	0	4	90	3	1	0	2
Bh3	85- 87	0	1	9	83	3	1	0	3
BC	87-100	0	1	2	92	2	1	0	2
C	100-150	0	0	10	85	4	1	1	0
B-101									
O	8- 0								
Ah	0- 5	1	1	10	77	6	2	2	2
E	5- 15	0	1	10	78	8	2	0	0
Bh	15- 18	1	2	12	76	4	1	1	3
Bhs	18- 28	1	2	13	74	5	1	1	3
Bs	28- 37	0	2	14	78	3	1	1	1
B/C	37- 59	0	2	11	77	7	0	1	1
Cr	59- 89	1	2	12	80	6	0	0	0
Cg	89-120	1	1	9	84	4	1	0	0
C	120-150	0	1	6	80	8	2	0	3
B-102									
O	3- 0								
Ep	0- 29	1	2	13	75	6	1	0	1
Bhm1	29- 47	1	3	16	70	4	0	0	6
Bhm2	47- 62	2	4	15	71	3	0	0	4
Bhm3	62- 77	1	2	14	71	5	0	1	5
B	77- 92	3	5	16	66	7	2	0	2
Bhm4	92-110	1	3	14	73	7	1	0	2
C	110-150	1	3	14	76	4	1	0	2

Horizon	Depth cm	2000-1000 %	1000-500 %	500-250 %	250-100 %	100-50 %	50-20 %	20-2 %	<2 %
		Particle Size (µm)							
B-103									
cover	0- 23								
Ahb	23- 30	1	2	16	74	4	1	1	1
Eb	30- 58	0	2	11	80	5	1	0	0
EBb	58- 85	0	2	11	79	5	1	0	1
Bh1b	85-103	1	2	14	78	4	0	0	1
Bh2b	103-125	0	2	15	74	5	1	0	3
Bh3b	125-155	2	3	15	72	3	1	0	4
Bhmb	155-170	0	0	8	81	4	1	1	4
B-104									
01	2- 1								
02	1- 0								
Ah	0- 5	1	2	23	55	4	6	4	5
E1	5- 18	1	2	13	68	6	6	3	2
E2	18- 33	1	2	11	72	4	6	2	2
Bh1	33- 36	1	2	15	64	4	6	3	5
Bh2	36- 40	1	2	14	63	4	6	3	7
Bh3	40- 42	1	2	22	61	2	5	3	4
Bhs1	42- 53	1	2	10	72	3	6	2	4
Bhs2	53- 70	1	1	10	72	9	6	3	2
2Cg (white)	70-100	0	1	9	66	7	6	3	8
2Cg (orange)		0	1	9	64	10	4	2	8
B-105									
0	2- 0								
Ah	0- 8	1	2	23	69	3	1	0	2
E	8- 23	0	1	16	78	2	1	0	1
Bh	23- 30	1	1	18	69	4	1	1	5
Bhs	30- 35	0	1	15	79	3	0	0	2
BC	35- 91	0	1	14	81	2	1	0	1
C	91-150	0	0	9	88	0	2	0	2
B-106									
O	7- 0								
Ah	0- 15	0	2	29	59	6	2	1	2
E	15- 31	0	1	9	80	7	2	1	1
BE	31- 40	0	1	8	77	8	1	2	3
Bh	40- 49	1	1	10	80	3	0	1	4
BC	49- 61	0	1	8	81	6	2	0	3
C	62-150	0	1	14	79	3	1	0	1

Horizon	Depth	Particle Size (μm)							
	cm	2000-1000 %	1000-500 %	500-250 %	250-100 %	100-50 %	50-20 %	20-2 %	<2 %
GMC-4									
O	5- 0								
E1	0- 12	1	2	2	6	66	15	6	3
E2	12- 19	1	2	2	6	65	15	7	3
BE	19- 22	1	3	4	8	71	9	2	1
Bh	22- 30	0	1	2	8	72	11	3	1
Bhs	30- 37	0	0	1	5	80	10	2	1
Bs	37- 42	0	0	0	4	75	15	3	2
2Cg	42- 58	0	1	1	4	49	27	13	6
2Cr1	58- 75	0	1	2	6	49	23	12	6
2Cr2	75- 95	0	1	1	5	64	16	9	4
GMC-6									
Ap	0- 12	1	4	5	7	6	9	35	33
E/B	12- 21	2	5	4	4	4	7	38	35
B/E	21- 30	1	2	2	2	1	5	37	52
Bt	30- 57	0	0	0	0	0	6	40	53
2Cr	57- 66	0	1	3	9	2	2	22	62
2C1	66- 73	1	5	16	18	2	2	12	45
2C2	73- 85	5	15	21	13	3	3	14	26
2C3	85- 92	4	10	16	17	4	4	23	23
3C	92-100	6	14	21	29	5	2	8	14
GMC-7									
Ah	0- 5								
Bs	5- 13	4	7	10	16	10	14	26	13
E	13- 25	5	7	10	16	11	13	28	11
Bt1	25- 54	2	4	6	14	12	13	31	19
Bt2	54- 69	3	6	9	16	13	14	25	15
BCr	69- 85	3	5	8	13	11	13	30	17
C	85-100	2	4	7	13	10	12	26	26
GMC-8									
Ah	0- 17	0	1	5	46	19	9	10	8
E	17- 30	0	1	4	47	26	10	8	4
EB	30-. 38	1	3	6	56	18	6	5	7
Bhm1	38- 53	4	13	9	56	9	2	3	4
Bhm2	53- 64	0	2	10	73	9	2	2	1
Bs	64- 80	1	5	11	69	9	2	1	1
BC	80- 93	1	2	8	74	10	3	1	2
2C	93-100	0	1	3	36	21	21	14	3

Horizon	Depth	Particle Size (μm)								Color
	cm	2000-1000 %	1000-500 %	500-250 %	250-100 %	100-50 %	50-20 %	20-2 %	<2 %	
GMC-13										
O	4- 0									
Ah	0- 10	3	8	16	31	17	9	10	6	
E1	10- 19	3	7	14	30	17	10	10	10	
Bs	19- 32	3	8	14	31	15	11	11	7	
E2	32- 46	3	7	12	26	20	14	11	6	
2Bt1	46- 68	3	6	10	19	14	13	17	19	
2Bt2	68- 96	3	6	10	21	22	13	8	18	
USA-1										
E	0- 23	0	3	46	42	1	3	2	3	
Bh	23- 32	0	3	41	44	3	3	3	4	
Bhs	32- 50	1	2	45	41	3	3	2	4	
BC	50- 88	0	2	45	44	2	2	1	4	
C	88-130	0	6	70	22	1	1	1	0	
CDN-14										
Ah		1	6	19	37	21	8	6	3	
Bhg1	20- 26	0	5	15	28	20	8	8	15	5YR 2/1
Bhg2	26- 46	0	3	8	20	23	15	10	20	5YR 2/1
BCg	46- 61	0	2	9	28	28	11	7	15	10YR 4/3
2C	+64	1	4	14	38	27	9	5	3	5YR 5/5
F-2										
Ah	0- 15	16	17	13	13	5	4	16	17	7.5YR 3/2
AB	15- 24	13	15	13	14	7	4	18	16	5YR 3/3
BA	24- 39	17	18	14	13	6	4	17	11	5YR 4/3
Bw1	39- 53	18	20	14	13	5	4	16	11	5YR 4/4
Bw2	53- 68	21	23	14	12	5	5	12	8	5YR 4/4
BC	68- 81	19	20	13	13	6	5	15	8	5YR 4/3
C	81-104	21	25	15	11	5	5	14	5	5YR 4/3
F-10										
Ah	0- 15	1	1	6	72	5	4	8	3	10YR 2/2
E1	15- 25	0	0	3	78	5	5	5	3	10YR 4/2
E2	25- 38	0	0	0	82	5	4	4	3	10YR 5/2
Bh	38- 52	0	0	2	88	4	0	2	3	7.5YR 3/2
Bs	52- 66	0	0	4	79	2	0	2	12	7.5YR 4/2
BC	66- 75	0	0	0	90	2	0	0	6	7.5YR 5/8
C	75-123	0	0	2	88	4	0	2	4	10YR 7/3

Horizon	Depth cm	Particle Size (µm) 2000–1000 %	1000–500 %	500–250 %	250–100 %	100–50 %	50–20 %	20–2 %	<2 %	Color
IRL-9										
O	0– 7									
E	10– 30	17	16	17	21	11	11	6	1	10YR 6/2
Bh	30– 36	7	11	18	26	13	14	7	4	5YR 3/3
Bs	40– 55	16	16	16	19	10	13	8	2	7.5YR 7/6
C	70– 80	13	14	16	23	14	13	5	2	10YR 7/4
SK-2										
O+Ah	0– 10	0	1	30	63	3	2	1	0	10YR 6/1
E	10– 58	0	1	33	62	2	0	1	0	10YR 8/1
EB+BE	58– 75	0	0	26	70	2	1	1	0	10YR 8/1
Bh1	75– 90	0	2	32	62	3	0	1	0	7.5YR 3/2
Bh2	90–108	0	1	14	73	9	1	1	1	7.5YR 3/2
Bh3	110–120	0	0	4	80	14	1	0	1	7.5YR-10YR 4/3
SK-3										
Ah	0– 2	0	2	44	48	2	2	1	1	10YR 6/2
E	10– 25	0	2	46	47	2	1	1	1	10YR 7/2
EB	30– 38	0	2	48	46	2	0	1	2	7.5YR 5/6
Bhs1	38– 46	0	2	44	47	1	1	1	4	5YR 4/4
Bhs2	46– 58	0	2	39	50	2	1	3	3	5YR-7.5YR 5/8
Bs	58– 66	0	1	21	70	3	1	2	3	5YR-7.5YR 5/8
Bw	75– 90	0	1	28	63	3	1	1	3	5YR-7.5YR 5/8
SK-4										
Ah	0– 10	0	0	2	83	7	2	2	4	10YR 3/4
AB	16– 25	0	0	2	83	7	3	1	4	10YR 4/4
Bw1	40– 55	0	0	2	84	7	1	2	4	10YR 5/8
Bw2	75– 95	0	0	2	84	7	3	1	4	7.5YR 5/6
BC	110–120	0	0	3	86	6	1	1	3	10YR 5/8

Horizon	Depth cm	Particle Size (µm) 2000–1000 %	1000–500 %	500–250 %	250–100 %	100–50 %	50–20 %	<2 %	Color
CDN-13									
Topsoil		2	2	11	26	8	44	7	
Ap	0– 18	2	2	10	26	13	39	8	5YR 4/4
E	18– 26	0	1	11	26	10	46	6	5YR 7/3
Bh	26– 43	1	2	7	23	14	47	7	2.5YR 4/6
B	43– 59	0	1	6	20	14	53	6	2.5YR 4/4
Ex	59– 72	1	2	10	29	14	38	6	5YR 5/4
Bx1	72– 81	0	1	6	26	16	45	5	2.5YR 4/4
Bx2	81–106	0	2	11	34	14	31	8	2.5YR 4/4
Bx3	106–131	2	3	16	34	11	29	5	2.5YR 4/4
Cx	131–180	1	2	12	36	11	29	8	2.5YR 4/4

Horizon	Depth cm	Particle Size (µm) 2000–50 %	50–2 %	<2 %	<0.2 %	Color
CDN-24						
E	0– 1	67	27	5		10YR 4/2
Bhs	1– 9	48	30	21	14	5YR 3/4
Bh1	9– 17	49	36	15	10	5YR 4/4
Bh2	17– 35	50	35	15	9	5YR 4/4
Bh3	35– 52	46	36	18	14	5YR 4/4
Bh4	52– 67	51	34	15	12	5YR 4/6
Bh5	67– 89	46	28	25	21	5YR 3/3
BCr	89–114	64	24	12	8	5Y 5/2
Cr1	114–134	60	31	8	4	5Y 5/2
Cr2	134–171	46	46	8	2	5Y 5/2

Horizon	Depth cm	Particle Size (µm) 2000-200 %	200-50 %	50-20 %	20-2 %	<2 %	Color
D-11							
Ah	0- 9	6	2	21	42	29	7.5YR 3/2
AB	9- 15	9	2	20	56	12	7.5YR 4/5
Bw1	15- 40	14	2	21	34	29	10YR 5/6
Bw2	40- 60	16	2	20	35	27	10YR 5/6
C	65- 75	22	3	19	33	24	2.5Y 5/6
IRL-1							
Ah1	0- 20	38	49	6	4	3	7.5YR 3/2
Ah2	20- 34	36	47	13	1	3	7.5YR 3.5/2
E	34- 50	39	52	4	3	2	7.5YR 5/2
Bh	50- 60	38	51	5	2	4	5YR 3/2
Bs1	60- 75	37	54	4	4	1	10YR 4/4
Bs2	80-105	34	54	6	2	3	7.5YR 4/4
C	135-145	33	63	1	2	1	10YR 5/6
N-1							
Ah1	0- 8	85	9	2	2	2	10YR 3/3
Ah2	8- 14	8	9	2	3	1	10YR 2/1.5
Ah3	14- 25	79	13	4	4	0	10YR 2/1.5
AC	25- 48	77	16	2	3	2	
C	48- 70	87	8	2	2	2	
N-2							
E	0- 8	21	35	24	18	1	10YR 7/2, 5/2
Bh1	8- 15	23	36	19	16	6	10YR 2/2
Bh2	15- 30	39	33	15	12	1	10YR 4/2
Bms	30- 33	42	33	14	10	1	5YR 3/6, 4/8
NL-2							
Ah	0- 5	48	34	9	4	4	10YR 4/1
AB	6- 10	51	32	9	3	4	10YR 4/1
Bh1	10- 25	54	30	8	3	4	10YR 4/2
Bh2	35- 55	61	26	7	3	3	10YR 6/3, 6/4
C	70- 80	73	24	2	0	1	10YR 6/4
S-2							
O	8- 0	22	22	17	28	11	7.5YR 2/2, 2/3
Ah	0- 6	25	32	20	17	5	7.5YR 3/2
E	6- 10	28	31	17	18	4	7.5YR 6/2
Bh	10- 16	26	30	18	18	7	7.5YR 3.5/4
Bs1	16- 26	31	28	15	18	7	7.5YR 4/6
Bs2	26- 55	33	29	15	18	6	7.5YR 4/6
C	55+	30	27	16	20	6	10YR 5/4, 4/4
S-9							
E	0- 5/7	24	61	9	5	0	7.5YR 7/2
Bh	6/8- 10/11	26	56	11	5	2	5YR 4/6
Bs	17- 27	30	54	9	6	1	7.5YR 5/8
BC	27- 38	28	52	14	5	1	10YR 6/4
2C1	45- 60	11	24	26	36	3	10YR 5/4
2C2	60- 70	21	41	22	14	1	10YR 5/4
2C3	72-105	1	9	37	49	3	10YR 5/4
S-10							
E	1- 12	4	42	42	11	1	7.5YR 7/2
Bh1	15- 22	2	42	43	12	2	5YR 3/3, 2/2
Bh2	22- 30	1	33	51	15	1	10YR 4/4, 5/4
2C1	25- 40	1	27	53	20	0	2.5Y 5.5/3
2C2	40- 60	0	29	51	19	1	2.5Y 5.5/3
2C3	60- 70	1	29	48	21	1	2.5Y 5.5/3
S-14							
E	0- 3	70	22	4	2	1	10YR 6/2
Bs	3- 10	52	38	5	2	2	7.5YR 4/8
B	10- 20	65	29	3	2	1	10YR 5/4
B	20- 30	27	68	3	1	1	10YR 5/4
B	30- 45	23	72	4	1	1	10YR 5/4
C	48- 70	49	50	1	0	0	10YR 7/4
S-15							
E	0- 10	25	43	16	14	3	10YR 4.5/2
Bh1	10- 25	13	40	20	23	4	10YR 2/3
Bh2	25- 40	37	24	18	17	4	7.5YR 2/1
Bh3	40- 55	30	28	20	20	3	7.5YR 2/2
BC	58- 65	16	44	16	20	5	10YR 4/3
S-16							
E	0- 6	16	46	20	17	2	10YR 7/1
Bs1	7- 15	13	42	23	20	2	7.5YR 4/8
Bs2	15- 30	17	42	21	17	2	10YR 5/8
C	70- 80	36	28	18	16	2	2.5Y 5/4
S-17							
E	0- 15	70	14	10	6	1	10YR 7/1
E	15- 20	66	18	7	8	1	10YR 7/1
Bh1	20- 35	41	31	15	13	0	7.5YR 3/1, 3/2
Bh2	35- 50	45	26	15	13	0	7.5YR 5/4
Bg1	50- 65	44	26	15	13	2	2.5Y 7/2
Bg2	65- 80	44	22	18	15	1	2.5Y 7/2
SF-4							
E	0- 10	68	19	6	7	0	7.5YR 6/2
Bhs	10- 20	69	16	5	10	0	5YR 3/6
Bs	20- 35	67	22	6	4	1	5YR 3/7
C	35- 70	63	20	9	6	2	5YR 6/7

APPENDIX 4A. SELECTED CHEMICAL PROPERTIES AND CARBON/SESQUIOXIDES ATOMIC RATIOS* OF DUTCH, BELGIAN AND SWISS PROFILES

		pH		Carbon		clay	Amorphous Matter Extractions							CEC		Pyrophosphate Extract						Atomic Ratios		
Hori-zon	Depth (cm)	KCl	H_2O	C_t %	C_h %	c %	Al_d %	Fe_d %	Al_o %	Fe_o %	C_p %	Al_p %	Fe_p %	Soil pH	pH 8.2	Ses	AM	Ses ÷ clay	AM ÷ clay	Al+C ÷ clay	Ses_p ÷ Ses_d	C_p/ Al_p	C_p/ Fe_p	C_p/ Ses_p
NL-101	Netherlands Orthic Podzol Typic Haplohumod																							
Ah	0- 5	3.0	4.0	2.76	1.16	1	.02	.09	.02	.03	.77	.02	.03	3.7	12.7	.05	.82	.05	.82	.79	.45	86.6	119	50.2
E1	5- 24	3.4	4.2	.43	.19	3	.01	.06	.00	.01	.15	.00	.01	3.8	4.9	.01	.16	<.01	.05	.05	.14	0	69.8	69.8
E2	24- 41	3.5	4.2	.20	.11	3	.01	.16	.00	.01	.13	.01	.01	1.1	2.1	.02	.15	<.01	.05	.05	.12	29.3	60.5	19.7
Bh1	41- 45	3.1	3.8	2.39	1.45	6	.14	.35	.12	.14	2.43	.17	.18	13.2	25.5	.35	2.78	.06	.46	.43	.71	32.2	62.8	21.3
Bh2	45- 47	3.4	3.8	2.11	1.75	7	.19	.47	.19	.30	2.06	.21	.28	16.6	24.6	.49	2.55	.07	.36	.32	.74	22.1	34.3	13.4
Bs1	47- 53	4.1	4.1	.45	.32	1	.10	.49	.09	.35	.46	.10	.31	3.0	7.7	.41	.87	.41	.87	.56	.69	10.4	6.9	4.1
Bs2	53- 82	4.4	4.4	.38	.30	0	.12	.29	.10	.12	.42	.11	.11	6.2	5.9	.22	.64	-	-	-	.54	8.6	17.8	5.8
C/B	82-150	4.6	4.6	.06	.05	0	.05	.14	.03	.03	.05	.04	.02	2.9	4.4	.06	.11	-	-	-	.32	2.8	11.6	2.3
fiber	95	4.4	4.4	.41	.29	1	.10	.19	.10	.08	.37	.13	.08	4.0	7.8	.21	.58	.21	.58	.50	.72	6.4	21.6	4.9
fiber	150	4.6	4.6	.07	.06	0	.06	.16	.04	.04	.07	.06	.04	.1	1.0	.10	.17	-	-	-	.45	2.6	8.1	2.0
Bh		4.2	4.2	1.23	1.17	1	.22	.31	.26	.22	1.08	.31	.19	4.1	15.4	.50	1.58	.50	1.58	1.39	.94	7.8	26.5	6.1
NL-102	Netherlands Gleyic Podzol Aeric Haplaquod																							
E1	0- 19	3.3	4.2	.82	.47	0	.01	.01	.01	.01	.45	.01	.01	2.3	4.2	.02	.47	-	-	-	1.00	101	209	68.3
E2	19- 39	3.6	4.0	.35	.25	1	.02	.00	.01	.00	.32	.02	.00	2.7	4.5	.02	.34	.02	.34	.34	1.00	36.0	-	36.0
Bh	39- 44	3.8	4.1	.82	.72	2	.06	.00	.06	.00	.84	.09	.00	6.5	7.7	.09	.93	.05	.47	.47	1.50	21.0	-	21.0
BC1	44- 89	4.1	4.4	.43	.47	2	.05	.00	.04	.00	.43	.07	.00	0	6.8	.07	.50	.04	.25	.25	1.40	13.8	-	13.8
BC2	89-150	4.3	4.4	.32	.31	1	.05	.00	.04	.00	.37	.05	.00	3.1	5.1	.05	.42	.05	.42	.42	1.00	16.7	-	16.7
NL-103	Netherlands Gleyic Podzol Aeric Haplaquod																							
Ahb	55- 59	4.3	4.4	.85	.61	3	.07	.09	.09	.06	.74	.09	.06	2.6	5.5	.15	.89	.05	.30	.28	.94	18.5	57.4	14.0
Eb	59- 73	4.7	5.0	.12	.05	0	.01	.01	.01	.00	.15	.01	.01	1.1	.2	.02	.17	-	-	-	1.00	33.8	69.8	22.8
BEb	73- 76	4.3	4.5	.77	.60	1	.10	.02	.09	.03	.81	.09	.02	3.1	7.8	.11	.92	.11	.92	.90	.92	20.3	188	18.3
Bh1b	76- 80	4.1	4.3	2.58	2.27	1	.34	.01	.34	.01	2.92	.37	.01	9.0	27.7	.38	3.30	.38	3.30	3.29	1.09	17.8	1363	17.5
Bh2b	80- 82	4.0	4.2	2.47	1.16	1	.32	.01	.30	.01	2.26	.33	.01	7.9	29.6	.34	2.60	.34	2.60	2.59	1.03	15.4	1055	15.2
Bh3b	82- 86	4.1	4.3	1.79	1.68	1	.39	.03	.44	.01	1.81	.40	.01	0	19.2	.41	2.22	.41	2.22	2.21	.98	10.2	845	10.1
BCb	86-102	4.5	4.5	.51	.55	1	.18	.03	.21	.01	.60	.20	.01	1.5	5.8	.21	.81	.21	.81	.80	1.00	6.8	279	6.6
C	102-150	4.5	4.6	.21	.24	0	.09	.03	.11	.01	.21	.09	.01	1.6	3.4	.10	.31	-	-	-	.83	5.3	97.7	5.0
NL-104	Netherlands Orthic Podzol Typic Haplohumod																							
Ah	0- 18	2.7	3.7	3.58	2.27	1	.04	.07	.03	.04	1.61	.04	.05	6.7	14.3	.09	1.70	.09	1.70	1.65	.82	90.6	150	56.5
E	18- 38	3.2	4.2	.54	.31	1	.03	.15	.00	.01	.36	.01	.01	1.1	0	.02	.38	.02	.38	.37	.11	81.0	168	54.6
Bhm	38- 47	3.0	3.8	3.81	3.15	3	.22	.27	.20	.24	3.01	.24	.21	12.3	21.2	.45	3.46	.15	1.15	1.08	.92	28.2	66.9	19.8
Bhs	47- 61	3.5	3.8	1.94	1.91	0	.18	.71	.16	.59	1.83	.21	.62	8.3	21.0	.83	2.66	-	-	-	.93	19.6	13.8	8.1
BC	61-120	4.2	4.2	.27	.28	1	.08	.24	.07	.08	.35	.08	.09	3.2	2.0	.17	.52	.17	.52	.43	.53	9.8	18.1	6.4
NL-105	Netherlands Orthic Podzol Typic Haplorthod/Typic Haplohumod																							
Ah	0- 7	2.8	3.8	3.89	1.55	0	.04	.11	.03	.05	1.51	.04	.05	6.0	14.4	.09	1.60	-	-	-	.60	84.9	141	52.9
E	7- 16	3.2	4.0	1.05	.44	2	.02	.10	.02	.03	.51	.02	.03	5.1	4.4	.05	.56	.03	.28	0.27	.42	57.4	79.1	33.3
Bh	16- 22	3.4	3.9	2.68	1.32	3	.17	.54	.16	.47	2.41	.19	.45	4.9	22.3	.64	3.05	.21	1.02	.87	.90	28.5	24.9	13.3
Bhs1	22- 30	3.7	4.0	1.59	1.31	2	.12	.66	.13	.55	1.35	.16	.54	5.2	12.2	.70	2.05	.35	1.03	.76	.90	19.0	11.6	7.2
Bhs2	30- 43	4.4	4.6	1.04	.71	0	.25	.30	.32	.15	.86	.26	.13	1.3	7.7	.39	1.25	-	-	-	.71	7.4	30.8	6.0
BC1	43- 61	4.6	4.7	.38	.30	0	.15	.23	.21	.06	.29	.14	.03	0	4.8	.17	.46	-	-	-	.45	4.7	45.0	4.2
BC2	61- 88	4.7	4.7	.10	.13	1	.05	.16	.05	.03	.10	.06	.02	0	0	.08	.18	.08	.18	.16	.38	3.8	23.3	3.2
C	88-150	4.8	5.0	.07	.06	0	.04	.11	.05	.02	.06	.04	.01	0	1.1	.05	.11	-	-	-	.33	3.4	27.9	3.0
NL-106	Netherlands Cambic Arenosol Spodic Udipsamment																							
Ah1	0- 6	3.1	4.0	6.02	2.46	4	.09	.14	.09	.09	2.25	.10	.11	5.9	22.0	.21	2.46	.05	.62	.59	.91	50.6	95.2	33.1
Ah2	6- 11	3.2	4.0	2.98	1.68	2	.05	.09	.05	.05	1.14	.04	.06	2.1	11.1	.10	1.24	.05	.62	.59	.71	64.1	88.4	37.2
E	11- 22	3.5	4.4	.86	.39	1	.01	.03	.02	.02	.38	.01	.02	0	2.9	.03	.41	.03	.41	.39	.75	85.5	88.4	43.5
Bhs1	22- 29	3.7	4.3	2.20	1.49	8	.22	.68	.25	.64	1.96	.26	.66	6.9	18.2	.92	2.88	.13	.36	.28	1.02	16.9	13.8	7.6
Bhs2	29- 35	4.1	4.4	2.11	1.55	6	.41	.61	.45	.54	2.07	.52	.51	5.0	19.1	1.03	3.10	.17	.52	.43	1.01	9.0	18.9	6.1
2BC	35- 45	4.4	4.5	.55	.35	2	.19	.22	.28	.13	.47	.17	.12	0	6.0	.29	.76	.15	.38	.32	.71	6.2	18.2	4.6
2Cg	45- 65	4.4	4.6	.19	.14	4	.11	.19	.17	.09	.20	.10	.08	1.4	3.5	.18	.38	.05	.10	.08	.60	4.5	11.6	3.2
NL-107	Netherlands Orthic Podzol Plaggeptic Haplohumod																							
Ah	0- 10	2.7	3.6	4.49	2.67	2	.03	.13	.03	.11	1.83	.04	.13	5.0	13.6	.17	2.00	.09	1.00	.94	1.06	103	65.5	40.0
Aan	10- 45	3.4	3.9	2.07	1.53	2	.06	.16	.05	.15	1.30	.07	.17	3.5	9.5	.24	1.54	.12	.77	.69	1.09	41.8	35.6	19.2
E	45- 49	3.7	4.2	1.25	.88	1	.04	.07	.05	.07	.85	.06	.08	2.4	3.0	.14	.99	.14	.99	.91	1.27	31.9	49.6	19.4
Bh	49- 52	3.7	4.1	3.31	2.32	2	.31	.37	.17	.36	3.21	.36	.37	9.5	23.6	.73	3.94	.37	1.97	1.78	1.07	20.1	40.4	13.4
Bhs1	52- 57	3.8	4.2	1.76	1.32	1	.20	.57	.21	.51	1.41	.24	.56	4.6	16.1	.80	2.21	.80	2.21	1.65	1.04	13.2	11.8	6.2
Bhs2	57- 60	4.0	4.3	1.04	.82	2	.13	.39	.15	.28	1.01	.18	.32	3.6	8.4	.50	1.51	.25	.76	.60	.96	12.6	14.7	6.8
BC	60- 78	4.2	4.4	.73	.54	0	.16	.15	.18	.09	.77	.20	.11	1.1	5.3	.31	1.08	-	-	-	1.00	8.7	32.6	6.8
C	78-150	4.5	4.6	.14	.11	0	.06	.07	.10	.02	.12	.07	.02	0	0	.09	.21	-	-	-	.69	3.9	27.9	3.4
fiber	90	4.5	4.5	.32	.30	0	.10	.07	.14	.03	.30	.11	.02	0	4.1	.13	.43	-	-	-	.76	6.1	69.8	5.6
NL-108	Netherlands Humic Podzol Typic Haplohumod																							
E1	0- 22	3.6	4.4	1.68	1.09	2	.07	.01	.06	.01	1.07	.07	.01	5.0	11.2	.08	1.15	.04	.58	.57	1.00	34.4	498	32.2
E2	22- 29	3.8	4.5	1.49	1.03	1	.13	.00	.13	.00	1.20	.13	.00	4.6	8.2	.13	1.33	.13	1.33	1.33	1.00	20.8	-	20.8
Bh	29- 37	4.0	4.5	1.53	1.46	2	.23	.02	.25	.00	1.41	.29	.01	5.8	14.3	.30	1.71	.15	.86	.85	1.20	10.9	658	10.8
Bsm	37- 53	4.4	4.6	.48	.45	0	.16	.23	.20	.17	.53	.17	.17	0.5	5.0	.34	.87	-	-	-	.87	7.0	14.5	4.7
BC1	53- 82	4.5	4.6	.41	.35	0	.14	.15	.18	.10	.41	.16	.09	0	3.0	.25	.66	-	-	-	.86	5.8	21.2	4.5
BC2	82-109	4.5	4.6	.21	.18	0	.08	.04	.10	.02	.20	.10	.02	0	0.5	.12	.32	-	-	-	1.00	4.5	46.5	4.1
C	109-150	4.6	4.6	.08	.09	0	.05	.04	.07	.02	.09	.05	.02	0	1.2	.07	.16	-	-	-	.78	4.1	20.9	3.4
NL-109	Netherlands Orthic Podzol Aquic Haplorthod																							
E1	0- 18	3.0	3.6	1.61	.89	5	.04	.03	.03	.01	.81	.04	.02	3.4	8.0	.06	.87	.01	.17	.17	.86	45.6	188	36.7
E2	18- 22	3.2	3.4	1.96	1.31	2	.06	.01	.06	.01	.86	.06	.01	3.1	9.1	.07	.93	.04	.47	.46	1.00	32.3	400	29.9
Bh	22- 29	3.9	3.9	1.31	1.14	4	.23	.12	.25	.05	1.37	.32	.05	3.5	9.7	.37	1.74	.09	.44	.42	1.06	9.6	128	9.0
Bhs	29- 52	4.2	4.2	.79	.70	2	.31	.57	.37	.42	.81	.30	.19	1.4	8.8	.49	1.30	.25	.65	.57	.56	6.1	19.8	4.7
2Cr	52-100	3.7	4.0	.13	.11	17	.12	.69	.11	.17	.18	.30	.17	0.9	9.3	.47	.65	.03	.04	.03	.58	1.4	4.9	1.1

Atomic Ratios																		CEC/			
C_t/									C_h/									C_t		C_h	
Al_d	Fe_d	Ses_d	Al_o	Fe_o	Ses_o	Al_p	Fe_p	Ses_p	Al_d	Fe_d	Ses_d	Al_o	Fe_o	Ses_o	Al_p	Fe_p	Ses_p	Soil pH	pH 8.2	Soil pH	pH 8.2
NL-101	Netherlands		Orthic Podzol			Typic Haplohumod															
311	143	98	311	429	180	311	429	180	131	60.1	41.2	131	180	75.7	131	186	75.7	1.3	4.6	3.2	10.9
96.7	33.4	24.9	-	200	200	-	200	200	42.7	14.8	11.0	-	88.7	88.7	-	88.7	88.7	8.8	11.4	20.0	25.8
45.0	5.8	5.2	-	93.3	93.3	45.0	93.3	30.4	24.8	3.2	2.8	-	51.3	51.3	24.8	51.3	16.7	5.5	10.5	10.0	19.1
38.4	31.9	17.4	44.8	79.7	28.7	31.6	62.0	20.9	23.3	19.3	10.6	27.2	48.3	17.4	19.2	37.6	12.7	5.5	10.7	9.1	17.6
25.0	21.0	11.4	25.0	32.8	14.2	22.6	35.2	13.8	20.7	17.4	9.5	20.7	27.2	11.8	18.8	29.2	11.4	7.9	11.7	9.5	14.1
10.1	4.3	3.0	11.3	6.0	3.9	10.1	6.8	4.1	7.2	3.0	2.1	8.0	4.3	2.8	7.2	4.8	2.9	6.7	17.1	9.4	24.1
7.1	6.1	3.3	8.6	14.8	5.4	7.8	16.1	5.2	5.6	4.8	2.6	6.7	11.7	4.3	6.1	12.7	4.1	16.3	15.5	20.7	19.7
2.7	2.0	1.1	4.5	9.3	3.0	3.4	14.0	2.7	2.3	1.7	1.0	3.8	7.8	2.5	2.8	11.7	2.3	48.3	73.3	58.0	88.0
9.2	10.1	4.8	9.2	23.9	6.7	7.1	23.9	5.5	6.5	7.1	3.4	6.5	16.9	4.7	5.0	16.9	3.9	9.8	19.0	13.8	26.9
2.6	2.0	1.1	3.9	8.2	2.7	2.6	8.2	2.0	2.3	1.8	1.0	3.4	7.0	2.3	2.3	7.0	1.7	1.4	14.3	1.7	16.7
12.6	18.5	7.5	10.6	26.1	7.6	8.9	30.2	6.9	12.0	17.6	7.1	10.1	24.8	7.2	8.5	28.7	6.6	3.3	12.5	3.5	13.2
NL-102	Netherlands		Gleyic Podzol			Aeric Haplaquod															
185	383	125	185	383	125	185	383	125	106	219	71.3	106	219	71.3	106	219	71.3	2.8	5.1	4.7	8.9
39.4	-	39.4	78.8	-	78.8	39.4	-	39.4	28.1	-	28.1	56.2	-	56.2	28.1	-	28.1	7.7	12.9	10.8	18.0
30.8	-	30.8	30.8	-	30.8	20.5	-	20.5	27.0	-	27.0	27.0	-	27.0	18.0	-	18.0	7.9	9.4	9.0	10.7
19.4	-	19.4	24.2	-	24.2	13.8	-	13.8	21.2	-	21.2	26.4	-	26.4	15.1	-	15.1	0	15.8	0	14.5
14.4	-	14.4	18.0	-	18.0	14.4	-	14.4	14.0	-	14.0	17.4	-	17.4	14.0	-	14.0	9.7	15.9	10.0	16.5
NL-103	Netherlands		Gleyic Podzol			Aeric Haplaquod															
27.3	44.1	16.9	21.3	66.1	16.1	21.3	66.1	16.1	19.6	31.6	12.1	15.3	47.4	11.5	15.3	47.4	11.5	3.1	6.5	4.3	9.0
27.0	56.0	18.2	27.0	-	27.0	27.0	56.0	18.2	11.3	23.3	7.6	11.3	-	11.3	11.3	23.3	7.6	9.2	1.7	22.0	4.0
17.3	180	15.8	19.3	120	16.6	19.3	180	17.4	13.5	140	12.3	15.0	93.3	12.9	15.0	140	13.5	4.0	16.1	5.2	13.0
17.1	1204	16.8	17.1	1204	16.8	15.7	1204	15.4	15.0	1059	14.8	15.0	1059	14.8	13.8	1059	13.6	3.5	10.7	4.0	12.2
17.4	1153	17.1	18.5	1152	18.2	16.8	1153	16.6	8.2	541	8.0	8.7	541	8.6	7.9	541	7.8	3.2	12.0	6.8	25.5
10.3	278	10.0	9.2	835	9.1	10.1	835	9.9	9.7	261	9.3	8.6	784	8.5	9.5	784	9.3	0	10.7	0	11.4
6.4	79.3	5.9	5.5	238	5.3	5.7	238	5.6	6.9	85.6	6.4	5.9	257	5.8	6.2	257	6.0	2.9	11.4	2.7	10.5
5.3	32.7	4.5	4.3	98.0	4.1	5.3	98.0	5.0	6.0	37.3	5.2	4.9	112	4.7	6.0	112	5.7	7.6	16.2	6.7	14.2
NL-104	Netherlands		Orthic Podzol			Typic Haplohumod															
201	239	109	269	418	163	201	334	126	128	151	69.3	170.	165	104	128	212	79.7	1.9	4.0	3.0	6.3
40.5	16.8	11.9	-	252	252	122	252	82.0	23.3	9.6	6.8	-	145	145	69.7	145	47.1	2.0	36.3	3.5	0
39.0	65.9	24.5	42.9	74.1	27.2	35.7	84.7	25.1	32.2	54.4	20.2	35.4	61.3	22.4	29.5	70.0	20.8	3.2	4.2	3.9	6.7
24.3	12.8	8.4	27.3	15.3	9.8	20.8	14.6	8.6	23.9	12.6	8.2	26.9	15.1	9.7	20.5	14.4	8.4	4.3	10.8	4.4	11.0
7.6	5.3	3.1	8.7	15.8	5.6	7.6	14.0	4.9	7.9	5.4	3.2	9.0	16.3	5.8	7.9	14.5	5.1	11.9	7.4	11.4	7.1
NL-105	Netherlands		Orthic Podzol			Typic Haplorthod/Typic Haplohumod															
219	165	94.1	292	363	162	219	363	137	87.2	65.8	37.5	116	145	64.5	87.2	145	54.4	1.5	3.7	3.9	9.3
118	49.0	34.6	118	163	68.5	118	163	68.5	49.5	20.5	14.5	49.5	68.4	28.7	49.5	68.4	28.7	4.9	4.2	11.6	10.0
35.5	23.2	14.0	37.7	26.6	15.6	31.7	27.8	14.8	17.5	11.4	6.9	18.6	13.1	7.7	15.6	13.7	7,3	1.8	8.3	3.7	16.9
29.8	11.2	8.2	27.5	13.5	9.1	22.4	13.7	8.5	24.6	9.3	6.7	22.7	11.1	7.5	18.4	11.3	7.0	3.3	7.7	4.0	9.3
9.4	16.2	5.9	7.3	32.4	6.0	9.0	37.3	7.3	6.4	11.0	4.0	5.0	22.1	4.1	6.1	25.5	5.0	1.3	7.4	1.8	10.8
5.7	7.7	3.3	4.1	29.6	3.6	6.1	59.1	5.5	4.5	6.1	2.6	3.2	23.3	2.8	4.8	46.7	4.4	0	13.6	0	16.0
4.5	2.9	1.8	4.5	15.6	3.5	3.8	23.3	3.2	5.8	3.8	2.3	5.8	20.2	4.5	4.9	30.3	4.2	0	0	0	0
3.9	3.0	1.7	3.2	16.3	2.6	3.9	32.7	3.5	3.4	2.5	1.5	2.7	14.0	2.3	3.4	28.0	3.0	0	15.7	0	18.3
NL-106	Netherlands		Cambic Arenosol			Spodic Udipsamment															
150	200	86.0	150	312	101	135	255	88.5	61.5	82.0	35.1	61.5	128	41.5	55.4	104	36.2	1.0	3.7	2.4	8.9
134	154	71.8	134	278	90.5	168	232	97.3	75.6	87.1	40.5	75.6	157	51.0	94.5	131	54.8	0.7	3.7	1.3	6.6
193	134	79.1	96.8	201	65.3	194	201	98.5	87.7	60.7	35.9	43.9	91.0	29.6	87.7	91.0	44.7	0	3.4	0	7.4
22.5	15.1	9.0	19.8	16.0	8.9	19.0	15.6	8.6	15.2	10.2	6.1	13.4	10.9	6.0	12.9	10.5	5.8	3.1	8.3	4.6	12.2
11.6	16.1	6.7	10.6	18.2	6.7	9.1	19.3	6.2	8.5	11.9	5.0	7.8	13.4	4.9	6.7	14.2	4.6	2.4	9.1	3.2	12.3
6.5	11.7	4.2	4.4	19.7	3.6	7.3	21.4	5.4	4.1	7.4	2.7	2.8	12.6	2.3	4.6	13.6	3.5	0	10.9	0	17.1
3.9	4.7	2.1	2.5	9.9	2.0	4.3	11.1	3.1	2.9	3.4	1.6	1.9	7.3	1.5	3.2	8.2	2.3	7.4	18.4	10.0	25.0
NL-107	Netherlands		Orthic Podzol			Plaggeptic Haplohumod															
336	161	109	337	191	122	253	161	98.4	200	95.8	64.8	200	113	72.3	150	95.8	58.5	1.1	3.0	1.9	5.1
77.6	60.4	34.0	93.1	64.4	38.1	66.5	56.8	30.6	57.4	44.6	25.1	68.8	47.6	28.1	49.2	42.0	22.7	1.7	4.6	2.3	6.2
70.3	83.3	39.1	56.3	83.3	33.6	46.9	72.9	28.5	49.5	58.7	26.8	39.6	58.7	23.6	33.0	51.3	20.1	1.9	2.4	2.7	3.4
24.0	41.7	15.2	43.8	42.9	21.7	20.7	41.7	13.8	16.8	29.3	10.7	30.7	30.1	15.2	14.5	29.3	9.7	2.9	7.1	4.1	10.2
19.8	14.4	8.3	18.9	16.1	8.7	16.5	14.7	7.8	14.9	10.8	6.3	14.1	12.1	6.5	12.4	11.0	5.8	2.6	9.1	3.5	12.2
18.0	12.4	7.4	15.6	17.3	8.2	13.0	15.2	7.0	14.2	9.8	5.8	12.3	13.7	6.5	10.3	12.0	5.5	3.5	8.1	4.4	10.2
10.3	22.7	7.1	9.1	37.9	7.4	8.2	31.0	6.5	7.6	16.8	5.2	6.8	28.0	5.4	6.1	22.9	4.8	1.5	7.3	2.0	9.8
5.3	9.3	3.4	3.2	32.7	2.9	4.5	32.7	4.0	4.1	7.3	2.6	2.5	25.7	2.3	3.5	25.7	3.1	0.0	0.0	0.0	0.0
7.2	21.3	5.4	5.1	49.8	4.7	6.5	74.7	6.0	6.7	20.0	5.0	4.8	46.7	4.4	6.1	70.0	5.6	0.0	12.8	0.0	13.7
NL-108	Netherlands		Humic Podzol			Typic Haplohumod															
54.0	784	50.5	63.0	784	58.3	54.0	784	50.5	35.0	509	32.8	40.9	509	37.8	35.0	509	32.8	3.0	6.7	4.6	10.3
25.8	-	25.8	25.8	-	25.8	25.8	-	25.8	17.8	-	17.8	17.8	-	17.8	17.8	-	17.8	3.1	5.5	4.5	8.0
15.0	357	14.4	13.8	-	13.8	11.9	714	11.7	14.3	341	13.7	13.1	-	13.1	11.3	681	11.1	3.8	9.3	4.0	9.8
6.8	9.7	4.0	5.4	13.2	3.8	6.4	13.2	4.3	6.3	9.1	3.7	5.1	12.4	3.6	6.0	12.3	4.0	1.0	10.4	1.1	11.1
6.6	12.8	4.3	5.1	19.1	4.0	5.8	21.3	4.5	5.6	10.9	3.7	4.4	16.3	3.5	4.9	18.1	3.9	0.0	7.3	0.0	8.6
5.9	24.5	4.8	4.7	49.0	4.3	4.7	49.0	4.3	5.1	21.0	4.1	4.1	42.0	3.7	4.1	42.0	3.7	0.0	0.2	0.0	0.3
3.6	9.3	2.6	2.6	18.7	2.3	3.6	18,7	3.0	4.1	10.5	2.9	2.9	21.0	2.5	4.1	21.0	3.4	0.0	15.0	0.0	13.3
NL-109	Netherlands		Orthic Podzol			(Aquic) Haplohumod															
90.6	250	66.5	121.	751	104	90.6	376	73.0	50.1	138	36.8	66.8	415	57.5	50.1	208	40.3	2.1	5.0	3.8	9.0
73.5	915	68.0	73.5	915	68.0	73.5	915	68.0	49.1	611	45.5	49.1	611	45.5	49.1	611	45.5	1.6	4.6	2.4	6.9
12.8	50.9	10.2	11.8	122	10.8	9.2	122	8.6	11.2	44.3	8.9	10.3	106	9.4	8.0	106	7.6	2.7	7.4	3.1	8.5
5.7	6.5	3.0	4.8	8.8	3.1	5.9	19.4	4.5	5.1	5.7	2.7	4.3	7.8	2.8	5.3	17.2	4.0	1.8	11.1	2.0	12.6
2.4	.9	.6	2.7	3.6	1.5	1.0	3.6	.8	2.1	.7	.5	2.3	3.0	1.3	.8	3.0	.6	6.9	71.5	8.2	84.5

Appendix 4A (ctd). Selected chemical properties and carbon/sesquioxides atomic ratios* of Dutch, Belgian and Swiss profiles

		pH		Carbon		clay	Amorphous Matter Extractions							CEC		Pyrophosphate Extract						Atomic Ratios		
																						C_p/		
Hori- zon	Depth (cm)	KCl	H_2O	C_t %	C_h %	c %	Al_d %	Fe_d %	Al_o %	Fe_o %	C_p %	Al_p %	Fe_p %	Soil pH	pH 8.2	Ses	AM	Ses ÷ clay	AM ÷ clay	Al+C ÷ clay	Ses_p ÷ Ses_d	Al_p	Fe_p	Ses_p
NL-110	Netherlands			Humic Podzol			Typic Haplohumod																	
Ah	0- 9	3.1	3.8	4.00	1.49	4	.06	.05	.07	.04	1.48	.06	.04	7.2	14.8	.10	1.58	.03	.40	.39	.91	55.5	172	42.0
E1	9- 20	3.2	4.2	.70	.33	0	.00	.00	.01	.00	.30	.00	.00	1.1	3.0	0	.30	-	-	-	-	-	-	-
fiber	20	3.0	4.0	1.22	.68	0	.02	.01	.01	.01	.66	.01	.01	3.6	4.4	.02	.68	-	-	-	.67	149	307	100
E2	20- 70	3.7	4.6	.08	.03	0	.00	.00	.00	.00	.05	.00	.00	0.7	0	0	.05	-	-	-	-	-	-	-
Bh1	70- 72	2.9	3.9	2.41	1.88	3	.12	.07	.12	.03	2.24	.13	.07	8.8	18.9	.20	2.44	.07	.81	.79	1.05	38.8	149	30.8
Bh2	72- 75	3.2	4.0	2.36	1.80	4	.16	.18	.16	.14	2.22	.17	.18	8.7	20.6	.35	2.57	.09	.64	.60	1.03	29.4	57.4	19.4
Bhs	75- 80	3.8	4.2	.68	.56	4	.10	.28	.12	.25	.70	.12	.25	3.2	4.7	.37	1.07	.09	.27	.21	.97	13.1	13.0	6.5
B	80- 85	4.2	4.5	.50	.43	2	.13	.12	.13	.08	.52	.14	.10	1.9	8.9	.24	.76	.12	.38	.33	.96	8.4	24.3	6.2
Bh3	85- 87	4.2	4.5	1.46	1.25	3	.28	.09	.28	.05	1.49	.29	.07	5.1	15.6	.36	1.85	.12	.62	.59	.97	11.6	99.3	10.4
BC	87-100	4.4	4.6	.21	.11	2	.08	.08	.07	.02	.18	.08	.04	1.4	3.0	.12	.30	.06	.15	.13	.75	5.1	20.9	4.1
C	100-150	4.5	4.9	.05	.01	0	.02	.03	.02	.00	.04	.02	.01	1.1	1.7	.03	.07	-	-	-	.60	4.5	18.6	3.6
B-101	Belgium			Orthic Podzol			Typic Haplorthod																	
Ah	0- 5	2.9	3.6	1.72	.78	2	.01	.15	.01	.07	.76	.01	.10	0	2.9	.11	.87	.06	.44	.39	.69	171	35.4	29.3
E	5- 15	3.4	4.1	.29	.16	0	.00	.02	.00	.02	.19	.00	.02	0	1.6	.02	.21	-	-	-	1.00	-	44.2	44.2
Bh	15- 18	4.0	4.1	1.14	.84	3	.16	.32	.14	.29	1.08	.16	.24	0.8	9.9	.40	1.48	.13	.49	.41	.83	15.2	20.9	8.8
Bhs	18- 28	4.1	4.2	1.15	.88	3	.24	.66	.27	.61	1.21	.24	.41	0.8	13.2	.65	1.86	.22	.62	.48	.72	11.3	13.7	6.2
Bs	28- 37	4.3	4.3	.47	.29	1	.24	.75	.21	.45	.44	.18	.35	1.0	7.2	.53	.97	.53	.97	.62	.54	5.5	5.9	2.8
B/C	37- 59	4.3	4.3	.16	.11	1	.09	.34	.08	.20	.16	.07	.13	0	2.7	.20	.36	.20	.36	.23	.47	5.1	5.7	2.7
Cr	59- 89	4.3	4.5	.03	.01	0	.02	.04	.02	.02	.08	.02	.01	0.8	1.6	.03	.11	-	-	-	.50	9.0	37.2	7.3
C1	89-120	4.2	4.3	.07	.04	0	.06	.46	.05	.21	.14	.04	.11	0.5	0.7	.15	.29	-	-	-	.29	7.9	5.9	3.4
C2	120-150	4.1	4.3	.03	.03	3	.04	.11	.04	.07	.00	.04	.04	1.0	0.5	.08	.08	.03	.03	.01	.53	0	0	0
B-102	Belgium			Gleyic Podzol			Aeric Haplaquod																	
Ep	0- 29	4.0	4.4	.39	.24	1	.03	.04	.02	.02	.30	.02	.03	0.6	1.8	.05	.35	.05	.35	.32	.71	33.8	46.5	19.6
Bhm1	29- 47	3.9	4.4	1.25	1.11	6	.20	.04	.20	.02	1.14	.22	.03	5.5	10.7	.25	1.39	.04	.23	.22	1.04	11.7	177	10.9
Bhm2	47- 62	3.9	4.4	1.11	1.11	4	.21	.04	.22	.01	1.07	.23	.02	3.3	8.8	.25	1.32	.06	.33	.33	1.00	10.5	250	10.0
Bhm3	62- 77	4.1	4.6	.88	.83	5	.18	.03	.19	.01	.76	.20	.01	4.9	6.8	.21	.97	.04	.19	.19	1.00	8.5	355	8.3
B	77- 92	4.2	4.6	.60	.63	2	.14	.02	.16	.01	.66	.15	.01	3.4	5.5	.16	.82	.08	.41	.41	1.00	9.9	308	9.6
Bh	92-110	4.1	4.5	.86	.83	2	.10	.01	.09	.00	.80	.11	.01	3.2	6.7	.12	.92	.06	.46	.46	1.09	16.4	373	15.7
C	110-150	4.3	4.7	.26	.25	2	.05	.01	.05	.00	.29	.05	.01	1.6	2.5	.06	.35	.03	.18	.17	1.00	13.1	135	11.9
B-103	Belgium			Gleyic Podzol			Aeric Haplaquod																	
Ahb	23- 30	3.7	4.3	3.40	2.09	1	.14	.12	.14	.11	2.52	.17	.12	8.2	17.8	.29	2.81	.29	2.81	2.69	1.11	33.4	97.7	24.9
Eb	30- 58	4.1	4.7	.18	.13	0	.01	.01	.01	.01	.23	.00	.01	0.8	0.3	.01	.24	-	-	-	.50	-	107	107
EBb	58- 85	4.1	4.6	.26	.24	1	.03	.00	.02	.01	.36	.03	.01	1.9	0.3	.04	.40	.04	.40	.39	1.33	27.0	168	23.3
Bh1b	85-103	4.0	4.6	.87	.75	1	.09	.01	.07	.01	.82	.10	.01	4.1	6.3	.11	.93	.11	.93	.92	1.11	18.5	383	17.6
Bh2b	103-125	4.0	4.5	.84	.81	3	.11	.01	.10	.01	.79	.17	.03	4.5	5.2	.20	.99	.07	.33	.32	1.67	10.5	123	9.6
Bh3b	125-155	4.0	4.5	.78	.70	4	.13	.01	.14	.01	.97	.19	.03	3.9	6.7	.22	1.19	.06	.30	.29	1.57	11.5	150	10.7
Bh4b	155-170	3.9	4.6	1.54	1.44	4	.19	.01	.18	.01	1.47	.25	.03	5.5	10.8	.28	1.75	.07	.44	.43	1.40	12.8	221	12.1
B-104	Belgium			Gleyic Podzol			Typic Haplaquod																	
Ah	0- 5	2.8	3.8	4.26	1.99	5	.05	.04	.06	.03	1.34	.06	.04	5.5	18.4	.10	1.44	.02	.29	.28	1.11	50.3	156	38.0
E1	5- 18	3.0	4.1	1.11	.51	2	.01	.00	.01	.00	.21	.01	.00	0.9	5.2	.01	.22	< .01	.11	.11	1.00	47.3	-	47.3
E2	18- 33	3.2	4.1	.46	.27	2	.01	.01	.02	.01	.18	.01	.01	1.3	5.8	.02	.20	.01	.10	.10	1.00	40.5	83.8	27.3
Bh1	33- 36	3.1	3.9	1.82	1.22	5	.09	.04	.07	.04	1.11	.10	.04	3.5	13.3	.14	1.25	.03	.25	.24	1.08	25.0	129	20.9
Bh2	36- 40	3.3	3.9	2.99	1.68	7	.21	.02	.19	.01	1.97	.21	.01	9.0	19.4	.22	2.19	.03	.31	.31	.96	21.1	919	2.6
Bh3	40- 42	3.6	4.1	4.13	3.28	4	.38	.04	.34	.02	3.00	.41	.02	6.1	27.8	.43	3.43	.11	.86	.85	1.02	16.5	698	16.1
Bhs1	42- 53	3.9	4.3	1.89	1.76	4	.47	.20	.50	.16	1.91	.55	.12	10.0	25.3	.67	2.58	.17	.65	.62	1.00	7.8	74.1	7.1
Bhs2	53- 70	4.1	4.4	1.12	1.03	2	.33	.07	.38	.05	1.12	.36	.06	4.0	16.6	.42	1.54	.21	.77	.74	1.05	7.0	86.9	6.5
2Cr	70-100	4.1	4.3	.17	.12	8	.10	.17	.13	.03	.14	.29	.07	2.3	5.2	.36	.50	.05	.06	.05	1.33	1.09	9.3	1.0
		4.1	4.3	.18	.11	8	.12	.57	.12	.24	.11	.23	.19	3.4	5.2	.42	.53	.05	.07	.04	.61	1.08	2.7	.8
B-105	Belgium			Gleyic Podzol			Aeric Haplaquod																	
Ah	0- 8	3.1	4.3	1.69	.67	2	.02	.01	.02	.01	.56	.02	.01	2.5	5.4	.03	.59	.02	.30	.29	1.00	63.0	261	50.7
E	8- 23	3.4	4.6	.29	.13	1	.01	.01	.00	.00	.15	.00	.00	0.6	1.7	0	.15	.00	.15	.15	-	-	-	-
Bh	23- 30	3.3	3.9	2.89	2.02	5	.20	.04	.19	.04	2.86	.23	.03	9.6	19.2	.26	3.12	.05	.62	.62	1.08	27.9	444	26.3
Bhs	30- 35	3.8	4.1	1.30	1.23	2	.30	.03	.34	.03	1.31	.34	.03	5.7	16.3	.37	1.68	.19	.84	.83	1.12	8.7	204	8.3
BC	35- 91	4.4	4.6	.23	.25	1	.08	.03	.10	.00	.26	.09	.01	1.7	3.1	.10	.36	.10	.36	.35	.91	6.5	121	6.2
C	91-150	4.4	4.6	.04	.02	2	.03	.08	.05	.00	.03	.04	.02	1.9	1.7	.06	.09	.03	.05	.04	.55	1.7	6.9	1.4
B-106	Belgium			Gleyic Podzol			Typic Haplaquod																	
Ah	0- 15	3.3	3.6	5.14	1.06	2	.06	.01	.07	.01	1.53	.07	.01	5.3	15.2	.08	1.61	.04	.81	.80	1.10	49.2	714	46.0
E	15- 31	4.2	4.2	.40	.18	1	.01	.00	.02	.00	.19	.02	.00	0.4	1.7	.02	.21	.02	.21	.21	2.00	21.4	-	21.4
BE	31- 40	4.2	4.2	.66	.44	3	.07	.00	.07	.00	.63	.08	.00	1.8	7.0	.08	.71	.03	.24	.24	1.14	17.7	-	17.7
Bh	40- 49	4.2	4.2	1.32	.84	4	.15	.00	.18	.00	1.14	.20	.00	3.3	4.4	.20	1.34	.05	.34	.34	1.33	12.8	-	12.8
BC	49- 61	4.3	4.4	.59	.40	3	.08	.00	.11	.00	.48	.14	.01	1.4	4.0	.15	.63	.05	.21	.21	1.88	7.7	224	7.5
C	61-150	4.3	4.5	.06	.01	1	.01	.00	.02	.00	.05	.02	.00	0.2	1.3	.02	.07	.02	.07	.07	2.00	5.6	-	5.6
SER-3	Switzerland			Ranker			Lithic Cryumbrept																	
Ah1	0- 9	4.0	5.2	2.6		5	.18	1.46	.15	.30	1.02	.13	.21			.34	1.36	.07	.27	.23	.21	17.7	22.6	9.9
Ah2	9- 17	3.9	5.4	1.4		5	.17	1.29	.14	.38	.60	.12	.29			.41	1.01	.08	.20	.14	.28	11.3	9.6	5.2
C1	17- 21	4.1	5.4	.8		4	.20	1.42	.14	.35	.35	.10	.13			.23	.58	.06	.15	.11	.14	7.9	12.5	4.8
C2	21- 27	4.3	5.6	.6		3	.14	1.55	.12	.38	.20	.05	.06			.11	.31	.04	.10	.08	.07	9.0	15.5	5.7
C3	27- 50	5.2	6.1				.09	2.48	.03	.23	.06	.01	.01			.02	.08	-	-	-	.01	13.5	27.9	9.1
R	50+						.00	.48	.00	.12	.47	.01	.02			.03	.50	-	-	-	.06	105	109	53.8
SER-10	Switzerland			Dystric Cambisol			Typic Dystrochrept																	
Ah	0- 3	2.8	3.7	25.9		28	.15	.71	.17	.30	4.79	.16	.32			.48	5.27	.02	.19	.18	.56	67.4	69.7	34.3
E	3- 12	2.5	4.1	2.0		9	.04	.22	.14	.06	.45	.05	.06			.11	.56	.01	.06	.06	.42	20.3	34.9	12.8
BE	12- 15	3.5	4.6	2.5		10	.38	4.09	.27	1.44	1.67	.24	.94			1.18	2.85	.12	.29	.19	.26	15.7	8.3	5.4
Bhs	15- 28	5.1	5.8	4.9		6	1.36	4.28	1.30	2.67	4.15	.99	1.24			2.23	6.38	.37	1.06	.86	.40	9.4	15.6	5.9
R	28+						.00	.18	.01	.02	.31	.00	.01			.01	.32	-	-	-	.06	-	144	144

Atomic Ratios																		CEC/			
C_t/									C_h/									C_t		C_h	
Al_d	Fe_d	Ses_d	Al_o	Fe_o	Ses_o	Al_p	Fe_p	Ses_p	Al_d	Fe_d	Ses_d	Al_o	Fe_o	Ses_o	Al_p	Fe_p	Ses_p	Soil pH	pH 8.2	Soil pH	pH 8.2
NL-110	Netherlands	Humic Podzol	Typic Haplohumod																		
150	373	107	129	467	101	150	467	114	55.9	139	39.9	47.9	173	37.5	55.9	174	42.3	1.8	3.7	4.8	9.9
-	-	-	158	-	158	-	-	-	-	-	-	74.2	-	74.2	-	-	-	1.6	4.3	3.3	9.1
137	569	111	274	569	185	274	569	185	76.5	317	61.6	153	317	103	153	317	104	3.0	3.6	5.3	6.5
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.9	0	2.3	0
45.2	161	35.3	45.2	375	40.3	41.7	161	33.1	35.3	125	27.5	35.3	292	31.5	32.5	125	25.8	3.7	7.8	4.7	10.1
33.2	61.2	21.5	33.2	78.7	23.3	31.2	61.2	20.7	25.3	46.7	16.4	25.3	60.0	17.8	23.8	46.7	15.8	3.7	8.7	4.8	11.4
15.3	11.3	6.5	12.8	12.7	6.4	12.8	12.7	6.4	12.6	9.3	5.4	10.5	10.5	5.2	10.5	10.5	5.2	4.7	6.9	5.7	8.4
8.7	19.4	6.0	8.7	29.2	6.7	8.0	23.3	6.0	7.4	16.7	5.2	7.4	25.1	5.7	6.9	20.1	5.1	3.8	17.8	4.4	20.7
11.7	75.7	10.2	11.7	136	10.8	11.3	97.3	10.1	10.0	64.8	8.7	10.0	116.7	9.2	9.7	83.3	5.1	3.5	10.7	4.1	12.5
5.9	12.3	4.0	6.7	49.0	5.9	5.9	24.5	4.8	3.1	6.4	2.1	3.5	25.7	3.1	3.1	12.8	8.7	6.7	14.3	12.7	27.3
5.6	7.8	3.3	5.6	-	5.6	5.6	23.3	4.5	1.1	1.6	0.7	1.1	-	1.1	1.1	4.7	2.5	22.0	34.0	110	170
																	0.9				
B-101	Belgium	Orthic Podzol	Typic Haplorthod																		
387	53.5	47.0	387	115	88.5	387	80.3	66.5	175	24.3	21.3	176	52.0	40.1	176	36.4	30.1	0	1.7	0	3.7
-	67.7	67.7	-	67.7	67.7	-	67.7	67.7	-	37.3	37.3	-	37.3	37.3	-	37.3	37.3	0	5.5	0	10.0
16.0	16.6	8.2	18.3	18.3	9.2	16.0	22.2	9.3	11.8	12.3	6.0	13.5	13.5	6.8	11.8	16.3	6.9	0.7	8.7	1.0	11.8
10.8	8.1	4.6	9.6	8.8	4.6	10.8	13.1	5.9	8.3	6.2	3.5	7.3	6.7	3.5	8.3	10.0	4.5	0.7	11.5	.9	15.0
4.4	2.9	1.8	5.0	4.9	2.5	5.9	6.3	3.0	2.7	1.8	1.1	3.1	3.0	1.5	3.6	3.9	1.9	2.1	15.3	3.4	24.8
4.0	2.2	1.4	4.5	3.7	2.0	5.1	5.7	2.7	2.8	1.5	1.0	3.1	2.6	1.4	3.5	3.9	1.9	0	16.9	0	24.5
3.4	3.5	1.7	3.4	7.0	2.3	3.4	14.0	2.7	1.1	1.2	0.6	1.1	2.3	.8	1.1	4.7	.9	26.7	53.3	80.0	160
2.6	.7	.6	3.2	1.6	1.0	3.9	3.0	1.7	1.5	.4	.3	1.8	.9	.6	2.3	1.7	1.0	7.1	10.0	12.5	17.5
1.7	1.3	.7	1.7	2.0	.9	1.7	3.5	1.1	1.7	1.3	.7	1.7	2.0	.9	1.7	3.5	1.1	33.3	16.7	33.3	16.7
B-102	Belgium	Gleyic Podzol	Aeric Haplaquod																		
29.3	45.5	17.8	43.9	91.0	29.6	43.9	60.7	25.5	28.0	28.0	11.0	27.0	56.0	18.2	27.0	37.3	15.7	1.5	4.6	2.5	7.5
14.1	146	12.8	14.1	292	13.4	12.8	194	12.0	12.5	129	11.4	12.5	259	11.9	11.4	173	10.7	4.4	8.6	5.0	9.6
11.9	129	10.9	11.4	518	11.1	10.9	259	10.4	11.9	129	10.9	11.4	518	11.1	10.9	259	10.4	3.0	7.9	3.0	7.9
11.0	137	10.2	10.4	411	10.2	9.9	411	9.7	10.4	129	9.6	9.8	387	9.6	9.3	387	9.1	5.6	7.7	5.9	8.2
9.6	140	9.0	8.4	280	8.2	9.0	280	8.7	10.1	147	9.5	8.9	294	8.6	9.4	294	9.2	5.7	9.2	5.4	8.7
19.4	401	18.4	21.5	-	21.5	17.6	401	16.9	18.7	387	17.8	20.8	-	20.7	17.0	387	16.3	3.7	7.8	3.9	8.1
11.7	121	10.7	11.7	-	11.7	11.7	121	10.7	11.3	117	10.3	11.3	-	11.2	11.3	117	10.3	6.2	9.6	6.4	10.0
B-103	Belgium	Gleyic Podzol	Aeric Haplaquod																		
54.6	132	38.7	54.6	144	39.6	45.0	132	33.6	33.6	81.3	23.8	33.6	88.7	24.4	27.7	81.3	20.6	2.4	5.2	3.9	8.5
40.5	84.0	27.3	40.5	84.0	27.3	-	84.0	84.0	29.2	60.7	19.7	29.2	60.7	19.7	-	60.7	60.7	4.4	1.7	6.2	2.3
19.5	-	19.5	29.3	121	23.6	19.5	121	16.8	18.0	-	18.0	27.0	112	21.8	18.0	112	15.5	7.3	1.2	7.9	1.3
21.8	406	20.6	28.0	406	26.2	19.6	406	18.7	18.8	350	17.8	24.1	350	22.6	16.9	350	16.1	4.7	7.2	6.5	8.4
17.2	392	16.5	18.9	392	18.0	11.1	131	10.2	16.6	378	15.9	18.2	378	17.4	10.7	126	9.9	5.4	6.2	5.6	6.4
13.5	364	13.0	12.5	364	12.1	9.2	121	8.6	12.1	327	11.7	11.3	327	10.9	8.3	109	7.7	5.0	8.6	5.6	9.6
18.2	719	17.8	19.2	719	18.7	13.9	240	13.1	17.1	672	16.6	18.0	672	17.5	13.0	224	12.3	3.6	7.0	3.8	7.5
B-104	Belgium	Gleyic Podzol	Typic Haplaquod																		
192	497	138	160	663	129	160	497	121	89.5	232	64.6	74.6	310	60.1	74.6	232	56.5	1.3	4.3	2.8	9.2
250	-	250	250	-	250	250	-	250	115	-	115	115	-	115	115	-	115	0.8	4.7	1.8	10.2
104	215	69.8	51.8	215	41.7	104	215	69.8	60.8	126	41.0	30.4	126	24.5	60.8	126	41.0	2.8	12.6	4.8	21.5
45.5	212	37.5	58.5	212	45.9	41.0	212	34.3	30.5	142	25.1	39.2	142	30.7	27.5	142	23.0	1.9	7.3	2.9	10.9
32.0	698	30.6	35.4	1395	34.5	32.0	1395	31.3	18.0	392	17.2	19.9	784	19.4	18.0	784	17.6	3.0	6.5	5.3	11.5
24.5	482	23.3	27.3	964	26.6	22.7	964	22.1	19.0	382.7	18.5	21.7	765	21.1	18.0	765	17.6	1.5	6.7	1.9	8.5
9.0	44.1	7.5	8.5	55.1	7.4	7.7	73.5	7.0	8.4	41.1	7.0	7.9	51.3	6.9	7.2	68.4	6.5	5.3	13.2	5.7	14.2
7.6	74.7	6.9	6.6	105	6.2	7.0	87.1	6.5	7.0	68.7	6.4	6.1	96.1	5.7	6.4	80.1	6.0	3.6	14.8	3.9	16.1
3.8	4.7	2.1	2.9	26.4	2.6	1.3	11.3	1.2	2.7	3.3	1.5	2.1	18.7	1.9	0.9	8.0	0.8	13.5	30.6	19.2	43.3
3.4	1.5	1.0	3.4	3.5	1.7	1.8	4.4	1.3	2.1	0.9	0.6	2.1	2.1	1.1	1.1	2.7	0.8	18.9	28.9	30.9	47.3
B-105	Belgium	Gleyic Podzol	Aeric Haplaquod																		
190	789	153	190	789	153	190	789	153	75.4	313	60.7	75.4	313	60.7	75.4	313	60.7	1.5	3.2	3.7	8.1
65.3	135	44.0	-	-	-	-	-	-	29.2	60.7	19.7	-	-	-	-	-	-	2.1	5.9	4.6	13.1
32.5	337	29.7	34.2	337	31.1	28.3	450	26.6	22.7	236	20.7	23.9	236	21.7	19.8	314	18.6	3.3	6.6	4.6	9.5
9.7	202	9.3	8.6	202	8.3	8.6	202	8.3	9.2	191	8.8	8.1	191	7.8	8.1	191	7.8	4.4	12.5	4.6	13.3
6.5	35.8	5.5	5.2	-	5.2	5.8	107	5.5	7.0	38.9	6.0	5.6	-	5.6	6.3	117	5.9	7.4	13.5	6.8	12.4
3.0	2.3	1.3	1.8	-	1.8	2.3	9.3	1.8	1.5	1.2	0.7	.09	-	0.9	1.1	4.7	0.9	47.5	42.5	95.0	85.0
B-106	Belgium	Gleyic Podzol	Typic Haplaquod																		
193	2400	178	165	2400	155	165	2400	155	39.8	495	36.8	34.1	495	31.9	34.1	495	31.9	1.0	3.0	5.0	14.3
90.0	-	90.0	45.0	-	45.0	45.0	-	45.0	40.5	-	40.5	20.3	-	20.3	20.3	-	20.3	1.0	4.3	2.2	9.4
21.2	-	21.2	21.2	-	21.2	18.6	-	18.6	14.1	-	14.1	14.1	-	14.1	12.4	-	12.4	2.7	10.6	4.1	15.9
19.8	-	19.8	16.5	-	16.5	14.9	-	14.9	12.6	-	12.6	10.5	-	10.5	9.5	-	9.5	2.5	3.3	3.9	5.2
16.6	-	16.6	12.1	-	12.1	9.5	275	9.2	11.3	-	11.3	8.2	-	8.2	6.4	187	6.2	2.4	6.8	3.5	10.0
13.5	-	13.5	6.8	-	6.8	6.8	-	6.8	2.3	-	2.3	1.1	-	1.1	1.1	-	1.1	3.3	21.7	20.0	130
SER-3	Switzerland	Ranker	Lithic Cryumbrept																		
32.5	8.3	6.6	39.0	40.3	19.8	45.0	57.6	25.3													
18.5	5.1	4.0	22.5	17.2	9.7	26.3	22.5	12.1													
9.0	2.6	2.0	12.9	10.6	5.8	18.0	28.6	11.1													
9.6	1.8	1.5	11.3	7.4	4.5	27.0	46.6	17.1													
SER-10	Switzerland	Dystric Cambisol	Typic Dystrochrept																		
389	170	118	343	402	185	364	377	185													
113	42.3	30.7	32.1	155	26.6	90.0	155	57.0													
14.8	2.8	2.4	20.8	8.1	5.8	23.4	12.4	8.1													
8.1	5.3	3.2	8.5	8.5	4.3	11.1	18.4	6.9													

APPENDIX 4B. SELECTED CHEMICAL PROPERTIES AND CARBON/SESQUIOXIDES ATOMIC RATIOS* OF PROFILES IN THE ISM COLLECTION

		pH		Carbon		clay	Amorphous Matter Extractions							CEC		Pyrophosphate Extract						Atomic Ratios C_p/		
Horizon	Depth (cm)	KCl	H_2O	C_t %	C_h %	c %	Al_d %	Fe_d %	Al_o %	Fe_o %	C_p %	Al_p %	Fe_p %	Soil pH	pH 7	Ses	AM	Ses ÷ clay	AM ÷ clay	Al+C ÷ clay	Ses_p ÷ Ses_d	Al_p	Fe_p	Ses_p
CDN-14	Canada	Gleyic Podzol			Typic Haplaquod																			
Ah		3.0	4.5	2.06	1.16	3	.05	.01	.04	.01	1.06	.05	.01		7.4	.06	1.12	.02	.37	.37	1.00	47.7	493	43.5
Bhg1	20- 26	3.3	4.1	2.95	2.68	15	.23	.01	.24	.01	2.66	.28	.01		18.3	.29	2.95	.02	.20	.20	1.21	21.4	1241.	21.0
Bhg2	26- 46	3.5	4.1	3.36	3.29	20	.41	.01	.44	.01	3.27	.48	.00		23.5	.48	3.75	.02	.19	.19	1.14	15.3	-	15.3
BCg	46- 61	3.9	4.5	2.97	.79	15	.15	.02	.17	.00	1.03	.17	.00		6.2	.17	1.20	.01	.08	.08	1.00	13.6	-	13.6
C	64+	3.9	4.8	.08	.09	3	.03	.31	.03	.06	.13	.03	.04		1.0	.07	.20	.02	.07	.05	.21	9.7	15.1	5.9
F-10	France	Cambic Arenosol			Spodic Udipsamment																			
Ah	0- 15	3.1	4.2	7.39	2.50	3	.02	.10	.01	.04	1.69	.02	.04		20.4	.06	1.75	.02	.58	.57	.50	190	197	96.7
E1	15- 25	3.2	4.3	1.78	.81	3	.01	.06	.01	.01	.58	.01	.02		5.6	.03	.61	.01	.20	.20	.43	131	135	66.3
E2	25- 38	3.4	4.4	.55	.27	3	.01	.04	.00	.01	.20	.01	.02		2.5	.03	.23	.01	.08	.07	.60	45.0	46.5	22.9
Bh	38- 52	3.4	4.3	.80	.46	3	.03	.21	.02	.13	.58	.03	.14		5.5	.17	.75	.06	.25	.20	.71	43.5	19.3	13.4
Bs	52- 66	3.9	4.7	.87	.60	12	.08	.40	.06	.23	.77	.10	.27		6.1	.37	1.14	.03	.10	.07	.77	17.3	13.3	7.5
BC	66- 75	4.0	4.9	.33	.23	6	.13	.69	.10	.15	.30	.73	.69		5.7	1.42	1.72	.24	.29	.17	1.73	.9	2.0	.6
C	75-123	3.8	4.6	.10	.06	4	.05	.33	.03	.04	.03	.23	.24		3.0	.47	.50	.12	.12	.06	1.24	.3	.6	.2
IRL-1	Ireland	Cambic Arenosol			Spodic Udipsamment																			
Ah1	0- 20	3.5	4.2	1.60	.92	3	.04	.27	.04	.08	.73	.03	.07		6.6	.10	.83	.03	.28	.25	.32	54.8	48.5	25.7
Ah2	20- 34	3.8	4.3	.57	.27	3	.02	.12	.02	.03	.29	.03	.03		3.4	.06	.35	.02	.12	.11	.43	21.8	45.0	14.7
E	34- 50	4.2	4.6	.21	.10	2	.01	.08	.01	.01	.12	.01	.01		1.7	.02	.14	.01	.07	.07	.22	27.0	55.9	18.2
Bh	50- 60	3.9	4.7	.65	.47	4	.08	.42	.07	.34	.60	.08	.22		6.4	.30	.90	.08	.23	.17	.60	16.9	12.7	7.2
Bs1	60- 75	4.6	5.3	.35	.21	1	.07	.20	.06	.12	.31	.08	.12		3.9	.20	.51	.20	.51	.39	.74	8.7	12.0	5.1
Bs2	80-105	4.6	5.4	.33	.19	3	.11	.45	.10	.23	.33	.11	.18		4.4	.29	.62	.10	.21	.15	.52	6.8	8.5	3.8
C	135-145	4.7	5.5	.13	.07	1	.05	.19	.08	.04	.09	.05	.03		2.4	.08	.17	.08	.17	.14	.33	4.1	14.0	3.1
S-17	Sweden	Orthic Podzol			Typic Cryorthod																			
E1	0- 15	3.3	4.5	.56	.30	1	.01	.01	.01	.01	.23	.01	.00		3.3	.01	.24	.01	.24	.24	.50	51.8	-	51.8
E2	15- 20	3.5	4.7	.76	.51	1	.05	.23	.05	.20	.56	.04	.11		5.9	.15	.71	.15	.71	.60	.51	31.5	23.7	13.5
Bh1	20- 35	3.8	4.9	6.98	5.77	0	1.23	1.78	1.34	1.78	6.36	1.34	1.32		55.1	2.66	9.02	-	-	-	.88	10.7	22.5	7.2
Bh2	35-50	4.2	5.3	2.47	2.37	0	.84	.68	1.23	.64	2.04	.77	.34		26.4	1.11	3.15	-	-	-	.73	6.0	28.0	4.9
Bg	50- 65	4.4	5.3	.94	.76	2	.30	.38	.54	.31	.80	.25	.15		10.6	.40	1.20	.20	.60	.53	.59	7.2	24.8	5.6
Bg	65- 80	4.4	5.3	.58	.35	1	.15	.23	.33	.19	.53	.13	.10		5.7	.23	.76	.23	.76	.66	.61	9.2	24.7	6.7
SK-2	Sarawak	Humic Podzol			Tropohumod																			
O+Ah	0- 10	3.6	4.9	1.29	.67	0	.00	.01	.01	.00	.29	.00	.00		5.2	0	.29	-	-	-	-	-	-	-
E	10- 58	4.5	5.0	.08	.06	0	.00	.00	.00	.00	.06	.00	.00		.2	0	.06	-	-	-	-	-	-	-
EB+BE	58- 75	4.0	4.8	.13	.06	0	.00	.00	.00	.00	.09	.00	.00		.6	0	.09	-	-	-	-	-	-	-
Bh1	75- 90	4.1	4.6	.74	.70	0	.07	.02	.06	.02	.68	.07	.02		4.1	.09	.77	-	-	-	1.00	21.9	158.7	19.2
Bh2	90-108	4.4	4.8	1.56	1.40	1	.23	.04	.25	.04	1.55	.27	.04		9.4	.31	1.86	.31	1.86	1.82	1.15	12.9	181.	12.1
Bh3	110-120	4.5	4.8	.72	.68	1	.14	.06	.14	.06	.46	.15	.05		4.5	.20	.66	.20	.66	.61	1.00	6.9	42.9	5.9
USA-1	United States	Orthic Podzol			Typic Haplorthod																			
E	0- 20	3.6	5.0	.27	.13	3	.00	.04	.01	.00	.02	.00	.00		1.1	.00	.02	0.0	.01	.01	0.0	-	-	-
Bh	20- 28	3.6	4.6	1.44	.89	4	.13	.42	.13	.30	1.04	.16	.34		9.3	.50	1.54	.13	.39	.30	.91	14.6	14.3	7.2
Bhs	28- 38	4.0	4.8	1.41	1.11	4	.34	.31	.47	.22	1.25	.34	.20		9.4	.54	1.79	.14	.45	.40	.83	8.3	29.2	6.4
BC	38- 50	4.2	5.1	.92	.79	4	.29	.15	.41	.08	.86	.25	.06		8.7	.31	1.17	.08	.29	.28	.70	7.7	66.9	6.9
C	50+	4.6	5.7	.07	.04	0	.04	.06	.05	.01	.03	.03	.01		1.2	.04	.07	-	-	-	.40	2.2	14.0	1.9

Atomic Ratios																		CEC/			
C_t/									C_h/									C_t		C_h	
Al_d	Fe_d	Ses_d	Al_o	Fe_o	Ses_o	Al_p	Fe_p	Ses_p	Al_d	Fe_d	Ses_d	Al_o	Fe_o	Ses_o	Al_p	Fe_p	Ses_p	Soil pH	pH 7	Soil pH	pH 7
CDN-14	Canada	Gleyic Podzol		Typic Haplaquod																	
92.7	961	84.5	116	961	103	92.7	961	84.5	52.2	541	47.6	65.3	541	58.2	52.2	541	47.6		3.6		6.4
28.9	1377	28.3	27.7	1377	27.1	23.7	1377	23.3	26.2	1251	25.7	25.1	1251	24.6	21.5	1251	21.2		6.2		6.8
18.4	1568	18.2	17.2	1568	17.0	15.8	-	15.7	18.1	1535	17.8	16.8	1535	16.6	15.4	-	15.4		7.0		7.1
44.6	693	41.9	39.3	-	39.3	39.3	-	39.3	11.9	184	11.1	10.5	-	10.5	10.5	-	10.5		2.1		7.8
6.0	1.2	1.0	6.0	6.2	3.1	6.0	9.3	3.7	6.8	1.4	1.1	6.8	7.0	3.4	6.8	10.5	4.1		12.5		11.1
F-10	France	Cambic Arenosol		Spodic Udipsamment																	
831	345	244	1663	862	568	831	862	424	281	117	82.5	562	292	192	281	292	143		2.8		8.2
400	138	103	400	831	270	400	415	204	182	63.0	46.8	182	378	123	182	189	92.8		3.1		6.9
124	64.2	42.3	-	257	257	124	128	63.0	60.8	31.5	20.7	-	126	126	60.8	63.0	30.9		4.5		9.3
60.0	17.8	13.7	90.0	28.7	21.8	60.0	26.7	18.5	34.5	10.2	7.2	51.8	16.5	12.5	34.5	15.3	10.6		6.9		12.0
24.5	10.2	7.2	32.6	17.7	11.5	19.6	15.0	8.5	16.9	7.0	4.9	22.5	12.2	7.9	13.5	10.4	5.9		7.0		10.2
6.7	2.2	1.6	7.4	10.3	4.3	1.0	2.2	0.7	4.0	1.6	1.1	5.2	7.2	3.0	0.7	1.6	0.5		17.3		24.8
IRL-1	Ireland	Cambic Arenosol		Spodic Udipsamment																	
90.0	27.7	21.2	90.0	93.3	45.8	120	107	56.5	51.8	15.9	12.2	51.8	53.7	26.3	69.0	61.3	32.5		4.1		7.2
64.1	22.2	16.5	64.1	88.7	37.2	42.8	88.7	28.8	30.4	10.5	7.8	30.4	42.0	17.6	20.3	42.0	13.7		6.0		12.6
47.3	12.3	9.7	47.3	98.0	31.9	47.3	98.0	31.9	22.5	5.8	4.6	22.5	46.7	15.2	22.5	46.7	15.2		8.1		17.0
18.3	7.2	5.2	20.9	8.9	6.3	18.3	13.8	7.9	13.2	5.2	3.7	15.1	6.5	4.5	13.2	10.0	5.7		9.8		13.6
11.3	8.2	4.7	13.1	13.6	6.7	9.8	13.6	5.7	6.7	4.9	2.8	7.9	8.2	4.0	5.9	8.2	3.4		11.1		18.6
6.8	3.4	2.3	7.4	6.7	3.5	6.8	8.6	3.8	3.9	2.0	1.3	4.3	3.9	2.0	3.9	4.9	2.2		13.3		23.2
5.8	3.2	2.1	3.7	15.2	2.9	5.8	20.2	4.5	3.2	1.7	1.1	2.0	8.2	1.6	3.2	10.9	2.4		18.5		34.3
S-17	Sweden	Orthic Podzol		Typic Cryorthod																	
126	261	85.0	126	261	85.0	126	-	126	67.5	140	45.5	67.5	140	45.5	67.5	-	67.5		5.9		11.0
34.2	15.4	10.6	34.2	17.7	11.7	42.8	32.2	18.4	23.0	10.3	7.1	23.0	11.9	7.8	28.7	21.6	12.3		7.8		11.6
12.8	18.3	7.5	11.7	18.3	7.1	11.7	24.7	7.9	10.6	15.1	6.2	9.7	15.1	5.1	9.7	20.4	6.6		7.9		9.5
6.6	17.0	4.8	4.5	18.0	3.6	7.2	33.9	6.0	6.3	16.3	4.6	4.3	17.3	3.5	6.9	32.5	5.7		10.7		11.1
7.1	11.5	4.4	3.9	14.2	3.1	8.5	29.2	6.6	5.7	9.3	3.5	3.2	11.4	2.5	6.8	23.6	5.3		11.3		13.9
8.7	11.8	5.0	4.0	14.2	3.1	10.0	27.1	7.3	5.3	7.1	3.0	2.4	8.6	1.9	6.1	16.3	4.4		9.8		16.3
SK-2	Sarawak	Humic Podzol		Tropohumod																	
-	602	602	290	-	290	-	-	-	-	313	313	151	-	151	-	-	-		4.0		7.8
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		2.0		3.3
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		4.6		10.0
23.8	173	20.9	27.8	173	23.9	23.8	173	20.9	225	163	19.8	26.3	163	22.6	22.5	163	19.8		5.5		5.9
15.3	182	14.1	14.0	182	13.0	13.0	182	12.1	13.7	163	12.6	12.6	163	11.7	11.7	163	10.9		6.0		6.7
11.6	56.0	9.6	11.6	56.0	9.6	10.8	67.2	9.3	10.9	52.9	9.1	10.9	52.9	9.1	10.2	63.5	8.8		6.3		6.6
USA-1	United States	Orthic Podzol		Typic Haplorthod																	
-	31.5	31.5	60.8	-	60.7	-	-	-	-	15.2	15.2	29.2	-	29.2	-	-	-		4.1		8.5
24.9	16.0	9.7	24.9	22.4	11.8	20.3	19.8	10.0	15.4	9.9	6.0	15.4	13.8	7.3	12.5	12.2	6.2		6.5		10.4
9.3	21.2	6.5	6.7	29.9	5.5	9.3	32.9	7.3	7.3	16.7	5.1	5.3	23.5	4.3	7.3	25.9	5.7		6.7		8.5
7.1	28.6	5.7	5.0	53.7	4.6	8.3	71.6	7.4	6.1	24.6	4.9	4.3	46.1	4.0	7.1	61.4	6.4		9.5		11.0
3.9	5.4	2.3	3.2	32.7	2.9	5.3	32.7	4.5	2.3	3.1	1.3	1.8	18.7	1.6	3.0	18.7	2.6		17.1		30.0

Appendix 4B (ctd). Selected chemical properties and carbon/sesquioxides atomic ratios* of profiles in the ISM collection

		pH			clay	Amorphous Matter Extractions							CEC		Pyrophosphate Extract					
Hori-zon	Depth (cm)	KCl	H_2O	C_t %	c %	Al_d %	Fe_d %	Al_o %	Fe_o %	C_p %	Al_p %	Fe_p %	pH 7	pH 8.2	Ses	AM	Ses ÷ clay	AM ÷ clay	Al+C ÷ clay	Ses_p ÷ Ses_d
CDN-13	Canada	Dystric Cambisol				Typic Fragiochrept														
Topsoil				1.76		.28	.89	.43	.41	.89	.26	.20	9.3		.46	1.35	.06	.17	.14	.39
Ap	0- 18		5.0	3.2	8	.37	1.16	.61	.62	1.12	.30	.22	13.1		.52	1.64	.07	.21	.18	.34
E	18- 26		5.2	2.1	6	.04	.39	.07	.02	.10	.06	.01	11.9		.07	.17	.01	.02	.02	.16
Bh	26- 43		5.3	1.8	7	.95	1.75	1.27	1.09	1.47	.64	.46	8.5		1.10	2.57	.16	.37	.30	.41
B	43- 59		5.1	.1	6	.11	.54	.18	.04	.12	.13	.02	6.2		.15	.27	.03	.05	.04	.23
Ex	59- 72		5.0	0	6	.07	.53	.11	.02	.02	.08	.01	4.8		.09	.11	.02	.02	.02	.15
Bx1	72- 81		5.2	0	5	.08	.51	.09	.02	.00	.06	.00	3.3		.06	.06	.01	.01	.01	.10
Bx2	81-106		5.0	0	8	.07	.48	.07	.02	.00	.05	.00	4.5		.05	.05	.01	.01	.01	.09
Bx3	106-131		5.2	0	5	.10	.53	.11	.03	.01	.07	.01	4.3		.08	.09	.01	.01	.01	.13
Cx	131-180		4.9	0	8	.11	.58	.06	.02	.01	.04	.00	4.9		.04	.05	.01	.01	.01	.06
CDN-24	Canada	Dystric Cambisol				Dystric Cryochrept														
E	0- 1				5	.11	.45	.11	.16	1.62	.11	.21	12.4		.32	1.94	-	-	-	.57
Bhs	1- 9		4.8	5.9	21	2.07	1.38	4.27	1.00	1.47	2.05	.45	40.0		2.53	4.00	.12	.19	.17	.73
Bh1	9- 17		5.1	3.8	15	1.00	1.36	2.16	.82	2.40	.80	.33	34.3		1.13	3.53	.08	.24	.21	.48
Bh2	17- 35		5.2	3.5	15	1.21	1.13	4.31	.83	2.66	.71	.16	31.6		.87	3.53	.06	.24	.22	.37
Bh3	35- 52		5.2	3.5	18	.72	.92	3.56	.68	1.39	.49	.09	34.1		.58	1.97	.03	.11	.10	.35
Bh4	52- 67		5.2	4.6	15	1.16	1.31	3.30	.69	2.06	.56	.16	39.0		.72	2.78	.05	.19	.17	.29
Bh5	67- 89		5.0	5.3	25	.78	1.41	2.71	1.06	1.18	.43	.23	45.2		.66	1.84	.03	.07	.06	.30
BCr	89-114		5.6	1.7	12	.17	.44	1.22	.21	.23	.13	.01	19.9		.14	.37	.01	.03	.03	.23
Cr1	114-134		6.2	.6	8	.15	.53	1.14	.42	.15	.11	.01	9.1		.12	.27	.02	.03	.03	.18
Cr2	134-171		6.1	.2	8	.11	.31	.95	.28	.18	.10	.01	6.7		.11	.29	.01	.04	.04	.26
D-11	Germany	Dystric Cambisol				Typic Dystrochrept														
Ah	0- 9	2.4	3.1	10.2	29	.21	2.44	.20	.70	3.75	.21	.84	41.8		1.05	4.80	0.04	.17	.14	.40
AB	9- 15	2.7	3.4	6.9	12	.36	3.19	.36	1.51	3.12	.34	1.43	36.4		1.77	4.89	.15	.41	.29	.50
Bw	15- 40	3.8	4.3	1.7	29	.36	2.32	.34	.60	.91	.32	.57	16.8		.89	1.80	.03	.06	.04	.33
Bw	40- 60	3.8	4.2	.7	27	.27	2.14	.24	.47	.38	.16	.24	13.2		.40	.78	.01	.03	.02	.17
C	65- 75	3.7	4.2	.3	24	.18	2.99	.12	.16	.18	.09	.12	9.0		.21	.39	.01	.02	.01	.07
F-2	France	Dystric Cambisol				Typic Dystrochrept														
A1	0- 15	3.4	4.2	6.0	17	.39	1.11	.26	.73	2.31	.19	.68	20.9		.87	3.18	.05	.19	.15	.58
AB	15- 24	3.7	4.4	6.1	16	.25	1.25	.31	.88	2.08	.32	.90	18.6		1.22	3.30	.08	.21	.15	.81
B1	24- 39	3.9	4.5	4.5	11	.34	1.35	.41	.92	2.22	.42	.98	17.6		1.40	3.62	.13	.33	.24	.83
B21	39- 53	4.1	4.7	3.5	11	.35	1.41	.41	.92	1.81	.43	.81	14.0		1.24	3.05	.11	.28	.20	.70
B22	53- 68	4.1	4.7	3.5	8	.40	1.18	.46	.97	1.76	.47	.95	11.8		1.42	3.18	.18	.40	.28	.90
BC	68- 81	4.2	4.7	3.0	8	.40	.98	.48	.90	2.07	.49	.73	10.7		1.22	3.29	.15	.41	.32	.88
C	81-104	4.4	4.9	2.6	5	.65	1.32	.82	.96	2.40	.67	.90	15.8		1.57	3.97	.31	.79	.61	.80
IRL-9	Ireland	Placic Podzol				Typic Placohumod														
E	10- 30	3.9	4.6	.6	1	.02	.03	.02	.02	.28	.02	.01	4.0		.03	.31	.03	.31	.30	.60
Bh	30- 36	3.8	4.4	1.4	4	.08	.08	.07	.04	.93	.10	.05	7.9		.15	1.08	.04	.27	.26	.94
Bs	40- 55	4.2	4.5	.2	2	.11	1.46	.06	.39	.31	.04	.11	4.9		.15	.46	.08	.23	.18	.10
C	70- 80	4.6	5.0	.2	2	.05	.83	.06	.19	.06	.04	.02	3.8		.06	.12	.03	.06	.05	.07
N-1	Norway	Calcaric Regosol				Typic Cryorthent														
Ah1	0- 8	7.1	7.6	1.8	2	.03	.10	.05	.09	.74	.01	.02	9.2		.03	.77	.02	.39	.38	.23
Ah2	8- 14	6.5	7.1	4.8	1	.04	.14	.06	.12	1.07	.03	.04	20.9		.07	1.14	.07	1.14	1.10	.41
Ah3	14- 25	6.7	7.3	2.0	0	.04	.15	.05	.11	.71	.03	.04	11.7		.07	.78	-	-	-	.37
AC	25- 48	7.3	8.1	.7	2	.01	.06	.02	.04	.73	.00	.01	4.6		.01	.74	.01	.37	.37	.14
C	48- 70	7.9	8.5	.3	2	.00	.05	.01	.03	.54	.00	.01	2.2		.01	.55	.01	.28	.27	.20
N-2	Norway	Gleyic Podzol				Placic Haplaquod														
E	0- 8	3.6	4.8	.8	1	.02	.06	.02	.06	.49	.03	.05	4.2		.08	.57	.08	.57	.52	1.00
Bh1	8- 15	3.8	4.7	5.8	6	.79	.97	.77	.81	5.84	.90	.87	38.2		1.77	7.61	.30	1.27	1.12	1.01
Bh2	15- 30	4.1	5.1	3.4	1	.91	.61	.81	.59	3.70	.97	.56	31.8		1.53	5.23	1.53	5.23	4.67	1.01
Bms	30- 33	4.6	6.2	1.0	1	.40	.99	.44	.70	.94	.46	.66	14.8		1.12	2.06	1.12	2.06	1.40	.81
NL-2	Netherlands	Cambic Arenosol				Typic Udipsamment														
Ah	0- 5	3.4	3.9	4.7	4	.17	.43	.17	.22	2.13	.17	.23		17.2	.40	2.53	.10	.63	.58	.67
AB	5- 10	4.1	4.3	2.0	4	.23	.39	.20	.15	1.03	.20	.17		9.7	.37	1.40	.09	.35	.31	.60
Bh1	10- 25	4.3	4.4	1.1	4	.20	.33	.22	.12	.65	.17	.14		6.1	.31	.96	.08	.24	.21	.58
Bh2	35- 55	4.3	4.5	.4	3	.12	.25	.16	.07	.24	.11	.08		3.1	.19	.43	.06	.14	.12	.51
C	70- 80	4.6	4.6	.1	1	.03	.10	.05	.01	.06	.02	.01		1.3	.03	.09	.03	.09	.08	.23

Atomic Ratios												CEC/C_t	
C_p/			C_t/										
Al_p	Fe_p	Ses_p	Al_d	Fe_d	Ses_d	Al_o	Fe_o	Ses_o	Al_p	Fe_p	Ses_p	pH 7	pH 8.2
CDN-13	Canada		Dystric Cambisol			Typic Fragiochrept							
7.7	20.7	5.6	25.7	16.7	10.1	16.7	36.3	11.5	27.7	74.5	20.2	5.3	
8.4	23.7	6.2	19.5	12.8	7.7	11.8	24.0	7.9	24.0	67.7	17.7	4.1	
3.8	46.5	3.5	180	38.2	31.5	103	745	90.4	120	1490	111	5.7	
5.2	14.9	3.8	4.3	4.8	2.3	3.2	7.7	2.3	6.3	18.2	4.7	4.7	
2.1	27.9	1.9	2.0	0.9	0.6	1.3	11.6	1.1	1.7	23.3	1.6	61.0	
.6	9.3	.5	0	0	0	0	0	0	0	0	0	-	
-	-	-	0	0	0	0	0	0	0	0	0	-	
-	-	-	0	0	0	0	0	0	0	0	0	-	
.3	4.7	.3	0	0	0	0	0	0	0	0	0	-	
.6	-	.6	0	0	0	0	0	0	0	0	0	-	
CDN-24	Canada		Dystric Cambisol			Dystric Cryochrept							
33.1	35.9	17.2											
1.6	14.3	1.4	6.4	19.9	4.8	3.1	27.5	2.8	6.5	57.2	5.8	6.8	
6.8	33.8	5.6	8.6	13.0	5.2	4.0	21.6	3.3	10.7	53.6	8.9	9.0	
8.4	77.4	7.6	6.5	14.4	4.5	1.8	19.6	1.7	11.1	102	10.0	9.0	
6.4	71.9	5.9	10.9	17.7	6.8	2.2	24.0	2.0	16.1	181	14.8	9.7	
8.3	59.9	7.3	8.9	16.3	5.8	3.1	31.0	2.8	18.5	134	16.2	8.5	
6.2	23.9	4.9	15.3	17.5	8.2	4.4	23.3	3.7	27.7	107	22.0	8.5	
4.0	107	3.8	22.5	18.0	10.0	3.1	37.7	2.9	29.4	791	28.4	11.7	
3.1	69.8	2.9	9.0	5.3	3.3	1.2	6.6	1.0	12.3	279	11.8	15.2	
4.1	83.8	3.9	4.1	3.0	1.7	0.5	3.3	0.4	4.5	93.1	4.3	33.5	
D-11	Germany		Dystric Cambisol			Typic Dystrochrept							
40.2	20.8	13.7	109	19.5	16.5	115	67.8	42.6	109	56.5	37.3	4.1	
20.6	10.2	6.8	43.1	10.1	8.2	43.1	20.5	13.9	45.7	22.5	15.1	5.3	
6.4	7.4	3.4	10.6	3.4	2.6	11.3	13.2	6.1	12.0	13.9	6.4	9.9	
5.3	7.4	3.1	5.8	1.5	1.2	6.6	6.9	3.4	9.8	13.6	5.7	18.9	
4.5	7.0	2.7	3.8	.5	.4	5.6	8.7	3.4	7.5	11.6	4.6	30.0	
F-2	France		Dystric Cambisol			Typic Dystrochrept							
27.4	15.8	10.0	34.6	25.2	14.6	51.9	38.4	22.1	71.1	41.2	26.1	3.5	
14.6	10.8	6.2	54.9	22.8	16.1	44.3	32.3	18.7	42.9	31.6	18.2	3.0	
11.9	10.5	5.6	29.8	15.6	10.2	24.7	50.0	16.5	24.1	21.4	11.3	3.9	
9.5	10.4	5.0	22.5	11.6	7.6	19.2	17.8	9.2	18.3	20.2	9.6	4.0	
8.4	8.8	4.4	19.7	13.8	8.1	17.1	16.8	8.5	16.8	17.2	8.5	3.4	
9.5	13.1	5.5	16.9	14.3	7.7	14.1	15.6	7.4	13.8	19.2	8.0	3.6	
8.1	12.4	4.9	9.0	9.2	4.5	7.1	12.6	4.6	8.7	13.5	5.3	6.1	
IRL-9	Ireland		Placic Podzol			Typic Placohumod							
31.5	130	25.4	67.5	93.1	39.1	67.5	140	45.5	67.5	279	54.4	6.7	
20.9	86.8	16.9	39.4	81.4	26.5	45.0	163	35.3	31.5	130	25.4	5.6	
17.4	13.2	7.5	4.1	.6	.6	7.5	2.4	1.8	11.3	8.5	4.8	24.5	
3.4	14.0	2.7	9.0	1.1	1.0	7.5	4.9	3.0	11.3	46.5	9.1	19.0	
N-1	Norway		Calcaric Regosol			Typic Cryorthent							
167	172	84.7	135	83.8	51.7	81.0	93.1	43.3	405	419	206	5.1	
80.3	125	48.8	270	160	100	180	186	91.5	360	559	219	4.4	
53.3	82.6	32.4	113	62.1	40.0	90.0	84.6	43.6	150	233	91.2	5.9	
-	340	340	158	54.3	40.4	78.8	81.4	40.0	-	326	326	3.1	
-	251	251	-	27.9	27.9	67.5	46.5	27.5	-	140	140	7.3	
N-2	Norway		Gleyic Podzol			Placic Haplaquod							
36.8	45.6	20.4	90.0	62.1	36.7	90.0	62.1	36.7	60.0	74.5	33.2	5.3	
14.6	31.3	10.0	16.5	27.8	10.4	16.9	33.3	11.2	14.5	31.0	9.9	6.6	
8.6	30.8	6.7	8.4	26.0	6.4	9.4	26.9	7.0	7.9	28.3	6.2	9.4	
4.6	6.6	2.7	5.6	4.7	2.6	5.1	6.6	2.9	4.9	7.1	2.9	14.8	
NL-2	Netherlands		Cambic Arenosol			Typic Udipsamment							
28.2	43.1	17.0	62.2	50.9	28.0	62.2	99.4	38.3	62.2	95.1	37.6		3.7
11.6	28.2	8.2	19.6	23.9	10.8	22.5	62.1	16.5	22.5	54.8	25.9		4.9
8.6	21.6	6.2	12.4	15.5	6.9	11.3	42.7	8.9	14.6	36.6	10.4		5.5
4.9	14.0	3.6	7.5	7.4	3.7	5.6	26.6	4.6	8.2	23.3	6.1		7.8
6.8	27.9	5.4	7.5	4.7	2.9	4.5	46.7	4.1	11.3	46.7	9.1		13.0

Appendix 4B (ctd). Selected chemical properties and carbon/sesquioxides atomic ratios* of profiles in the ISM collection

		pH		clay		Amorphous Matter Extractions							CEC		Pyrophosphate Extract					
Hori-zon	Depth (cm)	KCl	H_2O	C_t %	c %	Al_d %	Fe_d %	Al_o %	Fe_o %	C_p %	Al_p %	Fe_p %	pH 7	pH 8.2	Ses	AM	Ses ÷ clay	AM ÷ clay	Al+C ÷ clay	Ses_p ÷ Ses_d
GMC-4	Soviet Union			Gleyic Podzol			Typic Cryaquod													
E1	0- 12	3.0	3.7	1.55	3	.05	.01	.04	.01	.71	.05	.00	8.3		.05	.76	.02	.25	.25	.83
E2	12- 19	3.4	4.1	1.24	3	.07	.01	.07	.00	.78	.09	.00	6.7		.09	.87	.03	.29	.29	1.12
BE	19- 22	3.6	4.2	1.46	1	.15	.04	.14	.00	1.47	.14	.00	8.1		.14	1.61	.14	1.61	1.61	.74
Bh	22- 30	3.7	4.2	2.58	1	.36	.01	.38	.01	2.47	.43	.01	14.8		.44	2.91	.44	2.91	2.90	1.19
Bhs	30- 37	3.8	4.3	2.33	1	.45	.14	.50	.03	2.01	.55	.04	13.8		.59	2.60	.59	2.60	2.56	1.00
Bs	37- 42	4.2	5.1	.60	2	.18	.23	.23	.04	.51	.18	.06	3.9		.24	.75	.12	.38	.35	.59
2C1r	42- 58	3.7	4.9	.18	6	.05	.77	.06	.35	.21	.04	.11	7.1		.15	.36	.03	.06	.04	.18
2C2r	58- 75	4.2	5.6	.24	6	.03	.58	.03	.31	.09	.00	.02	3.4		.02	.11	<.01	.02	.02	.03
2C3r	75- 95	4.8	6.4	.07	4	.02	.38	.02	.20	.10	.00	.01	2.2		.01	.11	<.01	.03	.03	.02
GMC-6	Soviet Union			Orthic Luvisol			Typic Glossoboralf													
Ap	0- 12	5.6	6.4	3.08	33	.11	1.76	.10	.72	1.16	.03	.14	21.7		.17	1.33	.01	.04	.04	.09
E/B	12- 21	4.7	5.4	.78	35	.25	3.05	.20	1.05	.44	.03	.07	17.3		.10	.54	<.01	.02	.01	.03
B/E	21- 30	4.2	5.1	.50	52	.21	2.54	.21	1.16	.32	.04	.07	20.5		.11	.43	<.01	.01	.01	.04
Bt	30- 57	3.8	4.9	.34	53	.16	2.10	.16	.77	.22	.06	.07	22.0		.13	.35	<.01	.01	.01	.06
2Cr	57- 66	3.8	4.9	.35	62	.20	2.33	.17	.82	.27	.16	.15	20.9		.31	.58	.01	.01	.01	.12
2C1	66- 73	4.5	5.0	.40	45	.23	2.67	.13	.72	.26	.11	.12	16.6		.23	.49	.01	.01	.01	.08
2C2	73- 85	4.1	5.0	.60	26	.28	5.37	.11	.84	.25	.09	.14	12.0		.23	.48	.01	.02	.01	.04
2C3	85- 92	4.3	5.3	.23	23	.09	1.06	.08	.37	.06	.12	.09	9.2		.21	.27	.01	.01	.01	.18
3C	92-100	4.3	5.4	.20	14	.07	.76	.04	.27	.14	.02	.07	5.4		.09	.23	.01	.02	.01	.11
GMC-7	Soviet Union			Orthic Luvisol			Aquic Cryoboralf													
Bs	5- 13	3.9	4.8	1.31	13	.25	.74	.26	.35	.83	.24	.26			.50	1.33	.04	.10	.08	.51
E	13- 25	3.9	4.9	.31	11	.11	.63	.08	.22	.22	.07	.09	5.0		.16	.38	.01	.03	.03	.22
Bt1	25- 54	3.9	5.0	.20	19	.10	.97	.06	.29	.12	.02	.04	7.9		.06	.18	<.01	.01	.01	.06
Bt2	54- 69	4.5	5.7	.13	15	.08	.74	.04	.15	.06	.01	.02	5.7		.03	.09	<.01	.01	<.01	.04
BC	69- 85	4.5	5.8	.11	17	.09	.86	.03	.16	.04	.01	.01	6.7		.02	.06	<.01	<.01	<.01	.02
C	85-100	4.2	5.3	.53	26	.08	.74	.04	.14	.04	.00	.01	8.2		.01	.05	<.01	<.01	<.01	.01
GMC-8	Soviet Union			Orthic Podzol			Typic Haplorthod													
Ah	0- 17	5.2	6.1	1.71	8	.12	.30	.14	.26	.86	.11	.10	8.7		.21	1.07	.03	.13	.12	.50
E	17- 30	5.1	6.2	.17	4	.01	.02	.02	.03	.12	.03	.01	1.7		.04	.16	.01	.04	.04	1.33
BE	30- 38	4.4	5.6	.42	7	.07	.11	.08	.06	.40	.07	.05	4.4		.12	.52	.02	.07	.07	.67
Bhm1	38- 53	3.8	4.7	1.95	4	.35	.63	.36	.63	1.60	.42	.47	11.5		.89	2.49	.22	.62	.51	.91
Bhm2	53- 64	4.0	4.5	1.38	1	.34	.30	.39	.28	1.32	.50	.29	7.8		.79	2.11	.79	2.11	1.82	1.23
Bs	64- 80	4.2	4.6	.86	1	.32	.26	.33	.23	.87	.41	.22	5.6		.63	1.50	.63	1.50	1.28	1.09
BC	80- 93	4.3	4.6	.50	2	.21	.15	.26	.13	.52	.27	.13	3.2		.40	.92	.20	.46	.40	1.11
2C	93-100	4.3	4.7	.51	3	.22	.15	.28	.14	.22	.25	.13	4.1		.38	.60	.13	.20	.16	1.03
GMC-13	Soviet Union			Gleyic Acrisol			Aquic Hapludalf													
Ah	0- 10	3.0	3.9	1.44	6	.06	.04	.06	.03	.55	.07	.04	6.1		.11	.66	.02	.11	.10	1.10
E	10- 19	3.8	4.7	.25	10	.02	.04	.03	.02	.03	.02	.02	2.0		.04	.07	.01	.01	.01	.67
B	19- 32	4.2	5.2	.35	7	.14	.19	.20	.11	.27	.15	.07	3.3		.22	.49	.03	.07	.06	.67
E	32- 46	4.4	5.6	.15	6	.11	.34	.11	.16	.10	.07	.03	2.8		.10	.20	.02	.03	.03	.22
2Bt1	46- 68	3.6	4.4	.24	19	.12	.89	.12	.29	.10	.08	.06	8.8		.14	.24	.01	.01	.01	.13
2bt2	68- 96	3.8	4.5	.19	18	.08	.67	.08	.15	.09	.05	.05	6.3		.10	.19	.01	.01	.01	.13

Atomic Ratios												CEC/C_t	
C_p/			C_t/										
Al_p	Fe_p	Ses_p	Al_d	Fe_d	Ses_d	Al_o	Fe_o	Ses_o	Al_p	Fe_p	Ses_p	pH 7	pH 8.2
GMC-4	Soviet Union			Gleyic Podzol		Typic Cryaquod							
32.0	--	32.0	69.8	723	63.6	87.2	723	77.8	69.8	-	69.7	5.4	
19.5	-	19.5	39.9	579	37.3	39.9	-	39.9	31.0	-	31.0	5.4	
23.6	-	23.6	21.9	170	19.4	23.5	-	23.5	23.5	-	23.5	5.5	
12.9	1153	12.8	16.1	1204	15.9	15.3	1204	15.1	13.5	1204	13.4	5.7	
8.2	234	7.9	11.7	77.7	10.1	10.5	362	10.2	9.5	272	9.2	5.9	
6.4	39.7	5.5	7.5	12.2	4.6	5.9	70.0	5.4	7.5	46.7	6.5	6.5	
11.8	8.9	5.1	8.1	1.1	1.0	6.8	2.4	1.8	10.0	7.6	4.4	39.0	
-	20.9	20.9	18.0	1.9	1.7	18.0	3.6	3.0	-	56.0	56.0	14.2	
-	46.5	46.5	7.9	0.9	0.8	7.9	1.6	1.4	-	32.7	32.7	31.4	
GMC-6	Soviet Union			Orthic Luvisol		Typic Glossoboralf							
87.0	38.6	26.7	63.0	8.2	7.2	69.3	20.0	15.5	231	103	71.1	7.0	
33.0	29.3	15.5	7.0	1.2	1.0	8.8	3.5	2.5	58.5	52.0	27.5	22.2	
18.0	21.3	9.8	5.4	0.9	0.8	5.4	2.0	1.5	28.1	33.3	15.3	41.0	
8.2	14.6	5.3	4.8	0.8	0.7	4.8	2.1	1.4	12.8	22.7	8.2	64.7	
3.8	8.4	2.6	3.9	0.7	0.6	4.6	2.0	1.4	4.9	10.9	3.4	59.7	
5.3	10.1	3.5	3.9	0.7	0.6	6.9	2.6	1.9	8.2	15.6	5.4	41.5	
6.3	8.3	3.6	4.8	0.5	0.5	12.3	3.3	2.6	15.0	20.0	8.6	20.0	
1.1	3.1	.8	5.8	1.0	0.9	6.5	2.9	2.0	4.3	11.9	3.2	40.0	
15.8	9.3	5.9	6.4	1.2	1.0	11.3	3.5	2.6	22.5	13.3	8.4	27.0	
GMC-7	Soviet Union			Orthic Luvisol		Aquic Cryoboralf							
7.8	14.9	5.1	11.8	8.3	4.9	11.3	17.5	6.9	12.3	23.5	8.1	16.8	
7.1	11.4	4.4	6.3	2.3	1.7	8.7	6.6	3.7	10.0	16.1	6.2	16.1	
13.5	14.0	6.9	4.5	1.0	0.8	7.5	3.2	2.3	22.5	23.3	11.5	39.5	
13.5	14.0	6.9	3.7	0.8	0.7	7.3	4.0	2.6	29.2	30.3	14.9	43.9	
9.0	18.6	6.1	2.8	0.6	0.5	8.3	3.2	2.3	24.8	51.3	16.7	60.9	
-	18.6	18.6	14.9	3.3	2.7	29.8	17.7	11.1	-	247	247	15.5	
GMC-8	Soviet Union			Orthic Podzol		Typic Haplorthod							
17.6	40.0	12.2	32.1	26.6	14.5	27.5	30.7	14.5	35.0	79.8	24.3	5.1	
9.0	55.9	7.8	38.3	39.7	19.5	19.1	26.4	11.1	12.8	79.3	11.0	10.0	
12.9	37.2	9.6	13.5	17.8	7.7	11.8	32.7	8.7	13.5	39.2	10.0	10.5	
8.6	15.8	5.6	12.5	14.4	6.7	12.2	14.4	6.6	10.4	19.4	6.8	5.9	
5.9	21.2	4.6	9.1	21.5	6.4	8.0	23.0	5.9	6.2	22.2	4.9	5.7	
4.8	18.5	3.8	6.0	15.4	4.3	5.9	17.4	4.4	4.7	18.2	3.7	6.5	
4.3	18.6	3.5	5.4	15.6	4.0	4.3	17.9	3.5	4.2	17.9	3.4	6.4	
2.0	7.9	1.6	5.2	15.9	3.9	4.1	17.0	3.3	4.6	18.3	3.7	8.0	
GMC-13	Soviet Union			Gleyic Acrisol		Aquic Hapludalf							
17.7	64.0	13.9	54.0	168	40.9	54.0	224	43.5	46.3	168	36.3	4.2	
3.4	7.0	2.3	28.1	29.2	14.3	18.8	58.3	14.5	28.1	58.3	19.0	8.0	
4.1	18.0	3.3	5.6	8.6	3.4	3.9	14.8	3.1	5.3	23.3	4.3	9.4	
3.2	15.5	2.7	3.1	2.1	1.2	3.1	4.4	1.8	4.8	23.3	4.0	18.7	
2.8	7.8	2.1	3.6	1.0	0.8	3.6	3.1	1.6	5.3	14.8	3.9	46.3	
4.1	8.4	2.7	5.3	1.3	1.1	5.3	5.9	2.8	8.5	17.7	5.8	33.2	

Appendix 4B (ctd). Selected chemical properties and carbon/sesquioxides atomic ratios* of profiles in the ISM collection

		pH			clay	Amorphous Matter Extractions							CEC		Pyrophosphate Extract					
Hori- zon	Depth (cm)	KCl	H_2O	C_t %	c %	Al_d %	Fe_d %	Al_o %	Fe_o %	C_p %	Al_p %	Fe_p %	pH 7	pH 8.2	Ses	AM	Ses ÷ clay	AM ÷ clay	Al+C ÷ clay	Ses_p ÷ Ses_d
S-2	Sweden	Dystric Cambisol				Typic Dystrochrept														
Ah	0- 6	3.2	3.9	2.1	5	.06	.25	.06	.11	2.20	.06	.12	22.5		.18	2.53	.04	.51	.48	.58
E	6- 10	3.5	4.0	2.2	4	.04	.21	.05	.11	.83	.05	.13	9.2		.18	1.01	.05	.25	.22	.72
Bh	10- 16	3.7	4.1	2.8	7	.17	1.05	.19	.76	2.13	.20	.77	19.2		.97	3.10	.14	.44	.33	.80
Bs1	16- 26	4.5	4.5	2.0	7	.44	.74	.59	.51	1.60	.39	.29	14.8		.68	2.28	.10	.33	.28	.58
Bs2	26- 55	4.6	4.6	.9	6	.22	.37	.37	.21	.62	.14	.07	7.3		.21	.83	.04	.14	.13	.36
C	55+	4.7	4.7	.5	6	.18	.34	.25	.19	.44	.15	.12	5.5		.27	.71	.05	.12	.10	.52
S-9	Sweden	Orthic Podzol				Typic Cryorthod														
E	0- 7	3.2	4.4	.4	0	.01	.02	.02	.02	.20	.00	.01	2.6		.01	.21	-	-	-	.33
Bh	7- 17	3.6	4.5	1.5	2	.09	.81	.20	.70	1.48	.15	.39	14.3		.54	2.02	.27	1.01	.82	.60
Bs	17- 27	4.0	5.0	.6	1	.21	.39	.43	.32	.42	.11	.03	3.1		.14	.56	.14	.56	.53	.23
BC	27- 38	4.0	4.7	.2	1	.16	.42	.28	.40	.14	.07	.02	1.6		.09	.23	.09	.23	.21	.16
2C1	45- 60	4.0	5.3	.3	3	.17	.35	.30	.25	.18	.09	.03	3.1		.12	.30	.04	.10	.09	.23
2C2	60- 70	4.6	5.5	.1	1	.08	.17	.11	.11	.12	.07	.05	1.4		.12	.24	.12	.24	.19	.48
2C3	72-105	4.5	5.8	.2	3	.13	.43	.18	.28	.19	.10	.08	2.5		.18	.37	.06	.12	.10	.32
S-10	Sweden	Orthic Podzol				Typic Cryohumod														
E	1- 12	3.5	4.6	.9	1	.03	.01	.03	.00	.36	.04	.00	3.2		.04	.40	.04	.40	.40	1.00
Bh1	15- 20	4.0	4.8	5.3	2	.85	.23	1.05	.10	4.43	.97	.13	35.2		1.10	5.53	.55	2.77	2.70	1.02
Bh2	20- 30	4.4	5.2	1.2	1	.44	.69	.69	.37	1.11	.35	.21	7.4		.56	1.67	.56	1.67	1.46	.50
2C1	25- 40	4.5	5.2	.4	0	.16	.66	.24	.37	.37	.12	.16	2.6		.28	.65	-	-	-	.34
2C2	40- 60	4.5	5.2	.2	1	.11	.60	.16	.26	.20	.08	.07	1.4		.15	.35	.15	.35	.28	.21
2C3	60- 70	4.5	5.3	.2	1	.10	.54	.16	.33	.16	.07	.08	1.5		.15	.31	.15	.31	.23	.23
S-14	Sweden	Cambic Arenosol				Typic Cryopsamment														
E	0- 3	3.4	4.6	.9	1	.02	.07	.02	.03	.29	.02	.03	6.3		.05	.34	.05	.34	.31	.56
Bs	3- 10	4.5	5.3	.6	2	.19	.52	.41	.30	.44	.15	.04	6.6		.19	.63	.10	.32	.30	.27
B	10- 20	4.6	5.4	.4	1	.12	.31	.25	.16	.19	.07	.01	3.7		.08	.27	.08	.27	.26	.19
B	20- 30	4.6	5.4	.2	1	.06	.18	.15	.07	.08	.04	.01	2.0		.05	.13	.05	.13	.12	.21
B	30- 45	4.6	5.7	.1	1	.04	.13	.09	.06	.05	.02	.00	1.3		.02	.07	.02	.07	.07	.12
C	48- 70	5.2	6.3	0	0	.01	.06	.02	.03	.03	.01	.00	.6		.01	.04	-	-	-	.14
S-15	Sweden	Humic Podzol				Typic Cryohumod														
E	0- 10	3.4	4.5	2.1	3	.02	.02	.02	.02	.55	.02	.02	6.7		.04	.59	.01	.20	.19	1.00
Bh1	10- 25	3.8	4.5	2.4	4	.17	.06	.15	.05	1.79	.19	.06	13.8		.25	2.04	.06	.51	.50	1.09
Bh2	25- 40	4.0	4.9	4.6	4	.71	.85	.72	.87	4.69	.81	.83	41.7		1.64	6.33	.41	1.58	1.38	1.05
Bh3	40- 55	4.1	5.1	2.8	3	.53	.80	.53	.76	2.91	.66	.72	30.1		1.38	4.29	.46	1.43	1.19	1.04
BC	58- 65	4.3	5.2	1.1	5	.32	.32	.33	.24	.46	.34	.21	12.0		.55	1.01	.11	.20	.18	.86
S-16	Sweden	Dystric Cambisol				Dystric Cryochrept														
E	0- 6	3.3	4.3	.5	2	.02	.12	.03	.01	.18	.01	.01	4.6		.02	.20	.01	.10	.10	.14
Bs1	7- 15	5.0	5.9	1.7	2	.68	1.81	2.52	1.15	.91	.35	.04	21.8		.39	1.30	.20	.65	.63	.16
Bs2	15- 30	5.1	6.0	.3	2	.13	.48	.50	.27	.20	.05	.00	4.0		.05	.25	.03	.13	.13	.08
C	70- 80	4.8	5.9	.1	2	.06	.26	.20	.17	.06	.04	.01	2.2		.05	.11	.03	.06	.05	.16
SF-4	Finland	Orthic Podzol/Cambic Arenosol						Typic Cryorthod/Spodic Udipsamment												
E	0- 10	3.5	4.3	.7	0	.01	.02	.01	.01	.24	.01	.01	4.4		.02	.26	-	-	-	.67
Bhs	10- 20	4.4	4.8	3.0	0	.34	1.73	1.44	1.29	2.38	.55	.41	23.9		.96	3.34	-	-	-	.46
Bs	20- 35	5.2	5.5	.7	1	.15	.28	1.11	.20	.28	.13	.01	8.0		.14	.42	.14	.42	.41	.33
C	35- 70	5.1	5.7	.2	2	.03	.05	.39	.05	.05	.06	.00	2.8		.06	.11	.03	.06	.06	.75
SK-3	Sarawak	Cambic Arenosol				Typic Tropopsamment														
Ah	0- 2	4.2	4.6	1.3	1	.02	.37	.01	.02	.26	.00	.01	5.0		.01	.27	.01	.27	.26	.02
E	10- 25	4.0	4.6	.2	1	.02	.43	.00	.01	.15	.00	.02	.6		.02	.17	.02	.17	.15	.04
EB	30- 38	4.1	5.5	.2	2	.07	.95	.01	.07	.17	.02	.19	1.0		.21	.38	.11	.19	.10	.21
Bhs1	38- 46	4.2	4.5	.6	4	.20	2.12	.06	.35	.29	.09	.59	3.7		.68	.97	.17	.24	.10	.29
Bhs2	46- 58	4.7	5.3	.5	3	.48	3.85	.18	.62	.52	.27	1.22	2.8		1.49	2.01	.50	.67	.26	.34
Bs	58- 66	4.9	5.3	.3	3	.46	4.88	.08	.43	.29	.13	.51	1.9		.70	.99	.23	.33	.14	.13
Bw	75- 90	5.0	5.2	.2	3	.32	3.72	.05	.22	.05	.07	.42	1.0		.49	.54	.16	.18	.04	.12
SK-4	Sarawak	Cambic Arenosol				Typic Tropopsamment														
Ah	0- 10	4.0	4.3	.7	4	.20	2.12	.04	.08	.38	.04	.21	3.9		.25	.63	.06	.16	.11	.11
AB	16- 25	4.0	4.5	.5	4	.21	2.18	.03	.07	.29	.04	.25	4.2		.29	.58	.07	.15	.08	.12
Bw1	40- 55	4.1	5.3	.3	4	.13	1.73	.02	.10	.14	.03	.24	2.8		.27	.41	.07	.10	.04	.15
Bw2	75- 95	4.6	5.4	.1	4	.22	2.40	.03	.10	.00	.04	.23	1.8		.27	.27	.07	.07	.01	.10
BC	110-120	4.8	5.5	.1	3	.20	2.30	.02	.07	.14	.01	.08	1.1		.09	.23	.03	.08	.05	.04

Atomic Ratios												CEC/C_t	
C_p/			C_t/										
Al_p	Fe_p	Ses_p	Al_d	Fe_d	Ses_d	Al_o	Fe_o	Ses_o	Al_p	Fe_p	Ses_p	pH 7	pH 8.2
S-2	Sweden	Dystric Cambisol	Typic Dystrochrept										
88.1	91.1	44.8	78.8	39.1	26.1	78.8	88.9	41.7	78.8	81.4	40.0	10.7	
37.4	29.7	16.5	124	48.8	35.0	99.0	93.1	48.0	99.0	78.8	43.9	4.2	
24.0	12.9	8.4	37.1	12.4	9.3	33.2	17.1	11.3	31.5	16.9	11.0	6.9	
9.2	25.7	6.8	10.2	12.6	5.6	7.6	18.3	5.4	11.5	32.1	8.5	7.4	
10.0	41.2	8.0	9.2	11.3	5.1	5.5	19.9	4.3	14.5	59.8	11.6	8.1	
6.6	17.1	4.8	6.3	6.8	3.3	4.5	12.2	3.3	7.5	19.4	5.4	11.0	
S-9	Sweden	Orthic Podzol	Typic Cryorthod										
-	93.1	93.1	90.0	93.1	45.8	45.0	93.1	30.3	-	186	186	6.5	
22.2	17.7	9.8	37.5	8.6	7.0	16.9	10.0	6.3	22.5	17.9	10.0	9.5	
8.6	65.2	7.6	6.4	7.2	3.4	3.1	8.7	2.3	12.3	93.1	10.8	5.2	
4.5	32.6	4.0	2.8	2.2	1.2	1.6	2.3	1.0	6.4	46.5	5.6	8.0	
4.5	27.9	3.9	4.0	4.0	2.0	2.3	5.6	1.6	7.5	46.5	6.5	10.3	
3.9	11.2	2.9	2.8	2.7	1.4	2.0	4.2	1.4	3.2	9.3	2.4	14.0	
4.3	11.1	3.1	3.5	2.2	1.3	2.5	3.3	1.4	4.5	11.6	3.2	12.5	
S-10	Sweden	Orthic Podzol	Typic Cryohumod										
20.3	-	20.3	67.5	419	58.1	67.5	-	67.5	50.6	-	50.6	3.6	
10.3	159	9.7	14.0	107	12.4	11.4	247	10.9	12.3	190	11.5	6.6	
7.1	24.6	5.5	6.1	8.1	3.5	3.9	15.1	3.1	7.7	26.6	6.0	6.2	
6.9	10.8	4.2	5.6	2.8	1.9	3.8	5.0	2.1	7.5	11.6	4.6	6.5	
5.6	13.3	4.0	4.1	1.6	1.1	2.8	3.6	1.6	5.6	13.3	4.0	7.0	
5.1	9.3	3.3	4.5	1.7	1.2	2.8	2.8	1.4	6.4	11.6	4.1	7.5	
S-14	Sweden	Cambic Arenosol	Typic Cryopsamment										
32.6	45.0	18.9	101	59.8	37.6	101	140	58.7	101	140	58.7	7.0	
6.6	51.2	5.8	7.1	5.4	3.1	3.3	9.3	2.4	9.0	69.8	8.0	11.0	
6.1	88.4	5.7	7.5	6.0	3.3	3.6	11.6	2.7	12.9	186	12.0	9.3	
4.5	37.2	4.0	7.5	5.2	3.1	3.0	13.3	2.4	11.3	93.1	10.0	10.0	
5.6	-	5.6	5.6	3.6	2.2	2.5	7.8	1.9	11.3	-	11.2	13.0	
6.7	-	6.7	0	0	0	0	0	0	0	0	0	-	
S-15	Sweden	Humic Podzol	Typic Cryohumod										
61.9	128	41.7	236	489	159	236	489	159	236	489	159	3.2	
21.2	139	18.4	31.8	186	27.1	36.0	223	31.0	28.4	196	24.7	5.8	
13.0	26.4	8.7	14.6	25.2	9.2	14.4	24.6	9.1	12.8	25.8	8.5	9.1	
9.9	18.9	6.5	11.9	16.3	6.9	11.9	17.1	7.0	9.5	18.1	6.2	10.8	
3.0	10.2	2.3	7.7	16.0	5.2	7.5	21.3	5.5	7.3	24.4	5.6	10.9	
S-16	Sweden	Dystric Cambisol	Dystric Cryochrept										
40.5	83.8	27.3	22.5	7.8	5.8	15.0	93.1	12.9	45.0	93.1	30.3	23.0	
5.8	106.2	5.5	5.6	4.4	2.5	1.5	6.9	1.2	10.9	198	10.4	12.8	
9.0	-	9.0	5.2	2.9	1.9	1.4	5.2	1.1	13.5	-	13.5	13.3	
3.4	27.9	3.0	3.8	1.8	1.2	1.1	2.7	.8	5.6	46.5	5.0	22.0	
SF-4	Finland	Orthic Podzol/Cambic Arenosol	Typic Cryorthod/Spodic Udipsamment										
54.0	112	36.4	158	163	80.1	158	325	106	158	326	106	6.3	
9.7	27.0	7.2	19.9	8.1	5.7	4.7	10.8	3.3	12.3	34.1	9.0	8.0	
4.8	130	4.7	10.5	11.6	5.5	1.4	16.3	1.3	12.1	326	11.7	11.4	
1.9	-	1.9	15.0	18.6	8.3	1.2	18.6	1.1	7.5	-	7.5	14.0	
SK-3	Sarawak	Cambic Arenosol	Typic Tropopsamment										
-	121	121	146	16.4	14.7	293	303	149	-	605	605	3.8	
-	34.9	34.9	22.5	2.2	2.0	-	93.1	92.9	-	46.5	46.5	3.0	
19.1	4.2	3.4	6.4	1.0	.9	45.0	13.3	10.3	22.5	4.9	4.0	5.0	
7.2	2.3	1.7	6.8	1.3	1.1	22.5	8.0	5.9	15.0	4.7	3.6	6.2	
4.3	2.0	1.4	2.3	.6	.5	6.3	3.8	2.3	4.2	1.9	1.3	5.6	
5.0	2.4	1.6	1.5	.3	.2	8.4	3.2	2.3	5.2	2.4	1.7	6.3	
1.6	.6	.4	1.4	.3	.2	9.0	4.2	2.9	6.4	2.2	1.6	5.0	
SK-4	Sarawak	Cambic Arenosol	Typic Tropopsamment										
21.4	8.4	6.0	7.9	1.5	1.3	39.4	40.7	20.0	39.4	15.5	11.1	5.6	
16.3	5.4	4.1	5.4	1.1	.9	37.5	33.2	17.6	28.1	9.3	7.0	8.4	
10.5	2.7	2.2	5.2	.8	.7	33.8	14.0	9.9	22.5	5.8	4.6	9.3	
0	0	0	1.0	.2	.2	7.5	4.7	2.9	5.6	2.0	1.5	18.0	
31.5	8.1	6.5	1.1	.2	.2	11.3	6.6	4.2	22.5	5.8	4.6	11.0	

APPENDIX 5. SELECTED CHEMICAL DATA FROM LITERATURE AND CARBON/SESQUIOXIDE ATOMIC RATIOS

			clay	Amorphous Matter Extractions							Pyrophosphate Extract					
Hori- zon	Depth (cm)	C_t %	c %	Al_d %	Fe_d %	Al_o %	Fe_o %	C_p %	Al_p %	Fe_p %	Ses	AM	Ses ÷ clay	AM ÷ clay	Al+C ÷ clay	Ses_p ÷ clay
Countesswells England Brown Podzolic																
Ap	0- 25	6.6	11					4.1	.47	1.31	1.78	5.88	.16	.53		
Bs	25- 33	3.2	12					3.0	.72	.55	1.27	4.27	.11	.36		
BCx	33- 43	-	12					.6	.25	.17	0.42	1.02	.04	.09		
Brownrigg England Brown Podzolic																
Ap	0- 16	2.1	5					.6	.09	.24	.33	.93	.07	.19		
Bs	16- 31	1.0	6					.4	.12	.24	.36	.76	.06	.13		
BC	31- 80	-	4					.2	.09	.09	.18	.38	.05	.10		
Bowden England Brown Podzolic																
Ap	0- 25	5.4	29					2.1	.85	.56	1.41	3.51	.05	.12		
Bs	25- 38	1.9	19					1.0	.78	.50	1.28	2.28	.07	.12		
BC	38- 76	.9	16					.4	.34	.14	.48	.88	.03	.06		
England Brown Podzolic																
Ap	0- 24	4.2	24					.8	.21	.46	.67	1.47	.03	.06		
Bs	24- 45	2.0	14					.6	.45	.60	1.05	1.65	.08	.12		
England Brown Podzolic																
Ap	0- 26	3.3	16					.6	.12	.42	.54	1.14	.03	.07		
Bs	26- 40	1.2	17					.5	.23	.79	1.02	1.52	.06	.09		
Bx(g)	40- 65	-	17					.1	.09	.05	.14	.24	.01	.01		
Moor Gate England Brown Podzolic																
Ah/Ea	0- 12	12.	12					3.3	.25	.60	.85	4.15	.07	.35		
Ah/Bh	12- 25	5.3	10					2.9	.64	1.13	1.77	4.67	.18	.47		
Bs	25- 42	1.6	5					.9	.48	.31	.79	1.69	.16	.34		
BCx	42- 95	-	4					.4	.34	.05	.39	.79	.10	.20		
Bowden England Brown Podzolic																
H	4 - 0	26.	15					6.7	.11	1.06	1.17	7.87	.08	.52		
Ah	0 - 2.5	13.	16					3.9	.25	.91	1.16	5.06	.07	.32		
Ah/Bh	2.5-16	10.	21					4.7	.46	1.79	2.25	6.95	.11	.33		
Bs	16 -32	2.4	8					1.6	.37	.74	1.11	2.71	.14	.34		
BC(x)	32 -63		8					.4	.49	.52	1.01	1.41	.13	.18		
Sourhope England Brown Podzolic																
Ah	0 -10	6.4	23					2.4	1.00	.90	1.90	4.30	.08	.19		
Bs1	10 -18	4.5	13					2.3	.85	.85	1.70	4.00	.13	.31		
Bs2	18 -60	4.2	8					2.0	.60	.24	.84	2.84	.11	.36		
BCx	60 -90	-	11					1.0	.50	.08	.58	1.58	.05	.14		
Linhope England Brown Podzolic																
Ah/Ea	0 -15	5.5	22					1.9	.50	.43	.93	2.83	.04	.13		
Bs	15 -50	2.5	16					1.2	.63	.63	1.26	2.46	.08	.15		
Cx	50 -70	-	5					< .05	.17	< .01	.17	.22	.03	.04		
Manod England Brown Podzolic																
Ah/Ea	0 - 4	15.	30					2.0	.26	1.16	1.42	3.42	.05	.11		
AB	4 -15	5.2	31					1.6	.50	1.39	1.89	3.49	.06	.11		
Bs1	15 -29	2.2	25					.9	.45	1.14	1.59	2.49	.06	.10		
Bs2	29 -47	1.8	17					.7	.50	.89	1.39	2.09	.08	.12		
Bs3	47 -70	1.8	14					.8	.46	.68	1.14	1.94	.08	.14		
Hiraethog England Ironpan Stagnopodzol																
Oh	12 - 0	35.														
Ah/Eag	0 -14	5.6	19					2.3	.2	.3	.5	2.80	.03	.15		
Bf	14 -14.5	8.2	-					5.7	.5	5.9	6.4	12.1	-	-		
Bs	14.5-34	2.9	10					1.6	.8	3.0	3.80	5.40	.38	.54		
BC	34 -52	1.0	22					.3	.2	.3	.50	.8	.02	.04		

Atomic Ratios												Reference
$C_p/$			$C_t/$									
Al_p	Fe_p	Ses_p	Al_d	Fe_d	Ses_d	Al_o	Fe_o	Ses_o	Al_p	Fe_p	Ses_p	
Countesswells England Brown Podzolic												
19.6	14.6	8.4							31.6	23.5	13.5	Avery et al., 1977
9.4	25.5	6.9							10.0	27.2	7.3	
5.4	16.5	4.1							-	-	-	
Brownrigg England Brown Podzolic												
15.0	11.7	6.6							52.5	40.8	23.0	
7.5	7.8	3.8							18.7	19.4	9.6	
5.0	10.4	3.4							-	-	-	
Bowden England Brown Podzolic												
5.6	17.5	4.2							14.3	45.0	10.9	
2.9	9.3	2.2							5.5	17.7	4.2	
2.7	13.3	2.2							6.0	30.0	5.0	
England Brown Podzolic												
8.6	8.1	4.2							45.0	42.6	21.9	
3.0	4.7	1.8							10.0	15.6	6.1	
England Brown Podzolic												
11.3	6.7	4.2							61.9	36.7	23.0	
4.9	3.0	1.8							11.7	7.1	4.4	
2.5	9.3	2.0							-	-	-	
Moor Gate England Brown Podzolic												
29.7	25.7	13.8							108	93.3	50.1	
10.2	12.0	5.5							18.6	21.9	10.1	
4.2	13.6	3.2							7.5	24.1	5.7	
2.7	37.3	2.5							-	-	-	
Bowden England Brown Podzolic												
137	29.5	24.3							532	114	94.2	
35.1	20.0	12.7							117	66.7	42.5	
23.0	12.3	8.0							48.9	26.1	17.0	
9.7	10.1	4.95							14.6	15.1	7.4	
1.8	3.6	1.2							-	-	-	
Sourhope England Brown Podzolic												
5.4	12.4	3.8							14.4	33.2	10.0	
6.1	12.6	4.1							11.9	24.7	8.0	
7.5	38.9	6.3							15.8	81.7	13.2	
4.5	538	4.2							-	-	-	
Linhope England Brown Podzolic												
8.6	20.6	6.0							24.8	59.7	17.5	
4.3	8.9	2.9							8.9	18.5	6.0	
-	-	-							-	-	-	
Manod England Brown Podzolic												
17.3	8.1	5.5							129	60.3	41.2	
7.2	5.4	3.1							23.4	17.5	10.0	
4.5	3.7	2.0							11.0	9.0	4.9	
3.2	3.7	1.7							8.1	9.4	4.4	
3.9	5.5	2.3							8.8	12.4	5.1	
Hiraethog England Ironpan Stagnopodzol												
25.9	35.8	15.0							63.0	87.1	36.6	
25.7	4.5	3.8							36.9	6.5	5.5	
4.5	2.5	1.6							8.2	4.5	2.9	
3.4	4.7	2.0							11.3	15.6	6.5	

Appendix 5 (ctd). Selected chemical data from literature and carbon/sesquioxide atomic ratios

			clay	Amorphous Matter Extractions							Pyrophosphate Extract					
Horizon	Depth (cm)	C_t %	c %	Al_d %	Fe_d %	Al_o %	Fe_o %	C_p %	Al_p %	Fe_p %	Ses	AM	Ses ÷ clay	AM ÷ clay	Al+C ÷ clay	Ses_p ÷ clay
Hexworthy England Ironpan Stagnopodzol																
Oh	10 - 0	15.0														
Ah/Eag	0 -18	3.1	7					2.2	.3	.03	.33	2.53	.05	.36		
Bf	18 -18.5	8.0	-					5.5	.7	5.9	6.6	12.1	-	-		
Bs	18.5-30	3.1	8					1.6	.3	.9	1.2	2.8	.15	.35		
BC	30 -61	-	8					.7	.2	.1	.3	1.0	.04	.13		
Belmont England Ironpan Stagnopodzol																
Oh2	7 - 0	23.0														
Ea(g)	0 - 6	3.7	11					2.0	.3	.1	.4	2.4	.04	.22		
Bf	6 - 6.3	4.9	-					3.4	.3	2.9	3.2	6.6	-	-		
Bs1	6.3-23	1.5	10					.8	.3	.6	.9	1.7	.09	.17		
Bs2	23 -38	3.7	4					2.6	.6	2.5	3.1	5.7	.78	1.43		
Dod England Ironpan Stagnopodzol																
Om/Oh	18 - 0	50.0														
Ah/Eag	0 - 7	8.5	34					3.9	.5	.4	.9	4.8	.03	.14		
Bf	7 - 7.3	7.1	-					4.5	.4	5.6	6.0	10.5	-	-		
Bs	7.3-35	3.0	28					1.5	.9	2.0	2.9	4.4	.10	.16		
BCx	35 -45	.4	15					.4	.4	.5	.9	1.3	.06	.09		
Ebberston England Ironpan Stagnopodzol																
Oh	8 - 0	26.0														
Eag	0 -10	4.0	13					1.5	.1	.04	.14	1.64	.01	.13		
Bf/Bs	10 -11	5.4	-					2.9	.3	1.1	1.4	4.3	-	-		
Bw/E'b	11 -36	.6	30					.3	.2	.2	.4	.7	.01	.02		
B't	36 -62	-	46					.2	.2	.04	.24	.44	.01	.01		
BC	62 -93	-	25					.8	.1	.03	.13	.93	.01	.04		
Hafren England Ferric Stagnopodzol																
Ah	0 - 6	13.0	17													
Eg	6 -15	1.5	17					.6	.05	.2	.25	.85	.01	.05		
Bsg	15 -26	2.2	34					1.2	.3	2.1	2.4	3.6	.07	.11		
Bs	26 -34	2.4	32					1.2	.4	2.3	2.7	3.9	.08	.12		
Rough Tor England Ferric Stagnopodzol																
Ap	0 -14	5.2	16					1.9	.3	.8	1.1	3.0	.07	.19		
Eg	14 -25	1.7	14					.6	.1	.6	.7	1.3	.05	.09		
Bs(g)	25 -50	1.6	18					.9	.4	1.3	1.7	1.6	.09	.14		
BC	50 -77	-	9					.2	.1	.3	.4	.6	.04	.07		
Daletown England Humus-Ironpan Stagnopodzol																
Oh	10 - 0	34.0	-													
Ah/Ea	0 - 8	7.0	12					2.6	.2	.4	.6	3.2	.05	.27		
Bh	8 -13	6.2	15					2.4	.2	.8	1.0	3.4	.07	.23		
Eag	13 -19	3.7	15					1.4	.3	.4	.7	2.1	.05	.14		
Bf	19 -20	3.3	-					2.3	.4	3.4	3.8	6.1	-	-		
Bs	20 -32	2.1	16					1.2	.3	.8	1.1	2.3	.07	.14		
E'b/Bw	32 -51	-	11					.3	.2	.2	.4	.7	.04	.06		
B't/Bw	51 -88	-	18					.2	.2	.1	.3	.5	.02	.03		
Maw England Humus-Ironpan Stagnopodzol																
Oh	10 - 0	14.0	-													
Ah/Ea	0 -15	3.6	3					1.1	.1	.1	.2	1.3	.07	.43		
Bh	15 -17.5	4.1	12					2.5	.3	.3	.6	3.1	.05	.26		
Bf	17.5-18	4.1	-					2.8	.5	4.7	5.2	8.0	-	-		
Bs1	18 -26	1.7	7					1.2	.4	2.1	2.5	3.7	.36	.53		
Bs2	26 -43	.9	6					.5	.2	.5	.7	1.2	.12	.20		
BC	43 -53	-	5					.2	.1	.1	.2	.4	.04	.08		

Atomic Ratios												Reference
$C_p/$			$C_t/$									
Al_p	Fe_p	Ses_p	Al_d	Fe_d	Ses_d	Al_o	Fe_o	Ses_o	Al_p	Fe_p	Ses_p	
Hexworthy	England	Ironpan Stagnopodzol										
16.5	342	157							23.3	482	22.2	Avery et al., 1977
17.7	4.4	3.5							25.7	6.3	5.1	
12.0	8.3	4.9							23.3	16.1	9.5	
7.9	32.7	6.4							-	-	-	
Belmont	England	Ironpan Stagnopodzol										
15	93	12.9							27.8	173	23.9	
25.5	5.5	4.5							36.8	7.9	6.5	
6.0	6.2	3.1							11.3	11.7	5.7	
9.8	4.9	3.2							13.9	6.9	4.6	
Dod	England	Ironpan Stagnopodzol										
17.6	45.5	12.7							38.3	99.2	27.6	
25.3	3.8	3.3							39.9	5.9	5.2	
3.8	3.5	1.8							7.5	7.0	3.6	
2.3	3.7	1.4							2.3	3.7	1.4	
Ebberston	England	Ironpan Stagnopodzol										
33.8	175	28.3							90.0	467	75.5	
21.8	12.3	7.9							40.5	22.9	14.6	
3.4	7.0	2.3							6.8	14.0	4.6	
2.3	23.3	2.1							-	-	-	
18.0	124	15.8							-	-	-	
Hafren	England	Ferric Stagnopodzol										
27.0	14.0	9.2							67.5	35.0	23.1	
9.0	2.7	2.1							16.5	4.9	3.8	
6.8	2.4	1.8							13.5	4.9	3.6	
Rough Tor	England	Ferric Stagnopodzol										
14.3	11.1	6.2							39.0	30.3	17.1	
13.5	4.7	3.5							38.3	13.2	9.8	
5.1	3.2	2.0							9.0	5.7	3.5	
4.5	3.1	1.8							-	-	-	
Daletown	England	Humus-Ironpan Stagnopodzol										
29.3	3.3	14.9							78.8	81.7	40.1	
27.0	14.0	9.2							70.0	36.2	23.8	
10.5	16.3	6.4							27.8	43.2	16.9	
12.9	3.2	2.5							18.6	4.5	3.6	
9.0	7.0	3.9							15.8	12.3	6.9	
3.4	7.0	2.3							-	-	-	
2.3	9.3	1.8							-	-	-	
Maw	England	Humus-Ironpan Stagnopodzol										
24.8	51.3	16.7							81	168	54.7	
18.8	38.9	12.7							30.8	63.8	20.8	
12.6	2.8	2.3							18.5	4.1	3.3	
6.8	2.7	1.9							9.6	3.8	2.7	
5.6	4.7	2.6							10.1	8.4	4.6	
4.5	9.3	3.0							-	-	-	

Appendix 5 (ctd). Selected chemical data from literature and carbon/sesquioxide atomic ratios

			clay	Amorphous Matter Extractions							Pyrophosphate Extract					
Hori-zon	Depth (cm)	C_t %	c %	Al_d %	Fe_d %	Al_o %	Fe_o %	C_p %	Al_p %	Fe_p %	Ses	AM	Ses ÷ clay	AM ÷ clay	Al+C ÷ clay	Ses_p ÷ clay
Dartington	England+Wales			Brown Podzolic												
Ah	0 - 5		36	.37	3.17	1.17	1.74	2.44	.38	1.28	1.66	4.10	.05	.11	.08	.47
Bs1	5 -18		39	.57	3.63	1.80	2.00	1.01	.67	1.38	2.05	3.06	.05	.08	.04	.49
Bs2	18 -38		34	.56	3.39	1.85	1.74	.72	.65	1.11	1.76	2.48	.05	.07	.04	.45
Bs3	38 -51		21	.52	2.89	1.36	1.38	.63	.47	.73	1.20	1.83	.06	.09	.05	.35
BC	51 -64		9	.31	3.08	.69	.40	.25	.20	.19	.39	.64	.04	.07	.05	.12
Highweek	England+Wales			Brown Earth												
Ap			32	.37	2.90	1.30	1.60	.69	.17	.29	.46	1.15	.01	.04	.03	.14
Bw1			27	.37	2.96	1.12	1.24	.36	.13	.13	.16	.62	.01	.02	.02	.08
Bw2			27	.40	2.79	1.09	.92	.30	.14	.15	.29	.59	.01	.02	.02	.09
Moretonhampstead	England+Wales				Brown Podzolic											
Ah	0 -12		19	.13	.68	.29	.64	3.45	.34	.52	.86	4.31	.05	.23	.20	1.06
Ah/Bh	12 -20		15	.27	.95	.44	.74	2.91	.39	.80	1.19	4.10	.08	.27	.22	.98
Bs1	20 -32		14	.60	1.38	.62	.86	2.40	.57	1.04	1.61	4.01	.12	.29	.21	.81
Bs2	32 -85		12	.60	.89	.66	.36	1.02	.43	.37	.80	1.82	.07	.15	.12	.54
Lustleigh	England+Wales			Brown Earth												
Ap			28	.16	1.90	.91	.90	.74	.11	.20	.31	1.05	.01	.04	.03	.15
Bw			27	.42	1.17	.75	.70	.24	.21	.25	.46	.80	.02	.03	.02	.29
BC			19	.09	.85	.31	.19	.20	.09	.04	.13	.33	.01	.02	.02	.14
Bowden	England+Wales			Brown Podzolic												
Ah			29	.92	2.58	5.62	2.02	2.13	.85	.56	1.42	3.54	.05	.12	.10	.40
Bs			19	1.12	2.18	5.28	.44	1.01	.78	.50	1.28	2.29	.07	.12	.09	.39
BC			16	.62	1.53	2.78	.12	.37	.34	.14	.48	.85	.03	.05	.04	.22
Trusham	England+Wales			Brown Earth												
Ah			19	.57	5.64	1.33	.46	.47	.26	.16	.42	.89	.02	.05	.04	.07
Bw			11	.48	5.52	.64	.64	.10	.15	.06	.21	.31	.02	.03	.02	.04
BC			13	.43	4.20	.66	.58	.04	.02	.04	.06	.10	<.01	.01	<.01	.01
Manod	England+Wales			Brown Podzolic												
Ah			30	.19	1.18	1.00	.64	2.04	.26	1.16	1.42	3.46	.05	.12	.08	1.04
AB			31	.53	2.26	1.74	.30	1.65	.50	1.39	1.89	3.54	.06	.11	.07	.68
Bs1			25	.80	2.10	2.81	.48	.87	.45	1.14	1.59	2.46	.06	.10	.05	.55
Bs2			17	1.16	2.51	.92	1.76	.70	.43	.89	1.31	2.02	.08	.12	.07	.36
Bs3			14	.96	1.60	1.16	.94	.81	.46	.68	1.14	1.95	.08	.14	.09	.45
BC			10	.47	.84	.45	.30	.38	.28	.18	.46	.84	.05	.08	.07	.35
Vyrnwy	England+Wales			Podzol												
Ea	0 -15		20	.07	.16	.12	.08	1.57	.06	.13	.19	1.76	.01	.09	.08	.83
Bh	15 -20		37	1.21	3.61	1.22	3.40	10.39	1.05	3.02	4.07	14.46	.11	.39	.31	.84
Bs1	20 -30		29	1.85	4.71	1.41	3.74	5.47	1.02	3.83	4.85	10.32	.17	.36	.22	.74
Bs2	30 -40		21	1.87	3.90	2.32	3.22	5.41	.99	3.06	4.05	9.46	.19	.45	.30	.70
BC	40 -60		15	1.94	2.63	1.70	1.50	2.55	.18	.43	.61	3.16	.04	.21	.18	.13
	Japan	Andept														
B			9	1.42	3.70	5.38	2.90	.41	.42	.45	.87	1.28	.10	.14	.09	.17
Charr	England			Histic Placaquept												
H	10 - 3															
AE	3 -10	6.1	8		.32			2.75	.38	.39	.77	3.52	.10	.44	.39	
B2s	10 -18	2.3	9		1.04			1.15	.46	.81	1.27	2.42	.14	.27	.18	
B3x	28 -36	.9	15		.52			.60	.30	.25	.55	1.15	.04	.08	.06	
B3x	48 -56	.3	17		.42			.11	.25	.18	.43	.54	.03	.03	.02	
Cx	70 -80	.3	15		.31			.64	.27	.24	.51	1.15	.03	.08	.06	

Atomic Ratios												
$C_p/$			$C_t/$									Reference
Al_p	Fe_p	Ses_p	Al_d	Fe_d	Ses_d	Al_o	Fe_o	Ses_o	Al_p	Fe_p	Ses_p	
Dartington	England+Wales	Brown Podzolic										
14.4	8.9	5.5										Loveland and Bullock, 1976
3.4	3.4	1.7										
2.5	3.0	1.4										
3.0	4.0	1.7										
2.8	6.1	1.9										
Highweek	England+Wales	Brown Earth										
9.1	11.1	5.0										
6.2	12.9	4.2										
4.8	9.3	3.2										
Moretonhampstead	England+Wales	Brown Podzolic										
22.8	31.0	13.1										
16.8	17.0	8.4										
9.5	10.8	5.0										
5.3	12.9	3.8										
Lustleigh	England+Wales	Brown Earth										
15.1	17.3	8.1										
3.6	6.3	2.3										
5.0	23.3	4.1										
Bowden	England+Wales	Brown Podzolic										
5.6	17.8	4.3										
2.9	9.4	2.2										
2.4	12.3	2.0										
Trusham	England+Wales	Brown Earth										
4.1	13.7	3.1										
1.5	7.8	1.3										
4.5	4.7	2.3										
Manod	England+Wales	Brown Podzolic										
17.7	8.2	5.6										
7.4	5.5	3.2										
4.3	3.6	2.0										
3.7	3.7	1.8										
4.0	5.6	2.3										
3.1	9.9	2.3										
Vyrnwy	England+Wales	Podzol										
58.9	56.4	28.8										
22.3	16.1	9.3										
12.1	6.7	4.3										
12.3	8.3	4.9										
31.9	27.7	14.8										
-	Japan	Andept										
2.2	4.3	1.4										
Charr	England	Histic Placaquept										
16.3	32.9	10.9							36.1	73.0	24.2	Ragg and Clayden, 1973
5.6	6.6	3.0							11.3	13.3	6.1	
4.5	11.2	3.2							6.8	16.8	4.8	
.99	2.9	.73							2.7	7.8	2.0	
5.3	12.4	3.7							2.5	5.8	1.8	

Appendix 5 (ctd). Selected chemical data from literature and carbon/sesquioxide atomic ratios

			clay	Amorphous Matter Extractions							Pyrophosphate Extract					
Hori-zon	Depth (cm)	C_t %	c %	Al_d %	Fe_d %	Al_o %	Fe_o %	C_p %	Al_p %	Fe_p %	Ses	AM	Ses ÷ clay	AM ÷ clay	Al+C ÷ clay	Ses_p ÷ clay
Insch England Typic Cryochrept																
Ap	10 - 18	4.7	24		2.49			1.24	.58	.16	.74	1.98	.03	.08	.08	
Bs	28 - 33	1.0	15		1.58			.47	.37	.04	.41	.88	.03	.06	.06	
BC	36 - 43		11		1.86			.16	.24	.04	.28	.44	.03	.04	.04	
C	60 - 65		7		1.54			.66	.20	.06	.26	.92	.04	.13	.12	
C	95 -102		5		1.74			.30	.05	.04	.09	.39	.02	.08	.07	
Linhope England Dystric Cryochrept																
A	10 - 20	4.1	33		1.99			1.84	.42	.20	.62	2.46	.02	.07	.07	
B1s	40 - 50	3.1	20		3.46			1.76	.26	1.00	1.26	3.02	.06	.15	.10	
B2s	60 - 70	.9	17		2.24			.50	.35	.87	1.22	1.72	.07	.10	.05	
C	80 - 95	.6	12		2.03			.30	.25	.11	.36	.66	.03	.06	.05	
Dunsford England Typic Fragiochrept																
A	0 - 8	9.5	28		-			2.71	.30	.91	1.21	3.92	.04	.14	.11	
B1s	8 - 23	1.8	27		4.3			.72	.39	.73	1.12	1.84	.04	.07	.04	
B2s	23 - 40	-	23		4.0			.57	.36	.70	1.06	1.63	.05	.07	.04	
BC1tgx	53 - 75	-	17		-			.06	.16	.10	.26	.32	.02	.02	.01	
Tarves England Typic Fragiochrept																
A	3 - 12	7.2	10					2.79	.47	.30	.77	3.6	.08	.36	.33	
Bs	20 - 33	1.6	12					.81	.47	.17	.64	1.45	.05	.12	.11	
Bx	35 - 50	-	17					.17	.24	.06	.30	.47	.02	.03	.02	
C	58 - 70	-	12					.34	.37	.16	.53	.87	.04	.07	.06	
C	85 - 95	-	6					.36	.31	.10	.41	.77	.07	.13	.11	
Denbigh England Andic Dystrochrept																
AB	0 - 7	10.7	27		2.59			2.89	.31	1.26	1.57	4.43	.06	.16	.12	
AB	7 - 15	-	29		3.01			2.09	.61	1.55	2.16	4.25	.07	.15	.09	
B1s	15 - 27	1.9	29		3.29			.98	.66	1.17	1.83	2.81	.06	.10	.06	
B2s	27 - 45	3.3	18		4.41			1.63	.53	.70	1.23	2.86	.07	.16	.12	
C	45 - 65	-	11		1.12			.30	.33	.23	.56	.86	.05	.08	.06	
Dod-Minchmoor England Typic Placaquod																
H	13 - 3	18.5	-		-			4.98	.46	.17	.63	5.61	-	-	-	
AE	3 - 13	8.8	6		-			4.21	.80	.25	1.05	5.26	.18	.88	.84	
B2hs	15 - 23	9.5	4		-			4.82	.58	.26	.84	5.66	.21	1.42	1.35	
B3sx	28 - 38	1.7	8		-			.94	.44	.08	.52	1.46	.07	.18	.17	
C1x	50 - 60	.4	7		-			.21	.23	.02	.25	.46	.04	.07	.06	
C2x	80 - 90	.3	2		-			<.05	.18	.01	.19	.24	.10	.12	.12	
Telegraph England Typic Placaquod																
A	0 - 13	7.2	2		.19			1.68	.08	.05	.13	1.81	.07	.91	.88	
E1a	13 - 30	.3	5		.15			.34	.04	.03	.07	.41	.01	.08	.08	
B1h	30 - 41	1.0	10		.09			.51	.06	.10	.16	.67	.02	.07	.06	
B3s	46 - 64	.4	9		.52			.31	.08	.24	.32	.63	.04	.07	.04	
B3s	64 - 80	-	9		.76			.29	.08	.11	.19	.48	.02	.05	.04	
C	80 -127	-	5		.80			.20	.05	.02	.07	.27	.01	.05	.05	
Holden England Alfic Sideraquod																
Ea	0 - 10	1.9	1		-			-	-	-	-	-	-	-	-	
B1h	10 - 14	5.5	15		3.02			2.27	.21	.07	.28	2.55	.02	.17	.17	
IIBtg	18 - 50	.2	38		-			-	-	-	-	-	-	-	-	

Atomic Ratios												Reference
C_p/			C_t/									
Al_p	Fe_p	Ses_p	Al_d	Fe_d	Ses_d	Al_o	Fe_o	Ses_o	Al_p	Fe_p	Ses_p	
Insch	England		Typic Cryochrept									
4.8	36.2	4.3							18.2	137	16.1	Ragg and Clayden, 1973
2.9	54.9	2.7							6.1	116	5.8	
1.5	18.7	1.4							-	-	-	
7.4	51.3	6.5							-	-	-	
13.5	35.0	9.7							-	-	-	
Linhope	England		Dystric Cryochrept									
9.9	42.9	8.0							22.0	95.7	17.9	
15.2	8.2	5.3							26.8	14.5	9.4	
3.2	2.7	1.5							5.8	4.8	2.6	
2.7	12.7	2.2							5.4	25.5	4.5	
Dunsford	England		Typic Fragiochrept									
20.3	13.9	8.3							71.3	48.7	28.9	
4.2	4.6	2.2							10.4	11.5	5.5	
3.6	3.8	1.8							-	-	-	
.8	2.8	.7							-	-	-	
Tarves	England		Typic Fragiochrept									
13.4	43.4	10.2							34.5	112	26.4	
3.9	22.2	3.3							7.7	43.9	6.5	
1.6	13.2	1.4							-	-	-	
2.1	9.9	1.7							-	-	-	
2.6	16.8	2.3							-	-	-	
Denbigh	England		Andic Dystrochrept									
20.7	10.6	7.0							77.7	39.6	26.2	
7.7	6.3	3.5							-	-	-	
3.3	3.9	1.8							6.5	7.6	3.5	
6.9	10.9	4.2							14.0	22.0	8.6	
2.0	6.1	1.5							-	-	-	
Dod-Minchmoor		England		Typic Placaquod								
24.4	136.7	20.7							90.5	508	76.8	
11.8	78.6	10.3							24.8	164	21.5	
18.7	86.5	15.4							36.9	171	30.3	
4.8	54.8	4.4							8.7	99.2	8.0	
2.1	49.0	2.0							3.9	93.3	3.8	
.6	23.3	0.6							3.8	140	3.7	
Telegraph		England	Typic Placaquod									
47.3	157	36.3							203	672	156	
19.1	52.9	14.0							16.9	46.7	12.4	
19.1	23.8	10.6							37.5	46.7	20.8	
8.7	6.0	3.6							11.3	7.8	4.6	
8.2	12.3	4.9							-	-	-	
9.0	46.7	7.5							-	-	-	
Holden	England		Alfic Sideraquod									
-	-	-							-	-	-	
24.3	151	21.0							58.9	367	50.8	
-	-	-							-	-	-	

Appendix 5 (ctd). Selected chemical data from literature and carbon/sesquioxide atomic ratios

			clay	Amorphous Matter Extractions							Pyrophosphate Extract					
Hori-zon	Depth (cm)	C_t %	c %	Al_d %	Fe_d %	Al_o %	Fe_o %	C_p %	Al_p %	Fe_p %	Ses	AM	Ses ÷ clay	AM ÷ clay	Al+C ÷ clay	Ses_p ÷ clay
Minchmoor	England	Haplic Cryohumod														
H	8 - 0	52.4	-		-			-	-	-	-	-	-	-	-	
AE	1 - 9	5.7	12		.11			1.42	.16	.03	.19	1.61	.02	.13	.13	
B1h	10 - 15	8.7	10		.52			4.13	.48	.06	.54	4.67	.05	.47	.46	
B2s	23 - 28	2.9	14		3.11			1.65	.97	.95	1.92	3.57	.14	.26	.19	
C	58 - 75	.6	18		1.59			.34	.32	.12	.44	.78	.02	.04	.04	
Merrick	England	(Cryic) Fragiohumod														
H	10 - 2	13.3	-		-			-	-	-	-	-	-	-	-	
A	5 - 13	21.0	-		.99			10.72	.46	.66	1.22	11.84	-	-	-	
Bh	13 - 23	11.7	6		1.19			6.12	.79	.81	1.60	7.72	.27	1.29	1.15	
BC	43 - 53	1.9	11		.53			.94	.39	.11	.50	1.44	.05	.13	.12	
IICx	60 - 70	.5	12		.56			.05	.28	.01	.29	.34	.02	.03	.03	
Shirrel Heath	England	Ferrudalfic Haplohumod														
A	0 - 13	5.2	6		-			-	-	-	-	-	-	-	-	
E1a	13 - 25	-	5		-			-	-	-	-	-	-	-	-	
E2a	30 - 40	-	5		-			.31	.03	.05	.08	.39	.02	.08	.07	
B1h	58 - 74	1.4	10		.21			.61	.10	.08	.18	.79	.02	.08	.07	
B2hs	74 - 84	1.7	7		1.40			1.18	.19	.68	.87	2.05	.12	.29	.20	
BC	97 -107	.6	10		1.05			.40	.19	.35	.54	.94	.05	.09	.06	
Moretonhampstead	England	Typic Fragiorthod														
A	0 - 10	12.0	12		1.24			2.69	.25	.53	.78	3.47	.07	.29	.25	
ABh	10 - 20	5.3	10		1.47			1.95	.46	.75	1.21	3.16	.12	.32	.24	
Bs	20 - 40	1.6	5		1.35			.92	.40	.12	.52	1.44	.10	.29	.26	
Cx	40 -100	-	4					.33	.34	.06	.40	.73	.10	.18	.17	
Countesswells	England	Typic Fragiorthod														
Ap	5 - 15	6.6	13		.87			4.10	.47	1.31	1.78	5.88	.14	.45	.35	
Bs	23 - 30	3.2	14		1.26			3.05	.72	.55	1.27	4.32	.09	.31	.27	
Bx	33 - 43	-	15		1.44			.60	.25	.17	.42	1.02	.03	.07	.06	
Bx	53 - 63	-	17		1.10			.39	.10	.04	.14	.53	.01	.03	.03	
C	70 - 80	-	15		1.13			.71	.05	.04	.09	.80	.01	.05	.05	
Foudland	England	Cryic Fragiorthod														
H	4 - 0															
A	0 - 6	11.7	7		.64			3.8	.28	.10	.38	4.18	.05	.60	.58	
B1hs	6 - 9	9.0	7		2.77			4.69	.74	.60	1.34	6.03	.19	.86	.78	
B2s	14 - 24	3.6	9		2.32			2.74	.90	.59	1.49	4.23	.17	.47	.40	
B3x	40 - 50	1.3	7		1.01			.75	.42	.08	.50	1.25	.07	.18	.17	
C	80 - 90	.4	4		.94			1.0	.19	.05	.24	1.24	.06	.31	.30	
C	110 -118	.2	6		.91			.12	.13	.04	.17	.29	.03	.05	.04	
Merrick	England	Cryic Fragiorthod														
H	5 - 0	16.0														
A	0 - 18	7.5	7		2.6			4.0	.83	1.34	2.17	6.17	.31	.88	.69	
Bh	20 - 30	9.9	6		3.31			7.39	.89	3.07	3.96	11.35	.66	1.89	1.38	
IICx	50 - 60	.6	14		.92			.52	.23	.36	.59	1.11	.04	.08	.05	
Crannymoor	England	Typic Haplorthod														
A	0 - 20	7.1	3													
Ea	20 - 33	.8	2		.21			.34	.05	.02	.07	.41	.04	.21	.20	
B1h	33 - 40	2.5	10		.49			1.73	.28	.29	.57	2.30	.06	.23	.20	
B2hs	40 - 65	1.6	13		.77			1.21	.31	.57	.88	2.09	.07	.16	.12	
BC	65 - 75	4	5		.28			.37	.18	.10	.18	.65	.06	.13	.11	

Atomic Ratios												
C_p/			C_t/									Reference
Al_p	Fe_p	Ses_p	Al_d	Fe_d	Ses_d	Al_o	Fe_o	Ses_o	Al_p	Fe_p	Ses_p	
Minchmoor England Haplic Cryohumod												
-	-	-							-	-	-	Ragg and Clayden, 1973
20.0	221	18.3							80.2	887	73.5	
19.4	321	18.3							40.8	677	38.5	
3.8	8.1	2.6							6.7	14.2	4.6	
2.4	13.2	2.0							4.2	23.3	3.6	
Merrick England (Cryic) Fragiohumod												
-	-	-							-	-	-	
52.4	75.8	31.0							103	149	60.7	
17.4	35.3	11.7							33.3	67.4	22.3	
5.4	39.9	4.8							11.0	80.6	9.6	
0.4	23.3	0.4							4.0	233	3.9	
Shirrel Heath England Ferrudalfic Haplohumod												
-	-	-							-	-	-	
-	-	-							-	-	-	
23.3	28.9	12.9							-	-	-	
13.7	35.6	9.9							31.5	81.7	22.7	
14.0	8.1	5.1							20.1	11.7	7.4	
4.7	5.3	2.5							7.1	8.0	3.8	
Moretonhampstead England Typic Fragiorthod												
24.2	23.7	12.0							108	106	53.4	
9.5	12.1	5.3							25.9	33.0	14.5	
5.2	35.8	4.5							9.0	62.2	7.9	
2.2	25.7	2.0							-	-	-	
Countesswells England Typic Fragiorthod												
19.6	14.6	8.4							31.6	23.5	13.5	
9.5	25.9	7.0							10.0	27.2	7.3	
5.4	16.5	4.1							-	-	-	
8.8	45.5	7.4							-	-	-	
32.0	82.8	23.1							-	-	-	
Foudland England Cryic Fragiorthod												
30.5	177.3	26.1							94.0	546.0	80.2	
14.3	36.5	10.3							27.4	70.0	19.7	
6.9	21.7	5.2							9.0	28.5	6.8	
4.0	43.7	3.7							7.0	75.8	6.4	
11.8	93.3	10.5							4.7	37.3	4.2	
2.1	14.0	1.8							3.5	23.3	3.0	
Merrick England Cryic Fragiorthod												
10.8	13.9	6.1							20.3	26.1	11.4	
18.7	11.2	7.0							25.0	15.0	9.4	
5.1	6.7	2.9							5.4	7.1	3.4	
Crannymoor England Typic Haplorthod												
15.3	79.3	12.8							36.0	186.7	30.2	
13.9	27.8	9.3							20.1	40.2	13.4	
8.8	9.9	4.7							11.6	13.1	6.2	
4.6	17.3	3.6							5.0	18.7	3.9	

Appendix 5 (ctd). Selected chemical data from literature and carbon/sesquioxide atomic ratios

			clay	Amorphous Matter Extractions							Pyrophosphate Extract					
													Ses ÷	AM ÷	Al+C ÷	Ses_p ÷
Horizon	Depth (cm)	C_t %	c %	Al_d %	Fe_d %	Al_o %	Fe_o %	C_p %	Al_p %	Fe_p %	Ses	AM	clay	clay	clay	clay
Crannymoor	England	Typic Haplorthod														
A	10 - 15	12.8	16		-			-	-	-	-	-	-	-	-	
Ea	28 - 35	.6	4		-			-	-	-	-	-	-	-	-	
B1h	35 - 43	.7	6		.13			.65	.05	.07	.12	.77	.02	.13	.12	
B2h	45 - 50	1.1	8		.14			1.47	.11	.07	.18	1.65	.02	.21	.20	
B3h	55 - 60	.7	6		.16			.88	.11	.07	.18	1.06	.03	.18	.17	
B4	64 - 70	.6	4		.17			.41	.08	.07	.15	.56	.04	.14	.12	
C1g	73 - 75	6.5	10		-			-	-	-	-	-	-	-	-	
C2g	84 - 90	.7	4		-			-	-	-	-	-	-	-	-	
C3g	102 -117	.4	5		-			-	-	-	-	-	-	-	-	
Manod	England	Brown Podzolic														
Ah	0 - 4	15.2	30	.05	1.89	.72	3.55	2.04	.26	1.16	1.42	3.46	.05	.12		.73
A/B	4 - 15	5.2	31	.53	6.50	.40	3.55	1.65	.50	1.39	1.89	3.54	.06	.11		.27
Bs1	15 - 29	2.2	25	1.59	6.92	.49	3.89	.87	.45	1.14	1.59	2.46	.06	.10		.19
Bs2	29 - 47	1.8	17	2.28	7.69	.47	4.63	.70	.43	.89	1.32	2.02	.08	.12		.13
Bs3	47 - 70	1.8	14	2.33	5.17	1.58	3.35	.81	.46	.68	1.14	1.95	.08	.14		.15
BC	70 - 87	1.2	10	1.75	3.50	3.50	2.50	.38	.28	.18	.46	.84	.05	.08		.09
Dartington	England	Brown Podzolic														
Ah	0 - 5	6.7	36	.42	6.08	.74	3.03	2.44	.38	1.28	1.66	4.10	.05	.11		.26
Bs1	5 - 18	2.1	39	.85	6.50	.78	2.82	1.01	.67	1.38	2.05	3.06	.05	.08		.28
Bs2	18 - 38	1.2	34	1.01	6.29	1.17	2.82	.72	.65	1.11	1.76	2.48	.05	.07		.24
Bs3	38 - 51	1.1	21	1.06	5.45	1.01	2.72	.63	.47	.73	1.20	1.83	.06	.09		.18
BC	51 - 64	1.0	9	.69	4.97	.91	1.60	.25	.20	.19	.39	.64	.04	.07		.07
Moretonhampstead	England	Brown Podzolic														
Ah	0 - 12	12.5	19	.16	1.26	.22	.65	3.45	.34	.52	.86	4.31	.05	.23		.61
Ah/Bh	12 - 20	6.7	14	.58	4.76	.77	3.58	2.91	.39	.80	1.19	4.10	.09	.29		.22
Bs1	20 - 32	3.7	14	1.69	7.13	2.26	5.10	2.40	.57	1.04	1.61	4.01	.12	.29		.18
Bs2	32 - 85	1.4	12	2.01	4.34	2.92	2.40	1.02	.45	.37	.82	1.84	.07	.15		.13
Bowden	England	Brown Podzolic														
Ah	0 - 25	5.4	29	1.96	5.10	1.72	2.51	2.13	.85	.56	1.41	3.54	.05	.12		.20
Bs	25 - 38	1.9	19	2.06	4.62	3.10	2.03	1.01	.78	.50	1.28	2.29	.08	.12		.19
BC	38 - 76	.9	16	1.38	3.36	2.46	1.30	.37	.34	.14	.48	.85	.03	.05		.10
P1	Canada	Podzol humo-ferrique orthique														
H	15 - 0	50.0						2.84	.20	.04	.24	3.08	-	-	-	-
Ae	0 - 5	.6	3	.03	.04	.03	.02	.3	.02	.02	.04	.35	.01	.12	.11	.57
Bfh	5 - 10	4.6	5	1.99	2.25	2.64	2.09	3.11	1.36	.92	2.28	5.39	.46	1.08	.89	.54
Bf	10 - 20	1.8	8	.83	.93	2.07	1.80	.95	.37	.10	.47	1.42	.06	.18	.17	.27
BC	20 - 50	.6	4	.32	.22	.73	.22	.51	.14	.05	.19	.70	.05	.18	.16	.35
C	50+	.3	5	.20	.21	.31	.21	.21	.07	.03	.10	.31	.02	.06	.06	.24
P2	Canada	Podzol ferro-humique orthique														
H	2.5- 0	48.2						4.18	.15	.11	.26	4.44	-	-	-	-
Ae	0 - 5	.9	6	.02	.08	.02	.31	.30	.01	.02	.03	.33	.01	.06	.05	.30
Bhf	5 - 10	9.4	7	1.71	3.68	1.65	3.74	6.75	1.63	3.15	4.78	11.53	.68	1.65	1.20	.89
Bf1	10 - 41	1.7	10	1.23	1.29	1.54	1.55	1.22	.72	.43	1.15	2.37	.12	.24	.19	.46
Bf2	41 - 66	1.3	6	1.01	1.18	1.23	1.50	1.08	.64	.37	1.02	2.10	.17	.35	.29	.47
Cx	66+	.4	5	.36	.62	.48	1.00	.23	.11	.04	.15	.38	.03	.08	.07	.15
P3	Canada	Podzol ferro-humique orthique														
H	2.5- 0	51.4						3.52	.10	.03	.13	3.65	-	-	-	-
Ae	0 - 6	.6	2	.02	.10	.03	.40	.23	.01	.09	.10	.33	.05	.17	.12	.83
Bhf1	6 - 10	18.3	9	1.86	6.35	1.84	6.50	12.41	1.77	5.45	7.22	19.63	.80	2.18	1.58	.88
Bhf2	10 - 15	13.9	9	3.26	5.22	2.45	4.83	9.60	2.39	3.66	6.05	15.65	.67	1.74	1.33	.71
Bhf3	15 - 20	11.8	8	3.43	3.74	4.82	4.60	8.76	3.39	2.80	6.19	14.95	.77	1.87	1.52	.86
Bfh	20 - 41	5.7	9	2.20	2.03	2.33	2.75	3.56	2.12	1.22	3.34	6.90	.37	.77	.63	.79
IIC	41+	.7	2	.50	.79	.57	1.58	.48	.26	.15	.41	.89	.21	.35	.37	.32

Atomic Ratios												
C_p/			C_t/									Reference
Al_p	Fe_p	Ses_p	Al_d	Fe_d	Ses_d	Al_o	Fe_o	Ses_o	Al_p	Fe_p	Ses_p	
Crannymoor	England	Typic Haplorthod										
-	-	-							-	-	-	Ragg and
-	-	-							-	-	-	Clayden, 1973
29.3	43.3	17.5							31.5	46.7	18.8	
30.1	98.0	23.0							22.5	73.3	17.2	
18.0	58.7	13.8							14.3	46.7	11.0	
11.5	27.3	8.1							16.9	40.0	11.9	
-	-	-							-	-	-	
-	-	-							-	-	-	
-	-	-							-	-	-	
Manod	England	Brown Podzolic										
17.7	8.2	5.6	64.6	37.5	35.5				131.5	62.3	41.7	Loveland and
7.4	5.5	3.2	22.1	3.7	3.2				23.4	17.5	10.0	Bullock, 1975
4.4	3.6	2.0	9.9	1.5	1.3				11.0	9.0	4.95	
3.7	3.7	1.8	1.8	1.1	0.7				9.4	9.4	4.7	X
4.0	5.6	2.3	1.7	1.6	0.8				8.8	12.4	5.1	
3.1	9.9	2.3	1.5	1.6	0.8				9.6	31.1	7.4	
Dartington	England	Brown Podzolic										
14.4	8.9	5.5	35.6	5.1	4.5				39.7	24.4	15.1	Analyses
3.4	3.4	1.7	5.6	1.5	1.2				7.1	7.1	3.5	
2.5	3.0	1.4	2.7	.9	.7				4.2	5.0	2.3	[illegible]
3.0	4.0	1.7	2.3	.9	.7				5.3	7.0	3.0	
2.8	6.1	1.9	3.3	.9	.7				11.3	24.0	7.7	
Moretonhampstead	England	Brown Podzolic										mixed
22.8	31.0	13.1	177.1	46.3	36.7				82.7	112.2	47.6	
16.8	17.0	8.4	25.9	6.6	5.2				38.7	39.1	19.9	
9.5	10.8	5.0	4.9	2.4	1.6				19.6	16.6	7.8	
5.1	12.9	3.7	1.6	1.5	.8				7.0	17.7	5.0	
Bowden	England	Brown Podzolic										
5.6	17.8	4.3	6.2	4.9	2.7				14.3	45.0	10.8	
2.9	9.4	2.2	2.1	1.9	1.0				5.5	17.7	4.2	
2.4	12.3	2.0	1.5	1.3	.7				6.0	30.0	5.0	
P1	Canada	Podzol humo-ferrique orthique										
32.0	33.1	29.1	-	-	-	-	-	-	563	5833	513	Hubert and
34.9	72.3	23.5	45.0	70.0	27.4	45.0	140	34.1	67.5	140	45.5	Gonzalez, 1970
5.1	15.8	3.9	5.2	9.5	3.4	3.9	10.3	2.8	7.6	23.3	5.7	
5.8	44.3	5.1	4.9	9.0	3.2	2.0	10.5	1.6	10.9	84.0	9.7	
8.2	47.6	7.0	4.2	12.7	3.2	1.8	12.7	1.6	9.6	56.0	8.2	
6.7	32.7	5.6	3.4	6.7	2.2	2.2	6.7	1.6	9.6	46.7	8.0	
P2	Canada	Podzol ferro-humique orthique										
62.7	177	46.3	-	-	-	-	-	-	723	2045	534	
67.5	70.0	34.4	101	52.5	34.6	101	13.5	11.9	202	210	103	
9.3	10.0	4.8	12.4	11.9	6.1	12.8	11.7	6.1	13.0	13.9	6.7	
3.8	13.2	3.0	3.1	6.1	2.1	2.5	5.1	1.7	5.3	18.4	4.1	
3.7	13.6	2.9	2.9	5.1	1.9	2.4	4.0	1.5	4.5	16.4	3.5	
4.7	26.8	4.0	2.5	3.0	1.4	1.9	1.9	0.9	8.2	46.7	7.0	
P3	Canada	Podzol ferro-humique orthique										
79.2	548	69.2	-	-	-	-	-	-	1157	8000	1010	
51.8	11.9	9.7	67.5	28.0	19.8	45.0	7.0	6.1	135	31.1	25.3	
15.8	10.6	6.3	22.1	13.4	8.4	22.4	13.1	8.3	23.3	15.7	9.4	
9.0	12.2	5.2	9.6	12.4	5.4	12.8	13.4	6.5	13.1	17.7	7.5	
5.8	14.6	4.2	7.7	14.7	5.1	5.5	12.0	3.8	7.8	19.7	5.6	
3.8	13.6	3.0	5.8	13.1	4.0	5.5	9.7	3.5	6.0	21.8	4.7	
4.2	14.9	3.2	3.2	4.1	1.8	2.8	2.1	1.2	6.1	21.8	4.7	

Appendix 5 (ctd). Selected chemical data from literature and carbon/sesquioxide atomic ratios

			clay	Amorphous Matter Extractions							Pyrophosphate Extract					
Horizon	Depth (cm)	C_t %	c %	Al_d %	Fe_d %	Al_o %	Fe_o %	C_p %	Al_p %	Fe_p %	Ses	AM	Ses ÷ clay	AM ÷ clay	Al+C ÷ clay	Ses_p ÷ clay
P4	Canada	Podzol humo-ferrique minimal														
H	1.3- 0	17.2						2.72	.09	.14	.23	2.95	-	-	-	-
Ae	0 - 1.3	1.9	13	.08	.74	.11	.55	.52	.05	.44	.49	1.01	.04	.08	.04	.60
Bhf	1.3- 5	6.4	19	.74	3.80	.77	2.08	3.53	.66	2.79	3.45	6.98	.18	.37	.22	.76
Bfhl	5 - 25	4.3	21	.96	3.29	1.02	3.00	2.57	.83	2.36	3.19	5.76	.15	.27	.16	.75
Bfhj	25 - 46	3.4	21	1.06	2.33	1.05	1.66	2.23	1.01	1.38	2.39	4.62	.11	.22	.15	.71
Cx	46+	1.9	19	1.12	1.55	1.02	.91	1.30	.82	.50	1.32	2.62	.07	.14	.11	.49
Leon	United States	Aeric Haplaquod														
A1	0 - 18	5.4	1.3	.03	<.01	.03	<.01	1.6	.02	<.01	.02	1.62	.02	1.25	1.25	.67
A21	18 - 25	.4	.8	tr	<.01	tr	<.01	tr	tr	<.01	0	0	0	0	0	-
A22	25 - 41	.2	1.1	tr	<.01	tr	<.01	tr	tr	<.01	0	0	0	0	0	-
B21h	41 - 48	1.4	3.6	.15	<.01	.16	<.01	.9	.10	<.01	.10	1.00	.03	.28	.28	.67
B22h	48 - 56	1.1	3.8	.12	<.01	.14	<.01	1.0	.12	<.01	.12	1.12	.03	.30	.30	1.0
Leon	United States	Aeric Haplaquod														
A1	0 - 15	1.5	1.0	.01	<.01	.01	<.01	.3	tr	<.01	0	.3	0	.3	.3	-
A21	15 - 36	.1	1.0	tr	<.01	tr	<.01	.1	tr	<.01	0	.1	0	.1	.1	-
A22	36 - 43	.2	1.1	tr	<.01	tr	<.01	.2	tr	<.01	0	.2	0	.18	.18	-
B21h	43 - 51	.8	3.3	.06	<.01	.07	<.01	.7	.08	<.01	.08	.78	.02	.24	.24	1.67
B22h	51 - 81	1.5	2.8	.11	<.01	.11	<.01	1.3	.14	<.01	.14	1.44	.05	.51	.51	1.27
Leon	United States	Aeric Haplaquod														
A1	0 - 10	1.0	1.0	.01	<.01	tr	<.01	.4	tr	<.01	0	.4	0	.4	.4	-
A21	10 - 23	.3	1.0	.01	<.01	tr	<.01	tr	tr	<.01	0	0	0	0	0	-
A22	23 - 53	.1	1.2	tr	<.01	tr	<.01	tr	tr	<.01	0	0	0	0	0	-
B21h	53 - 61	1.0	1.6	.04	<.01	.07	<.01	.5	.03	<.01	.03	.53	.02	.33	.33	.75
B22h	61 - 68	.8	3.8	.23	<.01	.19	<.01	.4	.16	<.01	.16	.56	.04	.15	.15	.70
	United States	Humic Haplorthod														
A2	0 - 5	1.5	3.1		.17			.63	.01	.20	.21	.84	.07	.27	.21	
B21h	5 - 9	-	7.0		-			4.36	.18	1.24	1.42	5.78	.20	.83	.65	
B22ir	9 - 15	5.8	4.8		2.73			4.20	.42	1.52	1.94	6.14	.40	1.28	.96	
B22ir	15 - 20	8.6	3.8		1.77			5.66	1.18	1.52	2.70	8.36	.71	2.20	1.80	
B22ir	20 - 25	8.0	3.7		1.48			5.45	1.11	1.48	2.59	8.04	.70	2.17	1.77	
B22ir	25 - 30	6.2	1.6		1.47			4.95	1.05	1.42	2.47	7.42	1.54	4.64	3.75	
B22ir	30 - 36	5.7	2.4		1.20			4.20	1.11	1.04	2.15	6.35	.90	2.65	2.21	
B22ir	36 - 38	5.1	2.1		1.11			3.44	.82	1.02	1.84	5.28	.88	2.51	2.03	
B23	38 - 43	3.9	1.7		1.00			3.15	.82	.90	1.72	4.87	1.01	2.86	2.34	
	United States	Typic Sideraquod														
A2	0 - 5	.1	1.2		.02			.21	.01	.02	.03	.24	.03	.20	.18	
B21h	5 - 10	2.1	1.9		.22			2.44	.05	.24	.29	2.73	.10	.94	.86	
B22ir	10 - 17	2.4	2.5		1.32			1.89	.18	1.10	1.28	3.17	.51	1.27	.83	
B22ir	17 - 19	2.4	2.1		.88			1.60	.28	.80	1.08	2.68	.51	1.28	.90	
B22ir	19 - 24	1.6	2.1		.53			1.26	.29	.52	.81	2.07	.39	.99	.74	
B22ir	24 - 29	1.2	2.4		.47			.76	.19	.58	.77	1.53	.32	.64	.40	
B23	29 - 35	.5	tr		.27			.21	.02	.24	.26	.47	-	-	-	
	United States	(Cryic) Fragihumod														
A2	0 - 4	1.5	2.8		.11			.63	.89	.14	1.03	1.66	.37	.59	.54	
B21h	4 - 10	8.9	6.2		2.30			5.46	1.11	1.28	2.39	7.85	.39	1.27	1.06	
B22h	10 - 15	8.1	5.7		2.10			6.02	.45	1.34	1.79	7.81	.31	1.37	1.14	
B22h	15 - 20	9.4	4.5		1.86			6.42	1.60	.94	2.54	8.96	.56	1.99	1.78	
B22h	20 - 25	6.4	6.8		1.43			5.46	1.05	1.22	2.27	7.73	.33	1.14	.96	
B22h	25 - 30	7.3	7.2		.95			4.95	.02	.92	.94	5.89	.13	.82	.69	
B22h	30 - 36	6.3	5.2		.68			4.75	.28	.72	1.00	5.75	.19	1.11	.97	
B22h	36 - 41	4.9	5.7		.65			3.99	1.11	.60	1.71	5.70	.34	1.12	1.00	
B22h	41 - 46	4.4	4.5		.56			3.99	1.00	.52	1.52	5.51	.34	1.22	1.11	
B22h	46 - 48	4.9	4.0		.51			3.70	1.18	.58	1.76	5.46	.44	1.37	1.22	
IIA'2x	48 - 53	2.3	3.0		.30			1.68	.58	.44	1.02	2.70	.34	.90	.75	

Atomic Ratios												Reference
C_p/			C_t/									
Al_p	Fe_p	Ses_p	Al_d	Fe_d	Ses_d	Al_o	Fe_o	Ses_o	Al_p	Fe_p	Ses_p	
P4	Canada	Podzol humo-ferrique minimal										
68.0	90.7	38.9	-	-	-	-	-	-	430	573	246	Hubert and Gonzalez, 1970
23.4	5.5	4.5	53.4	12.0	9.8	38.9	16.1	11.4	85.5	20.2	16.3	
12.0	5.9	4.0	19.5	7.9	5.6	18.7	9.7	6.4	21.8	10.7	7.2	
7.0	5.1	2.9	10.1	6.1	3.8	9.5	6.7	3.9	11.7	8.5	4.9	
5.0	7.5	3.0	7.2	6.8	3.5	7.3	9.6	4.1	7.6	11.5	4.6	
3.6	12.1	2.8	3.8	5.7	2.3	4.2	9.7	2.9	5.2	17.7	4.0	
Leon	United States	Aeric Haplaquod										
180.0			405.0			405.0			607.5			Brandon et al., 1977
-			-			-			-			
-			-			-			-			
20.2			21.0			19.7			31.5			
18.8			20.6			17.7			20.6			
Leon	United States	Aeric Haplaquod										
-			337.5			337.5			-			
-			-			-			-			
-			-			-			-			
19.7			30.0			25.7			22.5			
20.9			42.2			42.2			24.1			
Leon	United States	Aeric Haplaquod										
-			225.0			-			-			
-			67.5			-			-			
-			-			-			-			
37.5			56.2			32.1			75.0			
5.6			7.8			9.5			11.2			
	United States	Humic Haplorthod										
142	14.7	13.3							337	35.0	31.7	Coen and Arnold, 1972
54.5	16.4	12.6										
22.5	12.9	8.2							31.1	17.8	11.3	
10.8	17.4	6.7							16.4	26.4	10.1	
11.1	17.2	6.7							16.2	25.2	9.9	
10.6	16.3	6.4							13.3	20.4	8.0	
8.5	18.9	5.9							11.6	25.6	7.9	
9.4	15.7	5.9							14.0	23.3	8.8	
8.6	16.3	5.7							10.7	20.2	7.0	
	United States	Typic Sideraquod										
47.3	49.0	24.1							22.5	23.3	11.5	
109	47.4	33.1							94.5	40.8	28.5	
23.6	8.0	6.0							30.0	10.2	7.6	
12.9	9.3	5.4							19.3	14.0	8.1	
9.8	11.3	5.2							12.4	14.4	6.7	
9.0	6.1	3.6							14.2	9.7	5.8	
23.6	4.1	3.5							56.3	9.7	8.3	
	United States	(Cryic)Fragihumod										
1.6	21.0	1.5							3.8	50.0	3.5	
11.1	19.9	7.1							18.0	32.5	11.6	
30.1	20.9	12.4							40.5	28.2	16.6	
9.0	31.9	7.04							13.2	46.7	10.3	
11.7	20.9	7.5							13.7	24.5	8.8	
557	25.1	24.0							821	37.0	35.4	
38.2	30.8	17.0							50.6	40.8	22.6	
8.1	31.0	6.4							9.9	38.1	7.9	
9.0	35.8	7.2							9.9	39.5	7.9	
7.1	29.8	5.7							9.3	39.4	7.6	
6.5	17.8	4.8							8.9	24.4	6.5	

Appendix 5 (ctd). Selected chemical data from literature and carbon/sesquioxide atomic ratios

			Clay	Amorphous Matter Extractions							Pyrophosphate Extract					
Hori-zon	Depth (cm)	C_t %	c %	Al_d %	Fe_d %	Al_o %	Fe_o %	C_p %	Al_p %	Fe_p %	Ses	AM	Ses ÷ clay	AM ÷ clay	Al+C ÷ clay	Ses_p ÷ clay
United States Typic Haplaquod																
A1	0 - 18	4.0	2	.04	0			.20	tr	tr	0	.20	0	.10		-
A2	18 - 38	.6	1	.02	0			.20	tr	tr	0	.20	0	.20		-
B21h	38 - 50	1.0	1	.02	0			.33	tr	tr	0	.33	0	.33		-
B22h	50 - 77	1.5	3	.16	0			1.20	.10	tr	.10	1.30	.03	.43		.62
B22h	77 - 90	1.3	5	.12	0			.74	.10	tr	.10	.84	.02	.17		.85
B22h	90 -114	1.4	7	.21	0			.80	.30	tr	.30	1.10	.04	.16		.70
B22h	114 -147	1.5	6	.22	0			.89	.20	tr	.20	1.09	.03	.18		.91
B22h	147 -220	1.5	5	.18	0			.84	.20	tr	.20	1.04	.04	.21		1.11
B22h	220 -260	1.3	6	.18	0			.76	.10	tr	.10	.86	.02	.14		.56
B22h	260 -286	.5	2	.06	0			.37	tr	tr	0	.37	0	.19		-
B22h	286 -306	.3	1	.04	0			.18	.10	tr	.10	.28	.10	.28		2.50
B23h	306 -359	1.8	2	.23	0			1.39	.30	tr	.30	1.69	.15	.85		1.30
B24h	359 -396	2.5	1	.36	0			2.16	.50	tr	.50	2.66	.50	2.66		1.39
B24h	396 -426	2.5	1	.42	0			2.29	.50	tr	.50	2.79	.50	2.79		1.19
B24h	426 -457	2.5	1	.30	0			1.92	.50	tr	.50	2.42	.50	2.42		1.67
B24h	457 -487	1.9	1	.28	0			1.74	.30	tr	.30	2.04	.30	2.04		1.01
B25h	487 -518	2.0	1	.22	0			1.37	.30	tr	.30	1.67	.30	1.67		1.36
B25h	518 -548	1.5	1	.22	0			1.14	.30	tr	.30	1.44	.30	1.44		1.36
B25h	548 -579	1.7	1	.23	0			1.57	.30	tr	.30	1.87	.30	1.87		1.30
B26h	579 -609	1.7	1	.26	0			1.51	.30	tr	.30	1.81	.30	1.81		1.15
B26h	609 -640	1.0	1	.14	0			.77	.30	tr	.30	1.07	.30	1.07		2.14
B26h	640 -670	1.1	1	.16	0			.71	.30	tr	.30	1.01	.30	1.01		1.88
B26h	670 -701	.9	2	.14	0			.85	.30	tr	.30	1.15	.15	1.15		2.14
C1	701 -731	.3	.4	.06	0			.15	.10	tr	.10	.25	.25	.25		1.67
C1	731 -762	.6	1	.26	0			.54	.10	tr	.10	.64	.10	.64		.38
IIC2	762 -1006	.4	4	.12	0			.09	.30	tr	.30	.39	.08	.39		2.50
United States Cryandept																
A2	0 - 11	2.4	30	.1	.2			.8	.1	.1	.2	1.0	.01	.03	.03	.7
IIB2hir	11 - 31	6.9	20	1.6	.7			5.4	1.9	.7	2.6	8.0	.13	.40	.36	1.1
IIIB31	31 - 53	9.7	28	2.9	1.0			6.4	3.2	.7	3.9	10.3	.14	.37	.34	1.0
IVB32	53 -100	18.3	49	5.3	2.1			8.4	3.3	.2	4.5	11.9	.09	.24	.24	.6
United States Aeric Haplaquod																
A1	0 - 8	1.1	.5	0	tr				tr	tr						
A2	8 - 41	.03	.4	0	tr				tr	tr						
A3	41 - 43	1.1	2.7	.06	.1				tr	tr						
B21h	43 - 46	2.5	1.7	.54	.1			2.20	.91	tr	.91	3.11	.54	1.83	1.83	1.42
B22h	46 - 51	1.0	2.2	.34	tr			.93	.51	tr	.51	1.44	.23	.65	.65	1.50
B3	51 - 69	.1	1.7	.05	tr				tr	tr						
C1	69 - 99	.02	.7	.02	tr				tr	tr						
IIC2	99 -110	.1	4.7	.07	.1				.10	tr						
76 Belgium Typic Haplaquod																
B21h	10 - 20	1.44	1.3	.18	.004			1.09	.18	.004	.18	1.27	.14	1.00	.98	1.00
B22h	20 - 40	.97	.8	.18	.004			.85	.18	.004	.18	1.03	.22	1.29	1.29	1.00
B3h	40 - 75	.61	1.3	.19	.027			.58	.20	.010	.21	.79	.16	.61	.60	.95
78 Belgium Aquic Haplohumod																
B21h	5 - 10	1.79	1.8	.12	.07			1.25	.12	.015	.14	1.39	.08	.77	.76	.74
B22h	10 - 20	1.74	1.5	.44	.09			1.39	.44	.04	.48	1.87	.32	1.25	1.22	.91
B31h	20 - 35	.71	1.8	.35	.12			.58	.33	.06	.39	.97	.22	.54	.51	.83
B32h	45 - 80	.91	1.3	.29	.03			.75	.24	.02	.26	1.01	.20	.78	.76	.81
74 Belgium Aquic Haplohumod																
B21h	14 - 24	2.06	2.1	.24	.02			1.44	.24	.02	.26	1.70	.12	.06	.80	1.00
B22h	24 - 45	1.09	1.2	.30	.04			.95	.32	.02	.34	1.39	.28	1.08	1.06	1.00
B3h	45 - 60	.31	1.0	.12	.07			.26	.13	.05	.18	.44	.18	.44	.39	.95
Cg	60+															
75 Belgium Typic Placohumod																
B21h	10 - 15	2.39	1.0	.29	.04			1.74	.30	.03	.33	2.07	.33	2.07	2.04	1.00
Placic		1.58		.40	3.98			1.07	.27	1.39	1.66	2.73	-	-	-	.38
B22hir	15 - 25	.35	1.5	.12	.14			.29	.11	.06	.17	.46	.11	.31	.27	.65
B22ir		.36	2.1	.24	.76			.19	.12	.10	.22	.41	.10	.20	.15	.22

Atomic Ratios												
C_p/			C_t/									Reference
Al_p	Fe_p	Ses_p	Al_d	Fe_d	Ses_d	Al_o	Fe_o	Ses_o	Al_p	Fe_p	Ses_p	
United States Typic Haplaquod												
-			225.0						-			Holzhey et al., 1975
-			67.5						-			
-			112.5						-			
27.0			21.1						33.8			
16.6			24.4						29.2			
6.0			15.0						10.5			
10.0			15.3						16.9			
9.4			18.8						16.9			
17.1			16.2						29.2			
-			18.8						-			
4.1			16.9						6.8			
10.4			17.6						13.5			
9.7			15.6						11.2			
10.3			13.4						11.2			
8.6			18.8						11.2			
13.1			15.3						14.2			
10.3			20.5						15.0			
8.6			15.3						11.2			
11.8			16.6						17.4			
11.3			14.7						12.8			
5.6			16.1						7.5			
5.3			15.5						8.2			
6.4			14.5						6.8			
3.4			11.2						6.8			
12.2			5.2						13.5			
.7			7.5						3.0			
United States Cryandept												
18.0	37.3	12.1	54.0	56.0	27.5				54.0	112.0	36.4	Singer et al., 1978
6.4	36.0	5.4	9.7	46.0	8.0				8.2	46.0	6.9	
4.5	42.7	4.1	7.5	45.3	6.5				6.8	64.7	6.2	
5.7	196.0	5.6	7.8	40.7	6.5				12.5	427.0	12.0	
United States Aeric Haplaquod												Soil Survey Staff, 1975
			41.2	51.3	22.9				6.2	-	6.2	
5.4	-	5.4	10.4	116.7	9.6				4.9	-	4.9	
4.1	-	4.1	7.3									
			4.5									
			2.2									
			3.2	4.7	1.9				2.2			
76 Belgium Typic Haplaquod												
14.0	1271.	13.9	18.0	1680.	17.8				18.5	1680.	18.3	Higashi et al., 1981
10.6	992.	10.4	12.1	1132.	12.0				12.1	1132.	11.9	
6.5	270.	6.3	7.2	105.	6.7				6.8	285.	6.6	
78 Belgium Aquic Haplohumod												
23.4	389.	22.1	33.6	119.	26.2				33.6	557.	31.6	
7.1	162.	6.8	8.9	90.	8.1				8.9	203.	8.5	
3.9	46.	3.6	4.6	27.	3.9				4.8	56.	4.4	
7.1	206.	6.9	7.1	142.	6.7				8.6	250.	8.3	
74 Belgium Aquic Haplohumod												
13.6	395.	13.1	19.3	481.	18.6				19.3	565.	18.7	
6.6	202.	6.4	8.2	127.	7.7				7.6	231.	7.3	
4.6	24.8	3.9	5.8	20.7	4.6				5.5	29.6	4.6	
75 Belgium Typic Placohumod												
13.1	271.	12.5	18.6	279.	17.4				18.0	372.	17.2	
8.9	3.6	2.6	8.9	1.8	1.5				11.6	1.6	1.4	
5.9	21.8	4.6	6.6	11.7	4.2				7.1	26.	5.6	
3.8	7.1	2.5	3.4	2.2	1.3				6.6	16.	4.6	

APPENDIX 6. DETERMINATION OF CARBON IN SOILS AND SOIL EXTRACTS[1]

A.J.M. van Oostrum[2] and D.L. Mokma[3]

The content of carbon in soils may be determined by either dry or wet combustion. In both methods soil C is converted to CO_2. The amount of evolved CO_2 is estimated by direct methods as measuring the volume of CO_2 or as weighing the CO_2 adsorbed on a solid or by back titration of excess hydroxide after absorption in aqueous or non-aqueous alkaline medium. The dry combustion method has long been regarded as the most accurate method for determining C in soils but the apparatus is expensive.

Different mixtures of $K_2Cr_2O_7$ and H_2SO_4 and later with H_3PO_4 have been used in wet combustion methods. Rapid methods are mostly based on wet combustion in which excess oxidant is determined for estimation of organic C. These methods do not give complete oxidation of all forms of organic matter and therefore require a conversion factor. The use of a factor may introduce an error as organic matter in different soils and in different horizons of the same profile is not always oxidized to the same degree. These methods are also affected by the presence of readily oxidizable substances other than C in the soil.

When directly measuring the evolved CO_2, a purifying train is used to remove the co-evolved gases, such as SO_2. Allison (1960) used powdered $K_2Cr_2O_7$ and a 3 : 2 mixture of H_2SO_4 and H_3PO_4 and a simplified purifying train to determine soil C, including C from calcareous and saline soils. Later, Anderson and Harris (1967) dissolved the $K_2Cr_2O_7$ in the H_2SO_4-H_3PO_4 mixture. Although several researchers have proposed modifications, Allison's method has been generally accepted as being the most reliable.

Evolved CO_2 can be absorbed quantitatively according to the reaction $CO_2 + 2OH^- + Ba^{2+} \rightarrow BaCO_3 \downarrow + H_2O$. Both the amount of consumed OH^- and the amount of $BaCO_3$ formed are a measure of the amount of C. The amount of $BaCO_3$ formed was determined by measuring the pH after dissolving the precipitate with EDTA (Begheijn, 1976). The amount of OH^- consumed is determined

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[1] The appendix 6 is a preliminary account of the work done on the determination of carbon undertaken for the research on podzols, but applicable under non-podzol conditions as well. The finalization of the paper is awaiting the results of further study on one of the three described methods. However, in its present form the paper is considered as a useful complement to the main paper and has therefore been attached.

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by back titration of excess hydroxide (Duursma, 1961; Römer, 1975; Sixta, 1977). Duursma (1961) and Sixta (1977) titrated the solution using a continuous coulometric technique whereas Römer (1975) titrated with NaOH using an automatic titrator reacting on the lowering of the pH as CO_2 is absorbed in the $Ba(OH)_2$, pH 10.2 solution. These titrimetric methods have low detection limits and are easy to perform.

To determine organic C in calcareous soils the carbonates must be determined separately or destroyed before combustion of the sample. Various acids have been used successfully in the determination of inorganic C in soils and rocks. To determine inorganic C Allison (1960) used H_2SO_4 to which $FeSO_4$ had been added to prevent oxidation of organic matter. Nömmik (1971) used hot, meta-phosphoric acid to remove inorganic C from soils before determining organic C. Sixta (1977) used hot H_3PO_4 to determine carbonates in rocks and found it superior to dilute H_2SO_4 in releasing inorganic C because dilute H_2SO_4 has slight oxidizing properties and oxidizes some of the organic C in samples containing organic matter.

To determine organic C in soil extracts, Allison (1960) recommended the extract be evaporated to dryness and then handled in a similar way as a soil sample. However, evaporation to dryness may cause a loss of C. Shaw (1959) determined organic C in plant extracts without evaporating to dryness. He doubled the quantities of $K_2Cr_2O_7$ and H_2SO_4-H_3PO_4 mixture when the volume of extract being analyzed was greater than 6 ml. Duursma (1961) used his wet combustion method to determine organic C in sea water.

The objective of this study was to develop simple, accurate and rapid methods to determine organic C in soils and soil extracts and inorganic C in soils and rocks. The organic C method is based on the wet combustion method of Allison (1960) while the inorganic C method is based on the H_3PO_4 combustion of Sixta (1977). In both methods the evolved CO_2 is measured using the sensitive detection method of Römer (1975).

Methods

Apparatus

The apparatus is shown in figure 1, the components being as follows: A, flow valve (Rotaflo TF/13); B, absorption tower filled with ascarite (sodium hydroxide-coated asbestos), 4-8 mesh; C, 250-ml Drechsel gas washing bottle filled with water, serving as bubble counter; D, 50-ml separating funnel (R.B. Radley FSO/50); E, Liebig condensor, 20 cm long (Quickfit C1/13) with Drechsel bottle head (joints NS 29), the inflow tube was cut off and a 2-ml graduated pipette, connected with rubber tubing, was added so the bottom of the pipette was 2 cm above the bottom of the digestion tube; F, digestion tube (Duran 50 glass), 11.5 cm long and 30 mm outside diameter, with joint NS 29; G, microscale gas burner, preferably shielded (Monastere); H, threeway

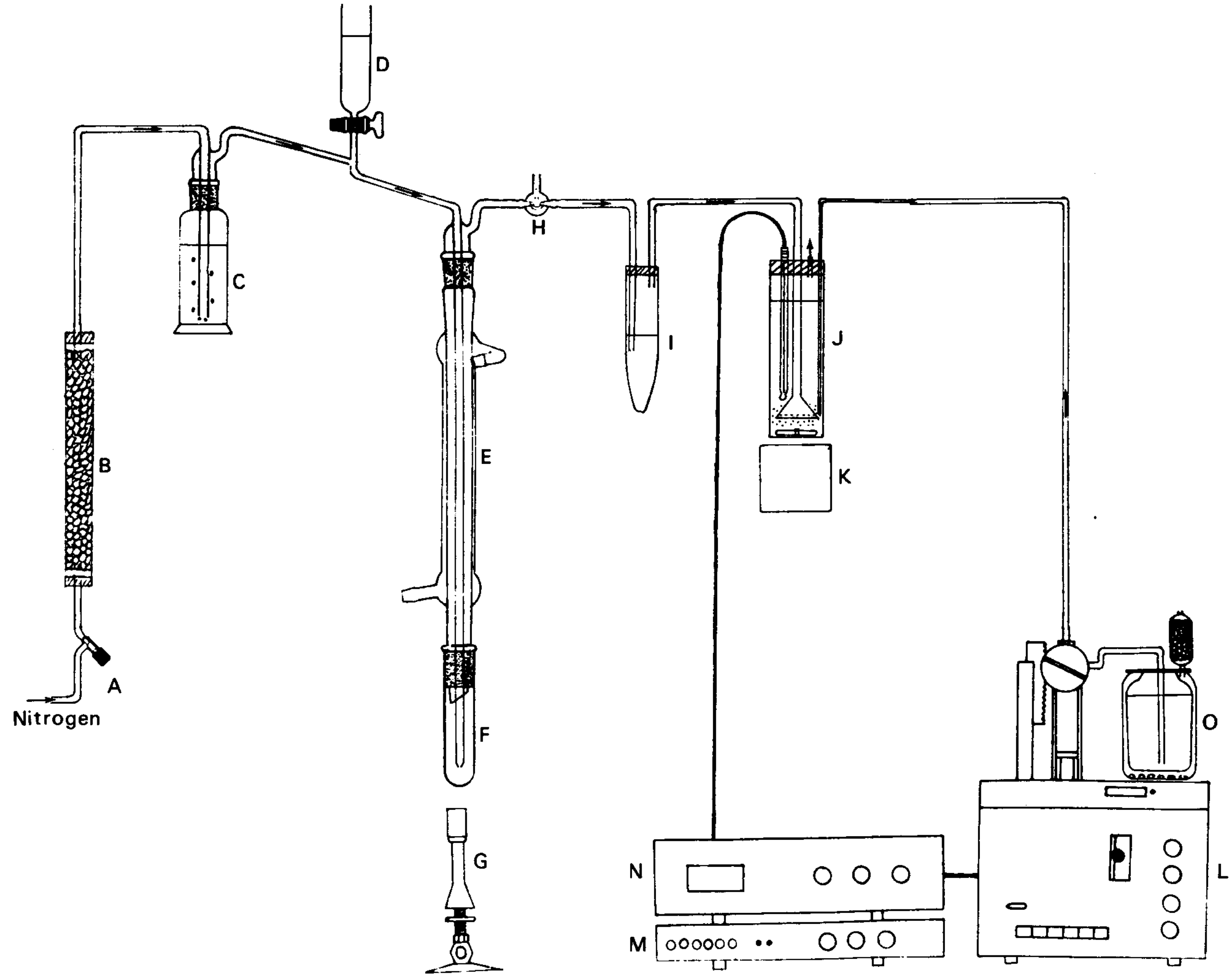

Figure 1. Apparatus for determination of carbon in soils and soil extracts

stopcock, plain (Vestale); I, 100-ml test tube filled with about 20 ml of concentrated H_2SO_4 (95-97%), inflow tube made from a 5 ml pipette extended 1.5 cm into the acid; J, absorption chamber of plexiglass, 16 cm high and 5 cm inside diameter, closed by rubber stopper with a fritted-glass gas dispersion tube in the center (35 mm in diameter, 20 cm long, porosity P2, no lip on rim), a delivery tip (Radiometer D 4346) for the titrant and an electrode; K, magnetic stirrer (TOYO MS-16B) with 35 mm stirring bar coated with PTFE in the absorption chamber; L, Autoburette (Radiometer ABU 13e) with 2.500-ml burette assembly (Radiometer B 220) with maximum speed set at 0.250 ml/min.; M, titrator (Radiometer TTT 60c); N, pH meter (Radiometer PHM 64b, research pH meter) with combined electrode, internal reference electrode systems saturated Ag/AgCl (Radiometer GK 2402C); O, titrant reservoir, 500-ml plastic bottle stored in glass botter with a tube filled with ascarite on the air inlet. Connections between glass components should be made with polyethylene tubing and kept to a minimal length. For routine analyses a second set of components A through H were mounted adjacent to the first set. While one analysis was being made, the CO_2 can be flushed from the other half of the system.

Reagents

Digestion mixture A. Dissolve 10.00 g $K_2Cr_2O_7$, reagent grade, powdered in a mixture of 120 ml H_2SO_4 (95-97%) and 80 ml of H_3PO_4 (85%) with heating. Do not allow temperature to exceed 125°C.

Digestion mixture B. Dissolve 10.00 g $K_2Cr_2O_7$, reagent grade, powdered in 120 ml H_2SO_4 (95-97%) with heating. Do not allow temperature to exceed 125°C.

Absorption solution. Dissolve 122.14 g $BaCl_2.2H_2O$ in about 800 ml of water, add 100 ml tertiary butyl alcohol (99%) and dilute to 1 l.

Titrant. Add an analytical concentrate from an ampoule (Baker) containing 0.4 mol NaOH to about 800 ml of CO_2-free water according to the directions provided with the ampoule, add 100 ml tertiary butyl alcohol (99% and dilute to 1 l with CO_2-free water.

Procedure

Total C in non-calcareous soil. Weigh 25 to 300 mg of finely ground soil into a digestion tube and record weight to nearest 0.1 mg. Add 1.0 ml water. Put tube on distillation column. Begin flow of N_2 gas at rate of 6-8 bubbles/sec to remove CO_2 with stopcock (H) open to atmosphere. Add 5 ml of digestion mixture A with 5-ml graduated cylinder to 50-ml separating funnel (D). When system is free of CO_2, stop H_2 flow and add digestion mixture A to digestion tube by opening stopcock on separating funnel (D). Begin heating and change stopcock (H) so CO_2 will enter absorption chamber. Bring digestion mixture to boiling in 3 to 4 minutes with a 1-cm flame, 1 cm below bottom of digestion tube. Begin timing with stopwatch. Adjust N_2 flow rate to 2 - 3 bubbles/sec. Heat for 10 min. Remove flame and increase N_2 flow to 6 - 8 bubbles/sec. Record the total amount of titrant added after each minute beginning with 11th minute. When the amount of titrant is 0.001 ml/min the absorption of CO_2 from the digestion of the sample is considered complete. Close stopcock H so air cannot enter the absorption chamber. Wash system including the inside of the lower part of the distillation column with water. Place the next soil sample in a digestion tube on the distillation column and begin flushing.

Each day a new precipitate must be formed. This should be done prior to the determination of a soil sample with a small amount of material containing C. At the same time the pH of the absorption solution is raised to pH 10.208 to insure absorption of CO_2. To test whether all components of the system were functioning properly, a chemical of known C content was run first each day. A blank was also run each day.

If a large amount of CO_2 is produced, the pH may go below 9.0. Before this happens reduce N_2 flow with flow valve (A), it may be necessary to stop the flow. If not much CO_2 is being produced the flow may be increased before the end of heating.

Inorganic C in calcareous soil. Weigh 25 to 300 mg of powdered soil in a digestion tube and record weight to nearest 0.1 mg. Add 1.0 ml water. Put tube on distillation column. To determine inorganic C add 2 ml H_3PO_4 (85%) with 5 ml graduated cylinder through separating funnel to sample without flushing. Set flow of N_2 at 2 - 3 bubbles per second. Heat for 7 minutes with a 1-cm flame 1 cm below bottom of digestion tube. Remove flame and increase flow of N_2 to 6 - 8 bubbles per second. Record the total amount of titrant added after each minute beginning with the 11th minute. When the amount of titrant added is 0.001 ml/min. the absorption of CO_2 from the digestion of the sample is complete.

Total C in soil extracts. Soil samples were extracted with 0.5N NaOH (Schnitzer et al., 1958; Schnitzer and Skinner, 1968; Chen et al., 1978) and 0.1M $Na_4P_2O_7$ (USDA, 1972). Add 1.0 ml of extract to digestion tube. No water is added. Repeat procedure for total C in non-calcareous soils. For a blank 1.0 ml of the extractant was used. To test the system 1.0 ml of extractant was added to the chemicals.

Testing materials

To test the procedure ascorbic acid, benzoic acid, potassium hydrogenphthalate, and calcium carbonate were mixed with sand to give C contents similar to those found in soils. The procedure for organic C was then applied to four soils (Table 1).

Table 1. Classification of soils according to the FAO-Unesco Legend (FAO, 1974) and Soil Taxonomy (Soil Survey Staff, 1975)

Soil Profile	FAO-Unesco	Soil Taxonomy
NL-102	Gleyic Podzol	Aeric Haplaquod
NL-106	Dystric Regosol	Spodic Udipsamment
B-103	Gleyic Podzol	Aeric Haplaquod
USA-1	Orthic Podzol	Typic Haplorthod

Results and Discussion

The reagent-grade chemicals used to test the method were completely oxidized (Table 2). Complete oxidation was achieved regardless of sample size, 50 to 150 mg. The reproducibility of the method is very good with a standard deviation of 0.02% for the chemicals and 0.04% for the soil sample.

The recovery of calcium carbonate in the inorganic carbon determination was also very good. The calculated carbon content was 1.20%. The measured carbon content was 1.20% with a standard deviation of 0.01% for five determinations.

The addition of 1 ml of sodium pyrophosphate or sodium hydroxide to the chemicals had no interference in the determination of C in the chemicals (Table 3). Neither the mean nor the standard deviations are significantly different.

The methods were used to determine total carbon (C_t) and carbon in sodium pyrophosphate (C_p) and sodium hydroxide (C_h) extracts of samples from four soil profiles (Table 4). C_p and C_h were lower or not significantly different from C_t. In the Ah and E horizons C_h was greater than or not significantly different from C. In the B and C horizons C_p and C_h were similar.

Conclusions

The methods described for determining organic C in soils and soil extracts and inorganic C in soils and rocks give complete combustion of the C and very accurate measurement of the evolved CO_2. The apparatus is built from readily available laboratory equipment or easily constructed parts. The apparatus and procedure are simple to operate and perform. A skilled analyst can complete up to 30 analyses in one day.

The determination of inorganic carbon with H_3PO_4 in soil samples needs further study and will be reported upon in a later publication.

Table 2. Carbon content of organic materials.

Material	Weight of Sample mg	Carbon Content Measured* %	Carbon Content Calculated %
Ascorbic Acid	50 - 70	1.01 ± 0.02	1.00
	70 - 90	1.00 ± 0.03	
	90 - 110	1.00 ± 0.02	
	> 110	1.00 ± 0.02	
	all samples	1.00 ± 0.02 (22)	
Benzoic Acid	50 - 70	1.19 ± 0.01	1.19
	70 - 90	1.19 ± 0.02	
	90 - 110	1.18 ± 0.03	
	all samples	1.18 ± 0.02 (18)	
Potassium Hydrogenphthalate	50 - 70	1.17 ± 0.03	1.16
	70 - 90	1.16 ± 0.02	
	90 - 110	1.16 ± 0.01	
	all samples	1.16 ± 0.02 (21)	
Becket B21ir Horizon	50 - 70	1.90 ± 0.02	
	70 - 90	1.92 ± 0.05	
	90 - 110	1.88 ± 0.01	
	all samples	1.90 ± 0.04 (15)	

* Mean and standard deviation. Number in parenthesis is number of determinations.

Table 3. Carbon content of chemicals with 1 ml H_2O (C_t), 1 ml 0.1M $Na_4P_2O_7$ (C_p) and 1 ml 0.5N NaOH (C_h).

Material	Determination	Carbon Content Measured* %	Calculated %
Ascorbic Acid	C_t	1.00 ± 0.03	1.00
	C_p	1.01 ± 0.01	
	C_h	1.00 ± 0.03	
Benzoic Acid	C_t	1.19 ± 0.02	1.19
	C_p	1.18 ± 0.02	
	C_h	1.19 ± 0.03	
Potassium Hydrogenphthalate	C_t	1.16 ± 0.01	1.16
	C_p	1.17 ± 0.03	
	C_h	1.16 ± 0.02	
Becket B21 ir Horizon	C_t	1.90 ± 0.04	
	C_p	1.22 ± 0.06	
	C_h	1.39 ± 0.11	

* Mean and standard deviation.

Table 4. Total carbon (C_t) and carbon in sodium pyrophosphate (C_p) and sodium hydroxide (C_h) extracts of soils.

			Carbon Content		
Profile	Horizon	Depth	C_t	C_p	C_h
		cm	%	%	%
NL-102	E1	0- 19	.82	.39	.47
	E2	19- 39	.35	.23	.25
	Bh	39- 44	.82	.62	.72
	BC1	44- 89	.44	.43	.47
	BC2	89-150	.32	.27	.31
NL-106	Ah1	0- 6	6.02	1.98	2.45
	Ah2	6- 11	2.98	.88	1.68
	E	11- 22	.86	.19	.39
	Bhs1	22- 29	2.20	1.60	1.49
	Bhs2	29- 35	2.11	1.66	1.55
	2BC	35- 45	.55	.42	.35
	2Cg	45- 65	.19	.11	.14
B-103	Ahb	23- 30	3.40	1.99	2.09
	Eb	30- 58	.18	.19	.13
	EBb	58- 85	.26	.36	.24
	Bh1b	85-103	.87	.82	.75
	Bh2b	103-125	.86	.79	.81
	Bh3b	125-155	.74	.76	.70
	Bhmb	155-170	1.54	1.47	1.44
USA-1	E	0- 23	.27	.02	.13
	Bh	23- 32	1.44	1.04	.89
	Bhs	32- 50	1.41	1.25	1.10
	BC	50- 88	.92	.86	.79
	C	88-130	.07	.03	.04

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APPENDIX 7. NOTE ON THE PLATE: "PODZOLS AND RELATED SOILS"

A large number of soils used in this study have been selected for representation on a colour plate on podzols and related soils. This plate is published as a seperate sheet. In some cases the classification of the soil profiles on the plate does not correspond with the classification given in this paper. This concerns soils with distinct podzol morphology, which could be classified as podzols on the basis of the presence of cracked coatings or dark pellets- (micro)morphologic criteria for spodic horizon - but they do not meet the chemical criteria. In the context of this publication such soils are not classified as podzols in order to stress the discrepancies between chemical and morphological criteria. However, on the plate they are placed with the podzols, notably the profiles IRL-1, F-10, NL-106, SER-10, S-16, SF-4 and SK-3.

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