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MINERALOGICAL COMPOSITION OF SHALLOW SOILS ON BASIC AND ULTRABASIC ROCKS OF EAST FENNOSCANDIA AND OF THE URAL MOUNTAINS, RUSSIA

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Abstract—The influence of epigenetic (pre-pedogenetic) alteration of basic and ultrabasic rocks leading to the formation of phyllosilicate mineral associations is not well known. The purpose of this study was to gain further understanding of the processes involved by investigating the mineral associations of shallow soils underlain by amphibolites and metamorphosed gabbro-diabases (East Fennoscandia) and by serpentinous dunites (olivinite) and metagabbro amphibolites (the Ural Mountains). Where phyllosilicates were absent from the bedrock, they were also absent from the sola. The pedogenic alteration of the initial mineral soil matrix was very weak and did not result in a significant accumulation of phyllosilicates in the soils (East Fennoscandia). Pedogenesis enhanced the transformation of phyllosilicates, a process initiated by epigenic rock alteration.

Phyllosilicates in the sola from basic and ultrabasic rocks of the Polar Urals were largely inherited according to their origin. The inherited phyllosilicate association of the sola from ultrabasic rocks included talc, serpentine, and chlorite. Saponite resulted from pedogenesis; its distribution in various thin soils depending on the processes of neoformation and decomposition, the latter probably taking place under the influence of lichens and moss.

Chlorite and illite and products of their transformation, including vermiculite, comprise the phyllosilicate association of a solum from basic rock, and traces of talc were found. The distribution of vermiculite and randomly interstratified chlorite-vermiculite (C-V) depended on the processes of chlorite vermiculitization and vermiculite decomposition.

Key Words—Basic and Ultrabasic Rocks, Mineral Transformation, Pedogenesis, X-ray Diffraction.

INTRODUCTION

The processes of weathering basic and ultrabasic rocks have been studied extensively (Fitzpatrick, 1963; Basham, 1974; Ducloux *et al*., 1976; Smith *et al*., 1987; Schirrmeister and Störr, 1994; Banfield *et al*., 1995) and mineral associations in soils derived from these substrates have been described widely (Wildman *et al*., 1968; Alexander, 1988; Bonifacio *et al*., 1996; Caillaud *et al*., 2004). The influence of epigene rock alteration (pre-pedogenesis) on phyllosilicate associations of fine earth and developed sola is not well known, however. In some cases, rock alteration as well as time and the climatic conditions affected the mineral association in a solum. The aim of the present work was to investigate the mineral associations of soils derived from and underlain by basic or ultrabasic rocks and to assess the relative importance of pedogenesis and inheritance from the 'fresh' or 'pedogenetically altered' parent rocks.

MATERIALS

The materials studied were recent sola underlain by basic or ultrabasic rocks located in East Fennoscandia (Kola Peninsula and Republic of Karelia) and the Polar Urals, Russia. The sola studied are examples of Holocene soil formation in a cold, humid climate without the influence of a previous pedogenetic stage which was erased by glacial activity. Some characteristics of the samples studied are listed (Table 1).

East Fennoscandia

Basic rocks have a limited local distribution. Other than 'soils' consisting of plant litter lying on solid rock, shallow soils also are formed from the fine earth of basic substrates. These mineral soils were not admixed with morainic material and constituted a rare example of soil formation in this area. Deep accumulation of fine earth did not take place.

In the northern taiga of the Kola Peninsula, to the south of the Khibini Mountains, tectonic blocks of basic composition were formed from amphibolites. The blocks are up to 5 m tall and ~10 m wide. Fine earth has accumulated in the micro-lows and small cavities in the rock to a thickness of up to 10 cm, forming acid, sandy, loamy soils (sample Pit X-05-3: A-Bw-R). In the middle taiga zone of the Karelia Republic ('Kivach' Reserve), outcrops of hard rocks occupy larger areas, consisting of metamorphosed gabbro-diabases which form local residual ridges (selgas). An accumulation of fine earth derived from these rocks was found in fissures and cavities as in the case of weathered amphibolites, forming acid, loamy soils (sample Pit K-04-04: A-Bhs-R).

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Table 1. Some characteristics of the objects

Pit index (bold), horizon sequence (letters), depth (cm, in parentheses)	Substrate	GPS coordinates	Climate characteristics Mean annual Temperature (ºC)	Precipitation (mm)	Natural environment	Soil name WRB[1]	Soil taxonomy[2]
East Fennoscandia							
X-05-3: A (0−2)-Bw (2−6)-R	Amphibolites	67º32′38.9″N 33º46′04.8″E	+1.5	800	Northern Taiga	Lithic Leptosol	Lithic Dystrudept
K-04-04: A (0−3)-Bhs (3−6)-R	Metamorphosed gabbro-diabases	62º15′09.8″N 33º57′16.6″E	+2.4	619	Middle Taiga	Epileptic Entic Podzol	Entic Lithic Haplorthod
The Ural Mountains							
Y-02-07: O (3−0)-Ah (0−4)-Bg (4−15)-Bgf (15−30)-R		66º52′03.3″N 65º19′33.6″E				Haplic Cryosols (Reductaquic)	Lithic Aquiturbels
Y-03-07: Bg (0−10)-Bgf (10−20)-R	Serpentinous dunites (olivinite)						
Y-01-07: A (0−2)-C1 (2−10)-C2 (10−52)-C3 (52−70)		66º51′00.5″N 65º40′55.8″E	−9.0	800	Mountainous tundra	Haplic Regosol (Eutric)	Typic Udorthent
Y-04-07: Ah (0−2)-Bwh (2−10)-BC (10−40)-BCg (40−60)-R		66º49′40.9″N 65º31′04.4″E				Stagnic Leptosol (Eutric)	Spodic Dystrudept
Y-05-07: O1 (2−0)-O2 (0−3)-Bw (3−5)−Bhs (5−10)−Bs (10−24)-BC (24−30)-R	Meta-gabbro amphibolites	66º48′31.2″N 65º46′20.1″E	−7.0	450	Northern Taiga	Epileptic Entic Podzols	Entic Lithic Haplorthod

[1] World Reference Base for Soil Resources (2006)
[2] Soil Survey Staff (2006)

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The Ural Mountains, ultrabasic rocks

Ultrabasic rocks of a dunite–harzburgite complex (ophiolite association) make up the Rai-Iz massif. Ophiolites are characterized by a combination of ultrabasic and basic complexes. The basic rocks are outwith the Rai-Iz massif. Sola from the ultrabasic rocks of this complex were studied. The key plot (200 m $\times$ 100 m) was located in the mountainous tundra of the Polar Urals, on a flat summit at an altitude of 664 m. The rock consists of serpentinous dunites, and medium-sized blocky detritus of this rock covers the surface. In some areas, circular permafrost polygons from stones (diameter of ~1 m) were found. Fine earth, olive in color (due to gleyzation), accumulated upon blocks of rock which behaved as aquifuges. The permafrost was at a depth of 30 cm. Angular, easily crushed stones and gravels make up 60–70% of the total volume in the solum. The crushed stone and gravel from the sola is ochreous-brown in color, in contrast to the yellowish color of the large blocks. The solum is loamy and neutral; and clayey loamy and alkaline in the basal horizon (sample Pit Y-02-07: O–Ah–Bg–Bgf-R). The surface of polygonal circles is covered by crushed stone and the underlying soil horizons were strongly differentiated by their color. A solum (sample Pit Y-03-07: Bg–Bgf-R) has a loam clay texture and alkaline pH (8.8–7.8).

The second key plot is at an altitude of 300 m and is situated on the southern slope of the Rai-Iz massif. The slope is angled at ~20º. The surface is covered by colluvial blocks of serpentinous dunites. Fine earth has accumulated as a result of redistributed weathering products and is weakly involved in the soil-forming process (sample Pit Y-01-07: A–C1–C2–C3). The solum is loamy, acid in the uppermost (A) horizon and alkaline in deeper ones.

The Ural Mountains, basic rocks

The basic rocks at the Ural Mountains site are represented by meta-gabbro amphibolites and are located outwith the Rai-Iz massif in the Polar Urals. The first key plot is situated in the tundra zone on a moraine ridge at an altitude of 300 m, to the north of Lake Yareity. The moraine ridge consists mostly of meta-gabbro amphibolitic material with scarce admixtures of ultrabasic rocks. Patterned ground occurs on the flat surface due to permafrost. The trench investigated transected the circle of the patterned ground. The solum is neutral–weakly alkaline, has a sandy-loamy and loamy texture (Pit Y-04-07: Ah-Bwh-BC-BCg-R).

The second key plot is located in the northern taiga area, at an altitude of 120 m, on a ridge of meta-gabbro amphibolites stretching along the river Sob. The plot is on the flat summit of a ridge with steep east and gradual west slopes. The fine earth accumulation is a result of local redistribution of meta-gabbro amphibolitic material. The soil is loamy–sandy, loamy, acid (sample Pit Y-05-07: O1–O2–Bw–Bhs–Bs–BC–R).

METHODS

The mineral compositions of the hard rocks were studied in thin section by optical microscopy using Zeiss Axioplan 2 and Polam P-312 microscopes. The mineral associations from the fine size fractions of the soils (<1, 1–5, and 5–10 μm), obtained by sequential sedimentation, were studied. Ammonium hydrate was used as a peptizing agent. Destruction of organic matter with Na-acetate-buffered H_2O_2 as well as the removal of Fe (hydr)oxides by citrate-bicarbonate-dithionite treatment was only necessary for bulk samples of soils derived from basic rocks. The XRD patterns were obtained from oriented specimens using a DRON-2 X-ray diffractometer, with CoKα radiation and a monochromator in the diffracted beam. The diffractometer tube was operated at 32 kV and 20 mA, with a goniometer speed of 4º/min. Pretreatment of samples included saturation with Mg, ethylene glycol solvation, and heating at 350ºC and 550ºC. Treatment with HCl (1 N, boiled for 2 h) was used for soil samples from ultrabasic rocks. A Rigaku-MiniFlex2 diffractometer (CuKα, 30 kV, 15 mA; count time 2.0 s/step, step width 0.04º2θ) was used for powder XRD work (rock samples and sola fine earth). The pH values were measured potentiometrically in the suspension with a soil:H_2O ratio of 1:2.5 (shaking for 2 h).

RESULTS

East Fennoscandia

The amphibolitic rock fragments consisted largely of hornblende and actinolite, sometimes replaced by epidote and chlorite with small aggregated grains of leucoxene and occasional biotite. The quartz grains observed had a predominantly granoblastic texture formed as a result of metamorphic recrystallization processes. Phyllosilicates appeared to be absent from the fine fractions separated from the fine earth.

In the metamorphosed gabbro-diabases, relicts of an ophitic texture represented by idiomorphic laths of plagioclases and monoclinic pyroxenes pointed to an initially basic rock composition. Scarce amygdales with carbonate, epidote, and chlorite (amygdaloidal structures) are results of the metamorphism and epigenetic transformation (Figure 1a,b). Metamorphic processes resulted in the predominance of amphiboles that were partly replaced by chlorite, rare epidote, and biotite, and probably the formation of epigenetic veins of quartz.

The phyllosilicates found in the fine size fractions include chlorite, illite, and randomly interstratified chlorite-vermiculite (smectite) (C-V) and illite-vermiculite (smectite) (I-V) with a small amount of expandable unit structures. Talc and kaolinite occurred in trace

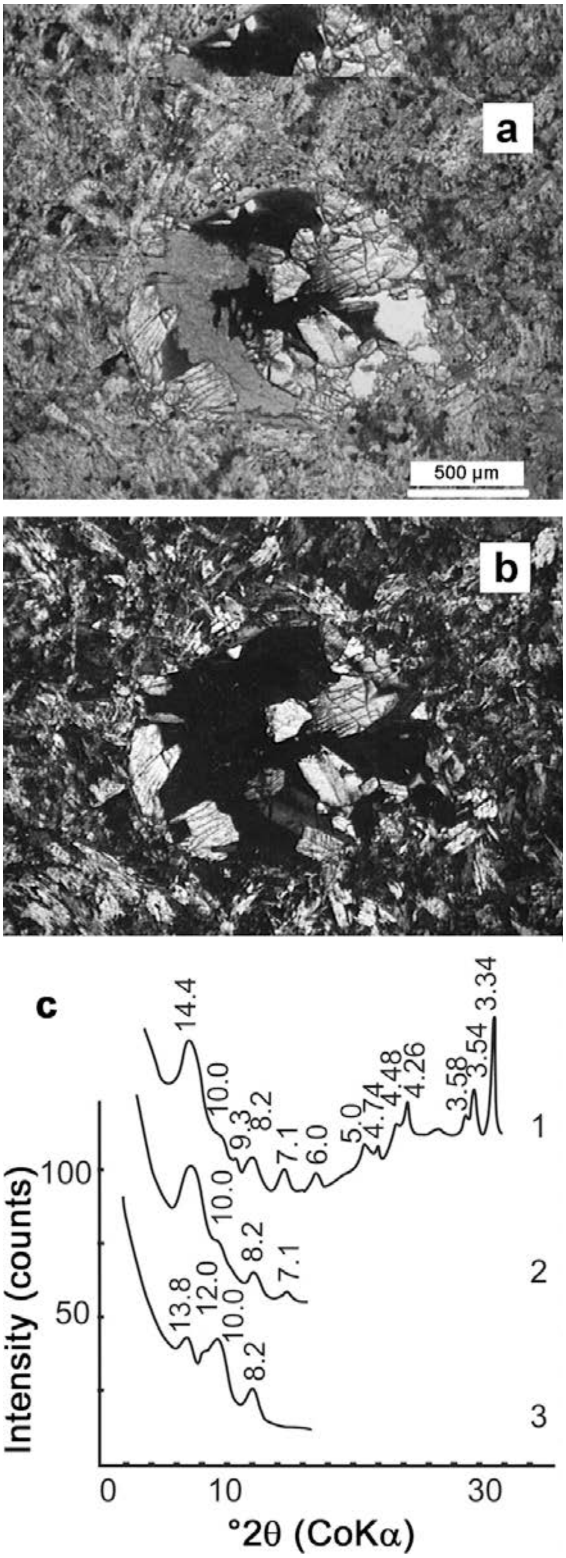

Figure 1. Amygdaloidal structure of metamorphosed gabbro diabases: (a) plain polars; (b) crossed nicols. (c) XRD patterns of the <1 µm fraction of pit K-04-04, Bhz 3–6 cm. 1: Mg-saturated; 2: ethylene glycol solvated; 3: 550ºC.

amounts, and quartz was found in all samples (peaks at 4.26 and 3.34 Å). Peaks with *d* values of 14.2–14.4, 4.74, and 3.54 Å that are stable after ethylene glycol solvation and showing a 001 peak shift to 13.8 Å after heating (550ºC) explicitly indicated the presence of chlorite. Illite was identified by peaks at 10.0 and 5.0 Å which were stable after ethylene glycol solvation and heating at 550ºC. I-V was identified by the characteristic asymmetry of the 10.0 Å peak and C-V by a decrease in intensity of the 13.8 Å peak and the appearance of a peak at 12.0 Å after heating (550ºC). Kaolinite was recognized in the presence of chlorite by a peak at 3.58 Å and talc by peaks at 9.3 and 3.12 Å. The XRD traces from these samples were very weak, suggesting little phyllosilicate content. One of the samples of sola from the metamorphosed gabbro-diabases is shown (Figure 1c).

The Ural Mountains, ultrabasic rocks

Serpentinous dunites preserved the initial structure of the rock. The olivine grains were broken into fragments (Figure 2). The rock is characterized by a reticulate structure with areas of thin laminations. In veins, olivine may be replaced by serpentines, talc, and chlorites. Serpentine is also replaced by magnesian chlorite. Occasional flakes of magnesian micas also occur, often chloritized to a considerable degree. The mineral association of the sola fine earth differed significantly from that of the rock. Quartz, feldspars, and amphiboles occurred in the coarser material of the sola.

In the fine size fractions of all sola (sample Pits Y-01-07, Y-02-07, and Y-03-07), the same associations of phyllosilicates, consisting of smectite, chlorite, serpentine, talc, and illite were represented (Figures 3–5). The smectite in the soils may be due to the alteration of olivine to saponite and/or nontronite (Meunier, 2005). Trioctahedral smectites were formed during the first stages of olivine weathering and subsequently may have been replaced by dioctahedral smectites (nontronite-beidellite) (Wilson, 2004). Thus, both saponite and nontronite might have been expected to occur in the soils studied. Smectite was confirmed by a peak at 14.2 Å, which shifted to 17.1 Å after ethylene glycol solvation and the appearance of a peak at 8.6 Å. On the XRD trace of the samples studied the smectite does not show an intense peak at 8.6 Å after ethylene glycol solvation, which is distinctive of nontronite, but does have a 3.38 Å peak which is more characteristic of saponite (Moore and Reynolds, 1997).

The 14.2 Å peak of chlorite is affected by the presence of saponite and is only discernible from a peak with *d* value of 17.1 Å of saponite only if the smectite content is relatively small. In the XRD patterns of all samples, in addition to the 3.54 Å peak, a reflection at 3.57 Å is also identified, which is stable after ethylene glycol solvation and heat treatment at 350ºC. The intensity of this peak and of that at 3.54 Å decreased after heating at 550ºC, suggesting the

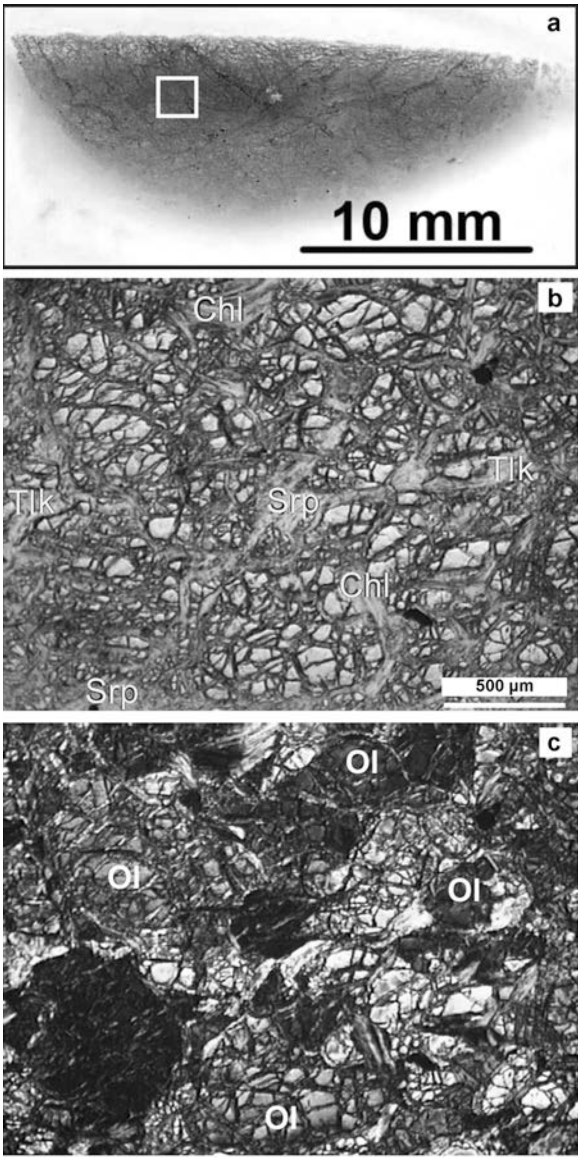

Figure 2. (a) Thin, polished section of serpentinous dunite. The white box indicates the area of study. (b,c) Reticulate structure of olivine grains (Ol), substitution by aggregate veins of serpentine (Srp) by talc (Tlk) and chlorite (Chl). Veins make up a net with relict fragments of olivine grains in loops (b: plain polars; c: crossed nicols).

possibility of two generations of chlorite or a small amount of kaolinite. Unambiguous identification of these minerals in the sola studied was difficult, even after HCl treatment. Serpentine was identified by peaks at 7.24 and 3.64 Å. In the 1–10 µm fractions where the intensities of the peaks were greater, a peak at 4.52 Å could be singled out. These *d* values largely corresponded to antigorite rather than to lizardite or chrysotile (Bailey, 1980). Illite was found in the sola as a minor component.

The Ural Mountains, basic rocks

The original rock of the meta-gabbro amphibolites was probably of basic, volcanic type. Following-high temperature regional metamorphism in the amphibolite facies, all remnants of the initial rock fabric were lost. Pyroxenes were replaced by amphiboles and plagioclase was sericitized. Quartz also crystallized in these rocks, and replaced some of the melanocratic minerals (Figure 6).

In mountainous tundra a mineral association in the <1 µm fraction of the solum on the basic moraine material, containing rare ultrabasic material (Pit Y-04-07), is the same as in sola underlain by ultrabasic rocks. A different mineral association in the fine size fractions occurred in the solum from the basic rocks of the northern taiga (sample Pit Y-05-07) (Figure 7). Those fractions are characterized by chlorite, illite, vermiculite, and irregular interstratified C-V and I-V. Talc was found only in the 1–5 µm and 5–10 µm fractions and not in the <1 µm fraction. In the presence of chlorite and in the absence of smectite, vermiculite was identified due to the 14 Å peak partially shifted to 10 Å after heating at 350ºC. In addition, the intensity of the 13.8 Å peak decreased after heating at 550ºC, indicating a reduction in the chlorite and an increase in the vermiculite contents. C-V occurred mainly in the <1 µm fraction, where the 13.8 Å peak partially shifted to 10 Å. In the 1–5 and 5–10 µm fractions, C-V was identified only in the upper horizons (O2–Bhs); in the deeper horizons, particularly Bs and BC, the 13.8 Å peak was symmetrical, suggesting the absence of C-V. In addition to phyllosilicates, the feldspars, amphiboles, and quartz also occur in the solum.

DISCUSSION

East Fennoscandia

Shallow, acidic soils occur here and were derived from the fine earth of basic rocks without any admixture of acid (granitoid) moraine substrate under the thallus of the lichen (*Cladonia sp.*), a distinctive trap for organic matter which was removed from the plant litter and was absorbed by friable products of weathering in the cracks and fissures formed in the rock. Taking into account the shallow depth of the sola, rock colonization by lichens is possibly implicated in the occurrence of phyllosilicates in the fine size fractions, especially <1 µm. Lichens may biochemically influence the solid rock on which they grow, as was first suggested >60 y ago by Polynov (1945), who studied the changes in granitic gneiss brought about by lithophilous lichens. In the shallow soils studied here, only small amounts of phyllosilicates were found in the solum developed from metamorphosed gabbro-diabases (sample Pit K-04-04) where pre-pedogenesis rock alteration resulted in accumulation of phyllosilicates. The proportion of vermiculitic

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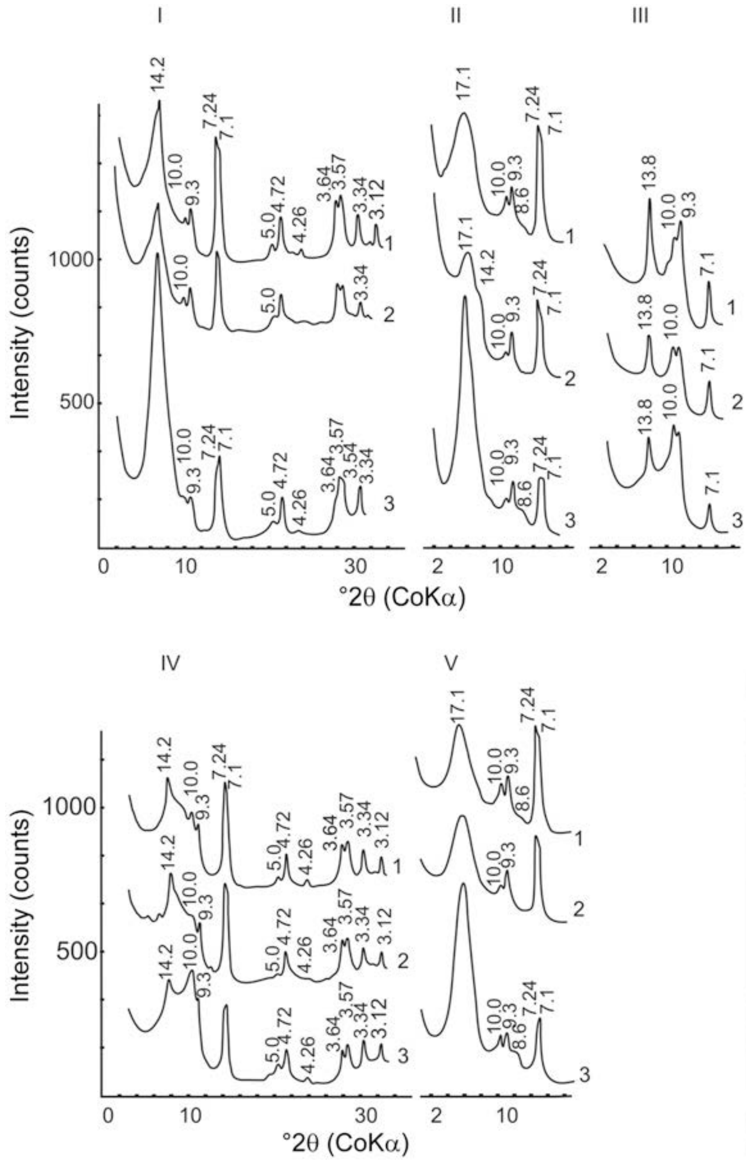

Figure 3. XRD patterns of the <1 μm fraction of Pit Y-02-07: (I) Mg-saturated; (II) ethylene glycol-solvated; (III) 350ºC; (IV) 350ºC + ethylene glycol; (V) 550ºC. Horizons: (1) Ah (0–4 cm); (2) Bg (4–15 cm); (3) Bgf (15–30 cm).

(smectitic) unit structures in the randomly interstratified minerals increased in a shallow mineral horizon under litter in comparison with a deeper horizon as a result of pedogenic phyllosilicate degradation. The quartz in the fine size fractions was probably inherited directly from the parent rock where this mineral formed through post-magmatic replacement.

Soils derived from basic igneous rocks are often enriched in phyllosilicates. In the sola on gabbroic rocks in Scotland, the dominant mineral in the clay-size fraction is trioctahedral vermiculite (Wilson *et al.*, 1984). Sola from basic material located near the present key plots (East Fennoscandia) were enriched by nontronite and talc on gabbro-norite (Republic of Karelia) (Krasil'nikov *et al.*, 1999) and by oxidized Fe-rich saponite on gabbro-diabases (Island Valaam) (Berkgaut *et al.*, 1993). Soil formation from the basic substrates with few or no phyllosilicates seems to have been rare, as determined by the initial silicate association in the rocks and pre-pedogenic rock transformation during the long geological history. In the soils studied, recent pedogenic processes involved only rock disintegration to form a mineral matrix, precipitation of Fe released from the weathered silicate minerals, and enhancement of phyllo-silicate transformations that are initiated by epigenic rock alteration (Lesovaya *et al.*, 2008).

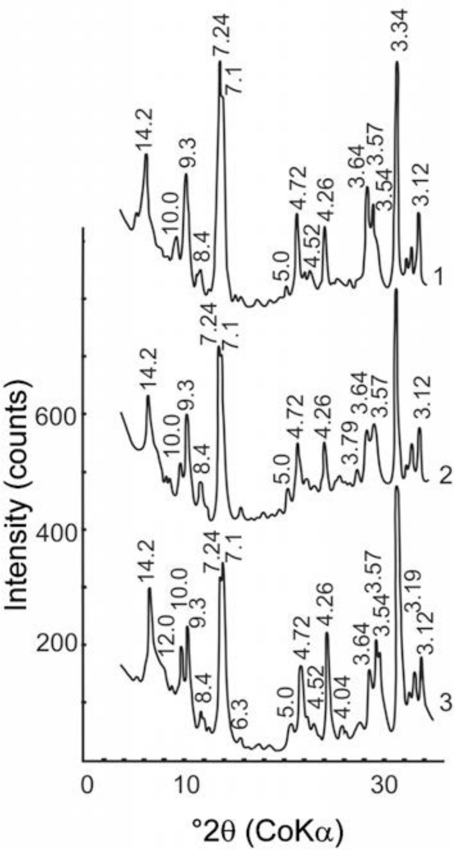

Figure 4. XRD patterns of the 1–5 μm fraction (air-dried) of Pit Y-02-07. Horizons: (1) Ah (0–4 cm); (2) Bg (4–15 cm); (3) Bgf (15–30 cm).

The Ural Mountains, ultrabasic rocks

Soils from ultrabasic rocks in mountainous tundra (Pits Y-02-07 and Y-03-07) were isolated from the influence of allochthonous substrates due to location. Nevertheless, in the fine size fractions, minerals that were not related to the ultrabasic rocks were present, probably due to eolian transfer. The influence of admixture materials was clearly detected in the XRD patterns of the rock and fine earth powders. Quartz and feldspars from meta-gabbro amphibolites may be the source of the admixed materials in the sola from the ultrabasic rocks.

Among phyllosilicates, the origin of illite and especially of kaolinite is not clear. Illite is apparently from micaceous material and, in that case, is inherited. Illite is not usually found in soils on ultrabasic rocks, though has been found as a minor mineral in the soils derived from serpentinites (Wilson *et al*., 1984). Eolian transfer is another possible reason for the presence of illite in the sola. The origin of kaolinite (though its presence has not been determined unambiguously) could be related to that of feldspars which are an admixture in serpentinous dunites.

Most phyllosilicates, including talc, serpentine, and chlorite, are considered to be of inherited origin. The relation between chlorite and serpentine in the sola was assessed by considering the relative intensities of the 7.1 Å and 7.24 Å peaks, which belong to chlorite and serpentine, respectively. Chlorite enrichment of the basal horizon in comparison with the upper horizons was clearly maintained only in case of the 5–10 μm fraction. In general, the serpentine content is greater in the 1–5 μm and 5–10 μm fractions than in the <1 μm faction and in the upper horizons, probably because of disintegration of serpentine in the coarser fractions. Talc is found in all horizons of the soils; the proportion is greater in coarser fractions (Figure 4). The redistribution and movement of ultrabasic substrates leads to a decrease in talc content as in sample pits Y-01-07 and Y-04-07.

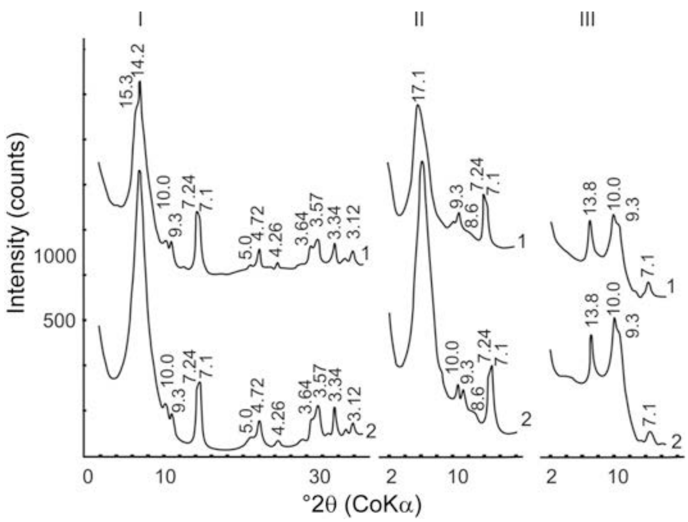

Figure 5. XRD patterns of the <1 μm fraction of Pit Y-03-07. (1) Mg-saturated; (II) ethylene glycol-solvated; (III) 550ºC. Horizons: (1) Bg (0–10 cm); (2) Bgf (10–20 cm).

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Unlike talc, serpentine, and chlorite, saponite is pedogenic in origin. Its content decreased considerably in fractions >1 μm. The maximum amount, as estimated on the basis of peak intensity, is in the basal horizon, especially in sample Pit Y-02-07 (Figure 3). Trioctahedral smectites may be unstable in basic solutions (Dixon, 1989), suggesting that saponite may be lost from the upper horizons because of their alkaline pH. The most alkaline pH values are in the basal horizon with the largest saponite content in this solum. In Pit Y-03-07 the decrease in saponite content is not so pronounced in the upper horizon, in spite of the fact that the pH value was greater than in Pit Y-02-07 (Figure 5). The results are impossible to explain by pH data alone. However, saponite destruction appears to be most intensive in Pit Y-02-07, where the surface is covered by lichens and moss; less intensive in Pit Y-03-07, where vegetation cover is absent; and least in the weakly differentiated solum of Pit Y-01-07. The instability of saponite may be due to the decomposing acidic effects of vegetation, especially moss and lichens,

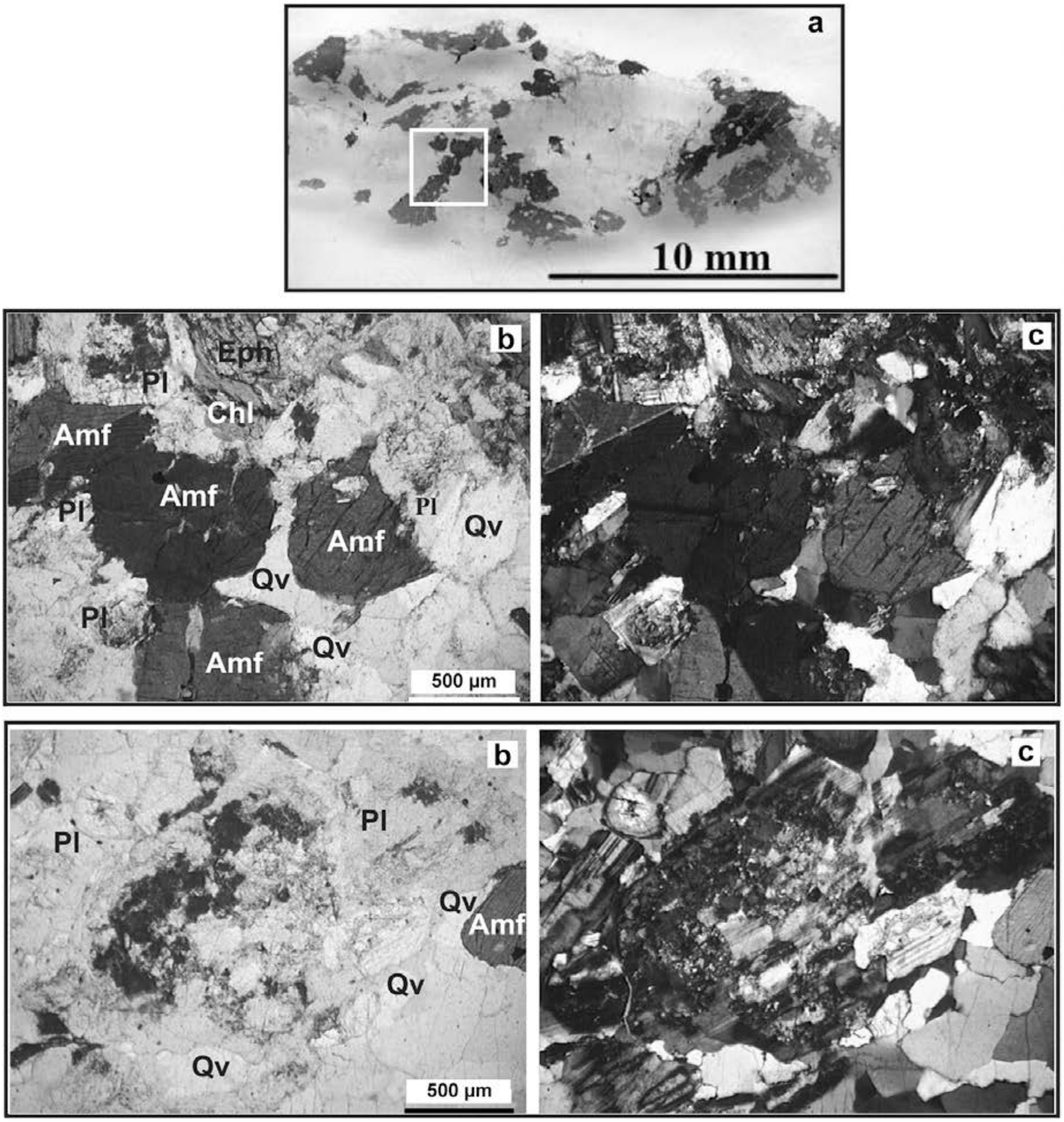

Figure 6. (a) Ratio of melanocratic to leucocratic minerals in meta-gabbro amphibolite (thin section). The white box indicates the area of study. (b,c) Nemato-granoblastic texture of meta-gabbro amphibolite (upper). Substitution of plagioclase lath by sericitic aggregate (lower). Pl: plagioclase; Qv: quartz, Amf: amphibole, Eph: epidote, Chl: chlorite (b: plain polars; c: crossed nicols).

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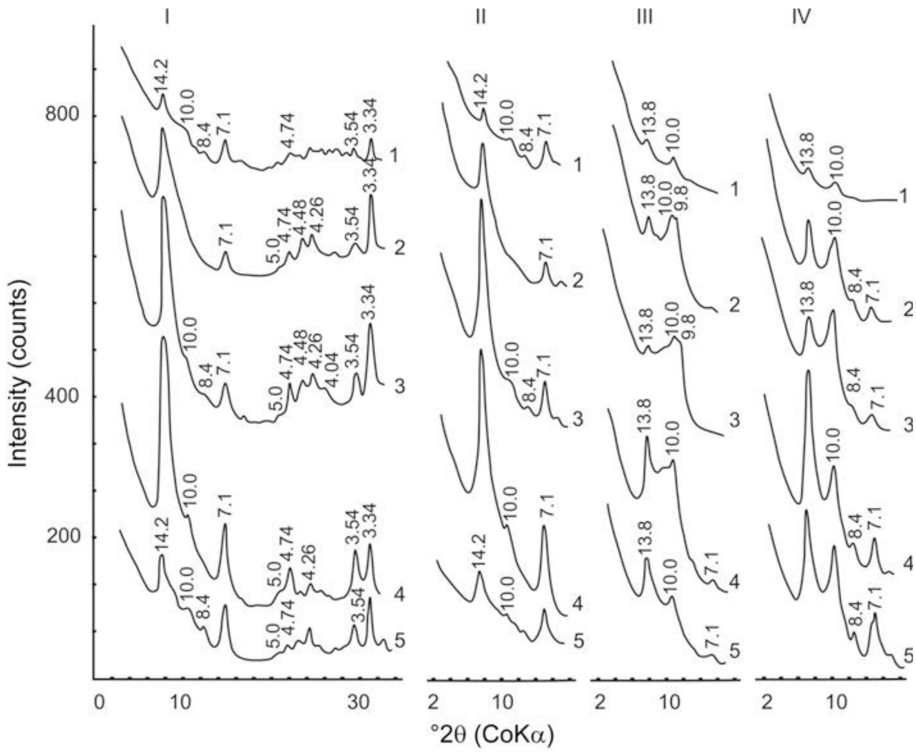

Figure 7. XRD patterns of the <1 μm fraction (I–III) and 1–5 μm (IV) of Pit Y-05-07. (I) Mg-saturated; (II) ethylene glycol-solvated; (III, IV) 550ºC. Horizons: (1) O2 (0–3 cm); (2) Bw (3–5 cm); (3) Bhs (5–10 cm); (4) Bs (10–24 cm); (5) BC (24–30 cm).

rather than alkaline conditions characteristic of the bulk samples, in accord with previous data from pedogenic saponite concentrated in the basal horizons and absent from more acidic upper horizons (Wilson and Berrow, 1978). Nevertheless, the suggestion of a strong influence by lichens and moss on the mineral matrix are inconsistent with the present data for the shallow sola under lichens in East Fennoscandia. The reason for this difference is thought to be the enrichment in phyllosilicates in case of sola from the ultrabasic rock that are not stable to biotic influence.

The Ural Mountains, basic rocks

The fine size-fractions of the solum underlain by meta-gabbro amphibolites in the northern taiga (Pit Y-05-07) differ from those in the sola underlain by basic rocks in East Fennoscandia because of enrichment in terms of inherited phyllosilicates, especially chlorite. Vermiculite was recognized in all studied fractions of this solum. A reduction in chlorite and an increase in vermiculite contents were identified in the upper horizons (O2 and Bw) (Figure 7). Chlorite can be weathered to produce vermiculite in soils (April *et al.*, 2004) and this process may have been induced by the oxidation of Fe(II) (Ross and Kodama, 1973). In the solum studied, randomly interstratified C-V was located in the <1 μm fraction in comparison with the 1–5 and 5–10 μm fractions where vermiculite was mostly found. The transformation of chlorite to C-V is more pronounced in the <1 μm fraction, where vermiculite was decomposed as the most unstable mineral in the acid environment. The distribution of vermiculite and C-V depended on the processes of chlorite vermiculitization and vermiculite decomposition.

Degradation of illite as a result of pedogenic transformation was also apparent in the <1 μm fraction even in the basal horizon and in the 1–5 μm fraction (the latter only in the upper (O2 and Bw) horizons). Such a pathway of illite transformation in the soil environment has also been demonstrated by others (Kodama and Brydon, 1968; Bain *et al.*, 1990). Thus, the transformations taking place in the silicate matrix as a result of soil formation in the solum include: (1) vermiculite decomposition; (2) vermiculitization of chlorite; and (3) degradation of illite.

CONCLUSIONS

The presence of phyllosilicates in the shallow soils from basic rocks is due to their silicate association and epigenic ('pre-pedogenic') rock alteration. In East Fennoscandia, the formation of fine earth fractions is a result of comminution (amphibolites), and comminution and degradation of the inherited phyllosilicates in the coarser fractions (metamorphosed gabbro-diabases). If phyllosilicates are absent in the bedrock, they are also absent in the fine size fractions of the associated solum. The pedogenic alteration of the inherited minerals is very weak and does not lead to a significant accumulation of phyllosilicates in the soil profile.

Enrichment with phyllosilicates of the fine size fraction of the solum underlain by meta-gabbro amphibolites of the Polar Urals is due to inheritance from rocks. Pedogenesis enhances the transformation of inherited phyllosilicate (chlorite, illite). The distribution in solum of vermiculite depends on the processes of chlorite vermiculitization and vermiculite decomposition.

The serpentinous dunites were a source of easily weathered minerals leading to soil formation on a matrix that is enriched in phyllosilicates, represented by talc, serpentine, and chlorite. Pedogenesis resulted in the appearance of saponite and its decomposition in the upper horizons, the latter in spite of the alkaline conditions, probably because of the influence of moss and lichens.

In the sola of the Polar Urals, the transformation of the mineral matrix depended more on rock composition than on climatic conditions and was more pronounced in the case of soil formation from basic meta-gabbro amphibolites than for ultrabasic serpentinous dunites.

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