ACIDIFICATION OF TILL IN NORTHERN FINLAND: EXPERIMENTAL STUDY

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The acid neutralizing capacity of till and some effects promoted by increasing acidity, were studied in a number of tills in northern Finland. pH profiles were measured in the field and acid neutralizing capacity (ANC mmol/100 g sample) in the laboratory as a function of the varying acidity in solution. The concentrations of Al, Ca, Mg, Fe, K, Mn, Zn, Cu and Sr in solutions were also analyzed. The results are presented in the form of graphs of ANC versus final pH of the solution and element concentration versus final pH. The total concentrations of the major elements were analyzed by XRF and those of trace elements by AAS.

The pH measured in the test pits was lowest just below the ground surface, and rose rapidly to a value of 6 at a depth of about 1 m and then it remained more or less constant with depth. The laboratory analyses clearly suggest that the acid neutralizing capacity of till correlates well with sample depth. The ANC values, which represent the fast-working part of the capacity, are higher in the surficial parts owing to the easily soluble aluminium and iron hydroxides which have their origin in the weathering processes. The experiments resemble acid rain conditions, where the higher pH-level buffers are unable to neutralize the increase in acidity immediately, so that lower pH-level buffering processes such as Al and Fe hydroxide buffers come into play. The situation can be hazardous for both forests and surface water.

Keywords: environmental geology, till, acidification, pH, buffers, neutralization, chemical elements, experimental studies, Northern Finland.

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INTRODUCTION

The present survey was carried out in connection with the SOMA (=Applied Surficial Geology) project financed by the Finnish Academy (Aario, 1984), which covered some hundreds of test pits made by tractor excavators in an area of about 100 000 km^2 in northern Finland (Fig. 1). The six sub-areas, which were chosen, represent areas of different climate, bedrock and till types and till landforms, including cover moraine, drumlins, Rogen moraines, radial moraines,

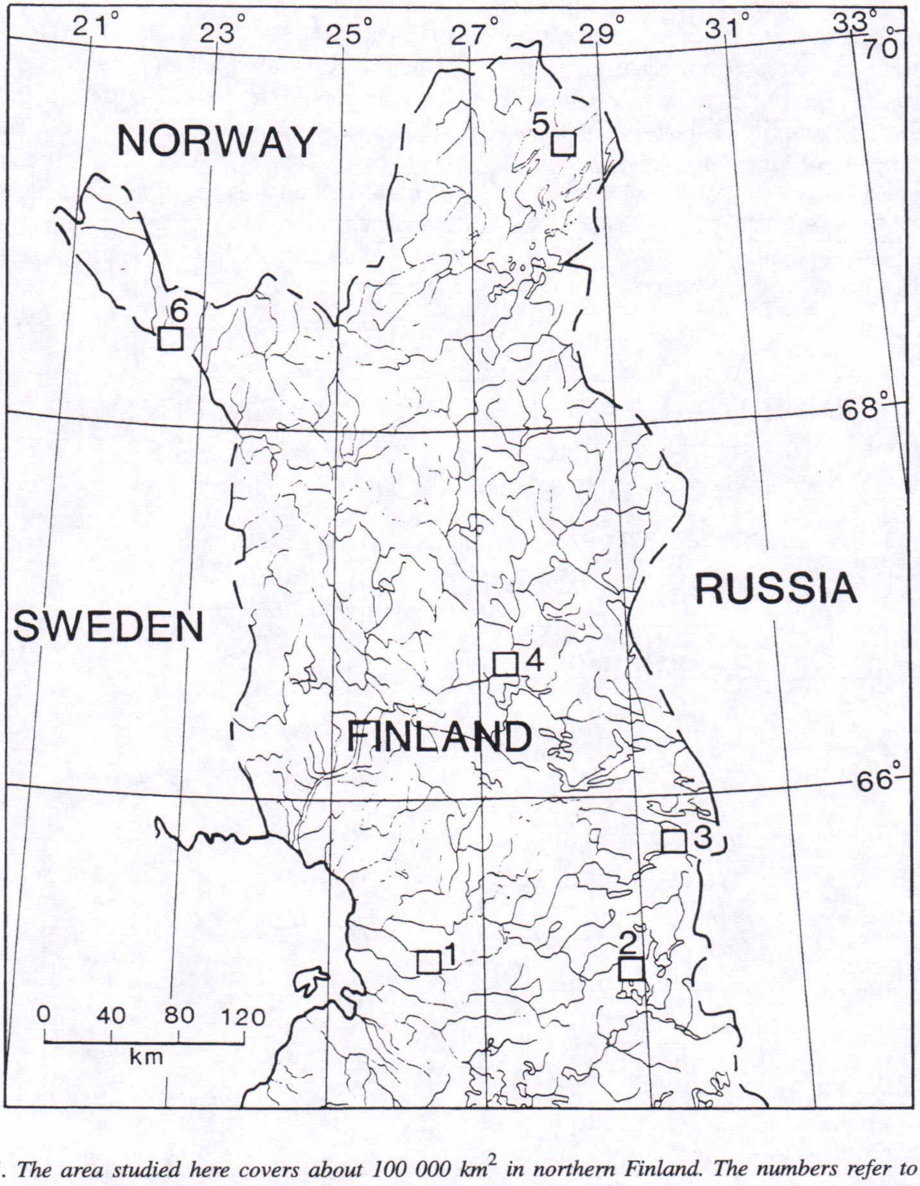

Figure 1. The area studied here covers about 100 000 km^2 in northern Finland. The numbers refer to sites of detailed investigations. 1: Korppikangas, an end moraine hill, 2: Kianta moraine, an interlobate train of morainic hummocks, 3: Säynäjäluoma drumlin, 4: Rogen ridge of Tohmo, 5: morainic assemblages at Sevettijärvi, cover moraine and morainic hummocks, 6: Pulju moraine at Kaaresuvanto.

hummocky disintegration moraines and end moraines (closer description in Aario, 1990).

The purpose of the survey was to study the effects of the natural postglacial acidification of tills in the target areas. Since the test pits were commonly excavated to a depth of 3–4 m it has been possible to obtain wide-scale areal information of thick till sequnces, in contrast to previous studies in Finland which have been concentrated predominantly on the soil horizons. Laboratory experiments were also performed to examine the acid neutralizing capacity of the tills. These matters are currently of great interest because of the human-induced increase in acidity, which is threatening the forests and lakes in Finland and is of great economic importance.

METHODS

An aerial photo interpretation was first performed in order to map the glacial features, their origins and their relationships to the ice flow patterns. In the field, the texture, structure and lithology of the till in the test pits were studied with reference to the genesis of the landforms. pH was measured at 20 cm intervals and the sequences were sampled for laboratory analyses. The samples were sieved into three fractions: <0.06, 0.06–0.25 and 0.25–0.6 mm. The acid neutralizing capacity (ANC meq/100 g sample) of each fraction was measured as a function of the increasing acidity of the solution.This was accomplished by adding sulphuric acid, H_2SO_4,

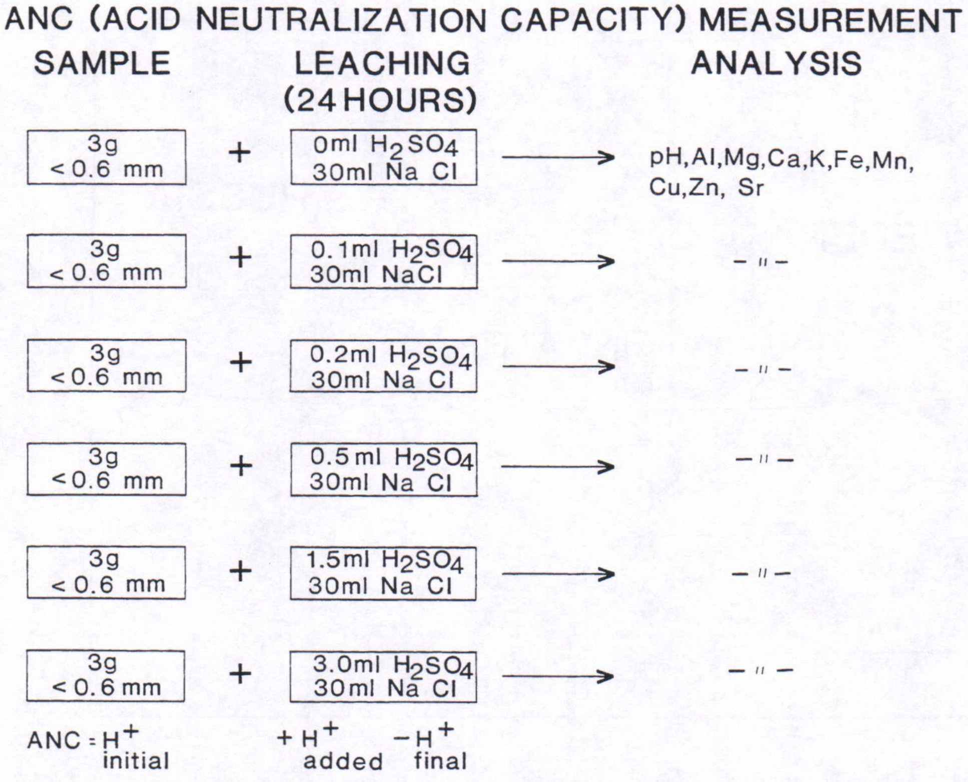

Figure 2. Procedures related to the ANC measurements.

in the solution (Fig. 2). The concentrations of Al, Ca, Mg, Fe, K, Mn, Zn, Cu and Sr in the solution were also analyzed. As the samples had a very low content of humus, no pretreatment was performed to remove it. The principles of the method used are those introduced by Wyatt (1984; cf. also Räisänen and Lahermo 1985).

This procedure also served to show the effect of grain size on the parameters measured. Most of the analyses were performed on the fraction < 0.6 mm, however, to give an indication of the bulk ANC of the till. As the experiments are based on a 24 hour leaching, one should remember that the measured ANC value tends to represent the fast-working part of the total capacity, a part which is particularly interesting in terms of acid rain conditions. The total element contents of the till sequences were analyzed by X-ray fluorescence for the major elements and by AAS for the trace elements. The total dissolution with a mixture of strong acids was used before AAS analysis.

RESULTS

As already mentioned, the survey included tills and till landforms of different types located in different climatic zones and on different types of bedrock. The properties proved to be quite consistent between the different test pits and different areas. It seems that even though the parent material has some effect on the measured properties the weathering processes were more or less similar troughout the area, being those of podzolic soil formation, and these had the dominant effect on the alteration characteristics. Because of the great similarity in ANC, pH and extractability of elements between the different profiles, only some representative examples are shown as graphs in Figs. 3–16.

pH

An example of the pH measurements is given in Fig. 3. There is a general trend for the pH measured in the profiles to be lowest in the uppermost sample taken from just below the ground surface. It rises rapidly by about one unit at a depth of 1 m and remains then more or less constant below 1 m. Variations in pH do occur, however, and there are also irregularities due to the layered structures of some tills.

Total element contents

The total element analyses show no great differences between sample depths deeper than 1 m. Enrichment of Al and Fe in particular could frequently be seen in the upper parts of the profile due to soil formation. Some trace elements, such as Zn and Cr at Korppikangas (Fig. 4), show a marked enrichment along with Al and Fe. Deeper down in the profiles one can see that Ca increases slightly with depth. All these features can be attributed mostly to the leaching

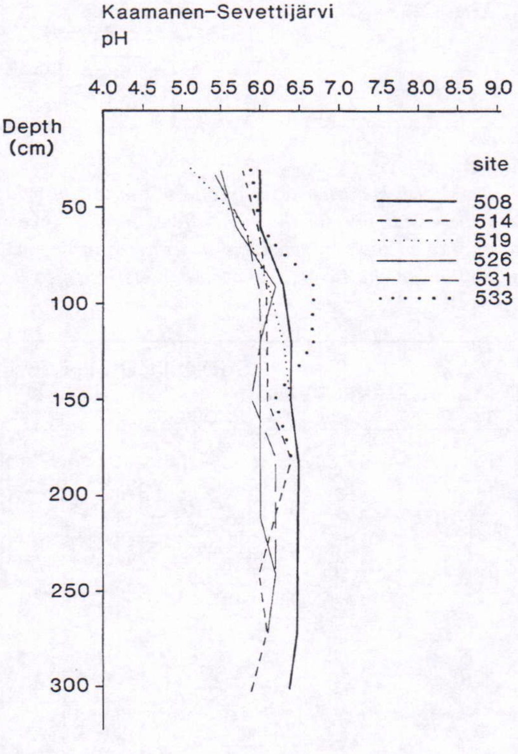

Figure 3. pH graphs for till profiles in the Kaamanen–Sevettijärvi area.

and re-precipitation related to soil formation processes.

There is a marked difference in geochemistry between profiles from Korppikangas and Sevettijärvi (Figs. 4–5). The contents of Mg, Ca, Fe, Cu, Ni, Co, Cr and Zn at Sevettijärvi are at higher level than those at Korppikangas. On the contrary the contents of Na and K at Korppikangas are at higher

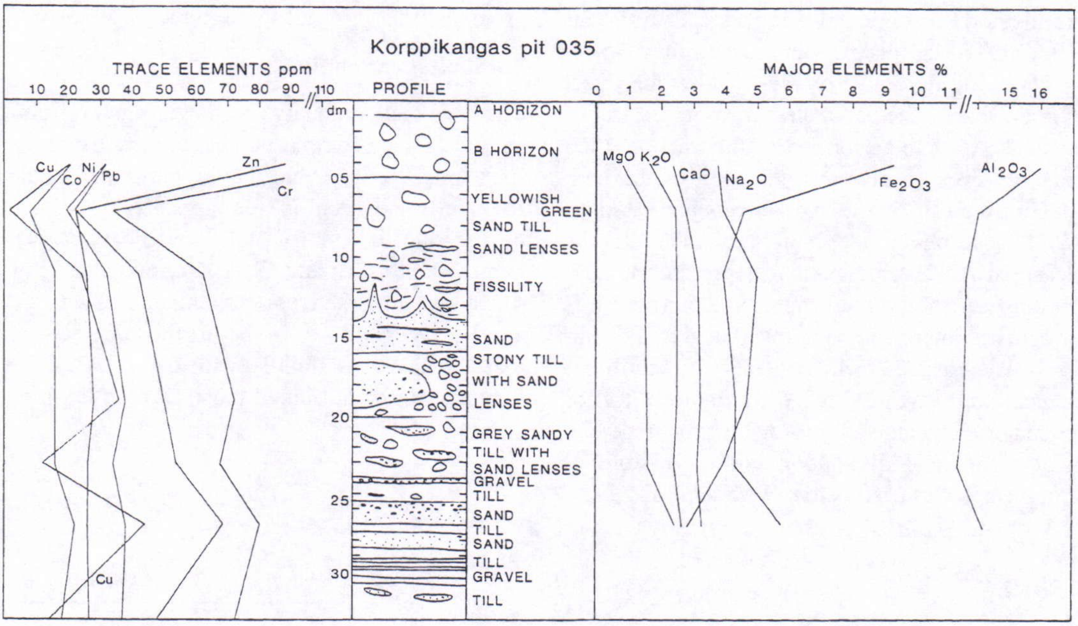

Figure 4. Till sequence seen in one of the test pits dug in Korppikangas, an end moraine hill. This pit was dug into the distal part of the hill, where the sequence was characterized by layers of flow till, but the layering seems not to have effected the measured parameters very much. There is an obvious enrichment of iron and aluminium at the surface. Some trace elements, in this case Zn and Cr are also enriched in the upper parts.

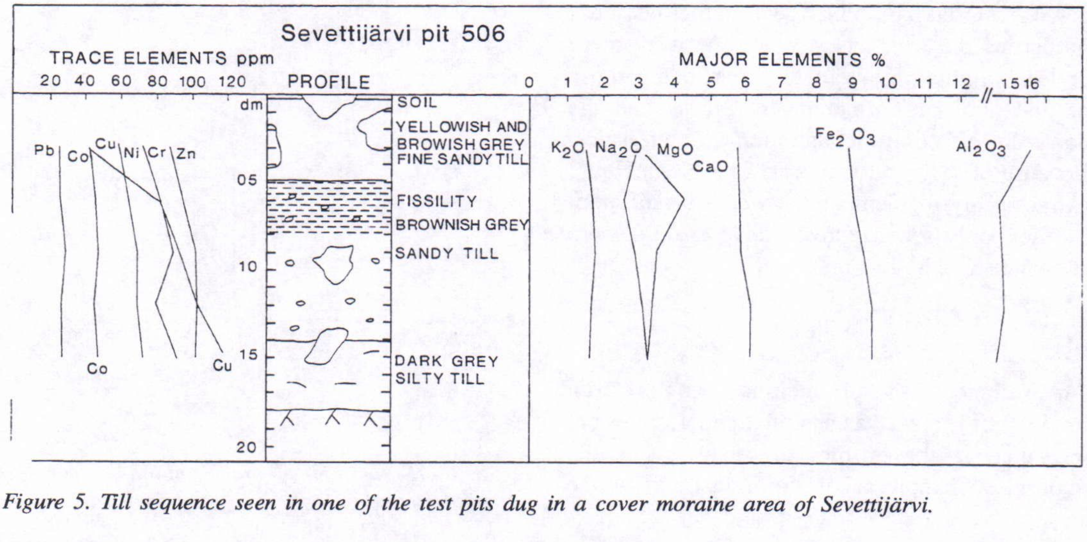

Figure 5. Till sequence seen in one of the test pits dug in a cover moraine area of Sevettijärvi.

level than those at Sevettijärvi. The clay fraction of till at Sevettijärvi contains more chlorite and amphibole than that at Korppikangas. This difference is due to the different rock types in bedrock: the Sevettijärvi site is situated in the area of early Proterozoic greenstone formation and Korppikangas in the area of early Proterozoic metasedimentary schists. The increasing Cu content with depth at Sevettijärvi (Fig. 5) most probably is an indication of a local Cu mineralization in the greenstone bedrock, which has not yet been found.

ANC

ANC graphs of different grain sizes are shown in Fig. 6 and an example of those produced for the vertical till profiles in Fig. 7. As one could anticipate, the ANC values are higher in the finer fractions of the deposits. This is evidently due to the large amount of adsorbed exchangeable cations on the clay mineral surfaces and to those more loosely bound to the minerals. A large part of the clay-size material in tills in Finland derives from reworked preglacial weathering products (cf. also Wilson,1986), with a high exchange capacity, but the finest fractions do not necessarily give the best indication of the total ANC. The values for grain size <0.6 mm at different depths show very clearly that the ANC values are higher in the uppermost parts of the till layers and decrease downwards (Fig. 7). The curves are closer to each other at depths below 1.5 m. This shows that the effects of the podzolisation usually reach down to this depth (cf. also Olsson and Melkerud, 1989; Soveri, 1989, p. 167; Aario and Peuraniemi, 1991a), although they sometimes were found to continue down to depths of more than 2 m.

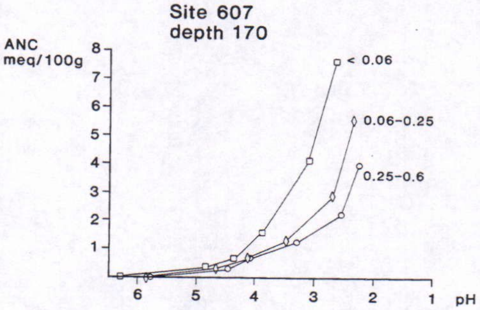

Figure 6. ANC graphs for different grain sizes of till at site 607, Tohmo Rogen ridge.

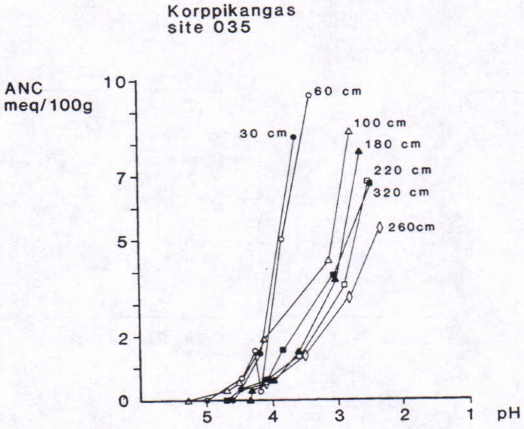

Figure 7. ANC graphs for different depths of a till profile at Korppikangas end moraine hill.

H_2SO_4 soluble elements

The easily soluble elements were analyzed by AAS after leaching the samples for 24 hours, so that the results show the fast response related to the increase in acidity. Aluminium is dissolved from the upper parts of the profiles in greater quantities and at higher pH (cf. also Derome, 1989) than deeper down (Fig. 8), where it is more firmly bound in the lattices of silicate minerals. Large amounts of H_2SO_4 soluble Al, a characteristic of the acid soils (e.g. Kennedy, 1986, pp. 155–157), exist down to a depth of 1 –1.5. m, and the H_2SO_4 soluble Fe behaves in a similar manner (Fig. 9).Pronounced precipitation of ferric iron in the B horizon may alter the figure in places, but it is already possible to see that the easily soluble Fe and Al hydroxides are more or less responsible for the higher ANC at

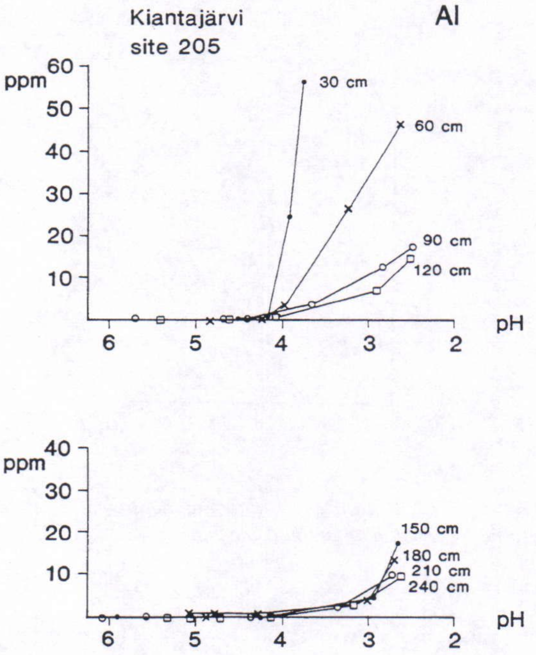

Figure 8. Dissolved Al versus pH at different depths in the till profile at site 205, Kiantajärvi, morainic hummock.

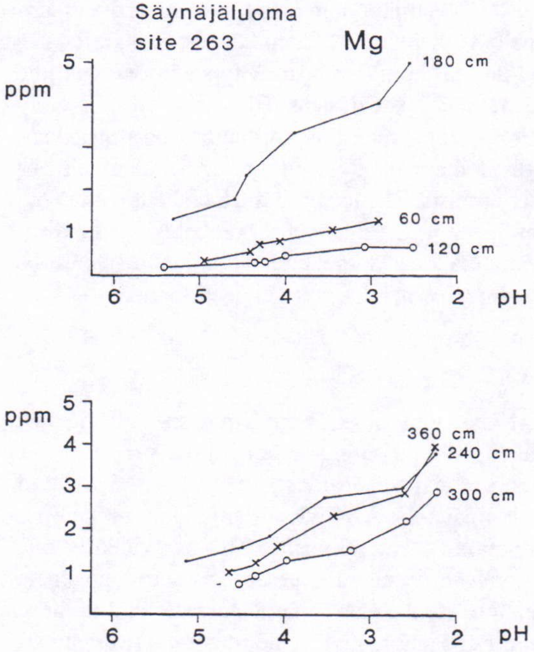

Figure 10. Dissolved Mg versus pH at different depths in the till profile at site 263, Säynäjäluoma drumlin.

the upper parts of the profiles (cf. Vuorinen and Lahermo 1987; Aario and Peuraniemi 1991b; Petäjä-Ronkainen *et al.*, 1992). These elements can occur as variously bounded to mineral particles and their surfaces (cf. Ottesen *et al.*, 1989; Räisänen *et al.*, 1989).

Magnesium, Ca, K and Sr seem to have been leached out from the upper parts (Figs. 10–13), but there seems not to occur any re-precipitation lower

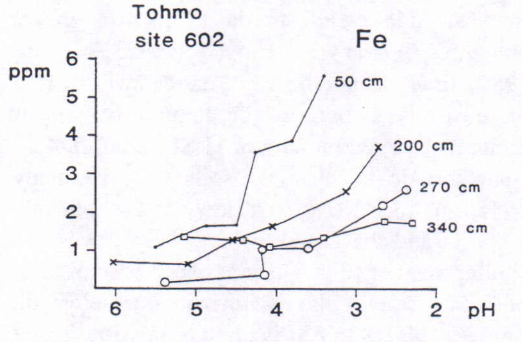

Figure 9. Dissolved Fe versus pH at different depths in the till profile at site 602, Tohmo Rogen ridge.

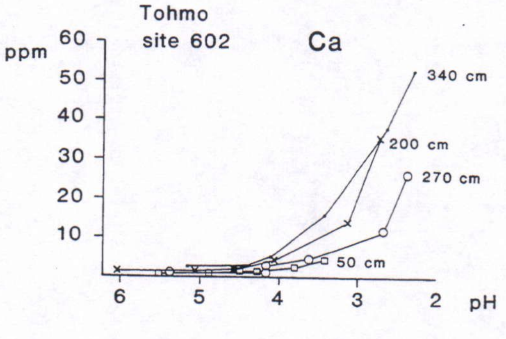

Figure 11. Dissolved Ca versus pH at different depths in the till profile at site 602, Tohmo Rogen ridge.

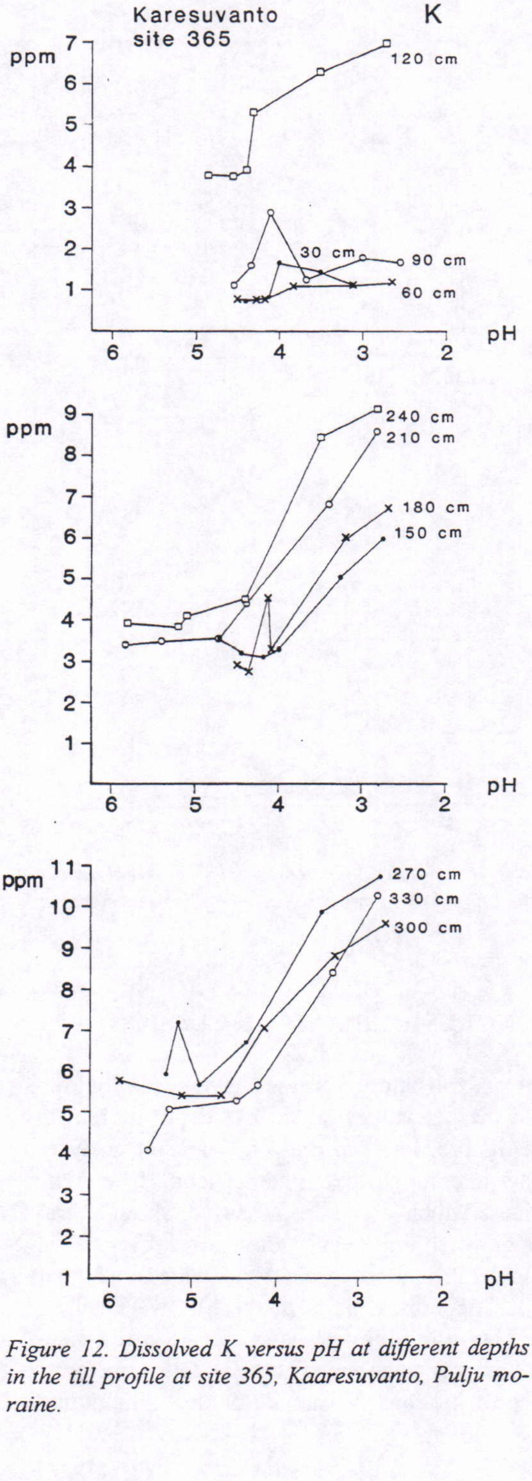

Figure 12. Dissolved K versus pH at different depths in the till profile at site 365, Kaaresuvanto, Pulju moraine.

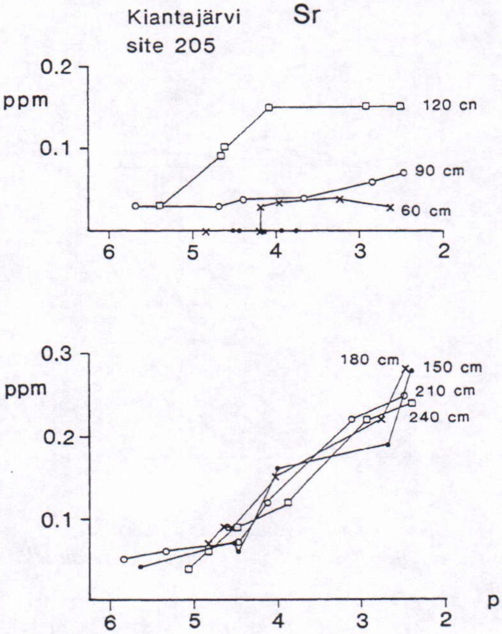

Figure 13. Dissolved Sr versus pH at different depths in the till profile at site 205, Kiantajärvi morainic hummock.

down. Pronounced leaching commonly takes place around pH 4, and Ca is leached even around pH 3–3.5. This could be due to a coating of other mineral matter around the Ca mineral grains, preventing the leaching processes before the pH level at which the coating itself will be dissolved. It can be suggested that this kind of coating may be that of hydrous Al and Fe oxides. Aluminium and Fe liberated from the upper parts are precipitated deeper down, especially around the Ca-and Mg-rich mineral grains, because the pH is higher very near the surfaces of these minerals. Manganese commonly has also been leached out from the upper parts (Figs. 14–15), but re-precipitated in places, as the results from Korppikangas show (Fig. 15). Zinc shows in the same time an enrichment into the hydrous Mn oxides. Usually Cu and Zn show no systematic trend in the analyses (Figs. 16–17), but some concentration of Zn into upper layers can be seen in places.

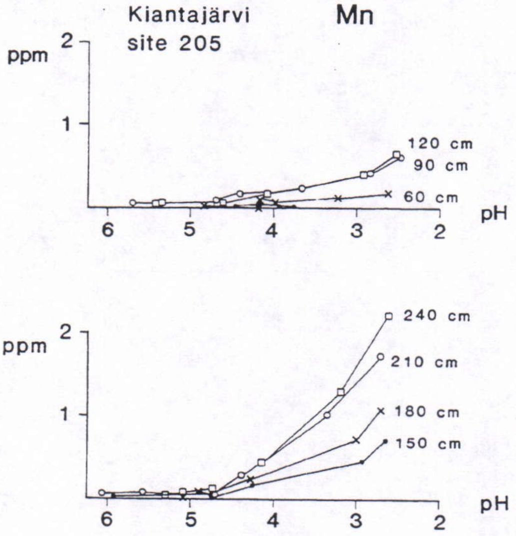

Figure 14. Dissolved Mn versus pH at different depths in the till profile at site 205, Kiantajärvi morainic hummock.

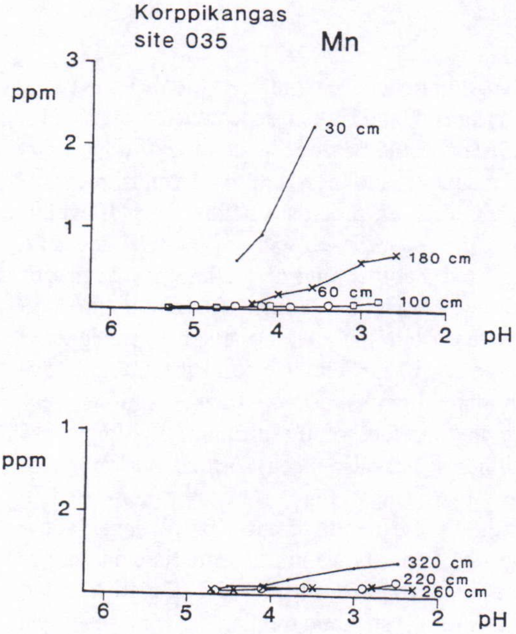

Figure 15. Dissolved Mn versus pH at different depths in the till profile at site 35, Korppikangas end moraine hill. The higher amount of Mn at the depth of 30 cm

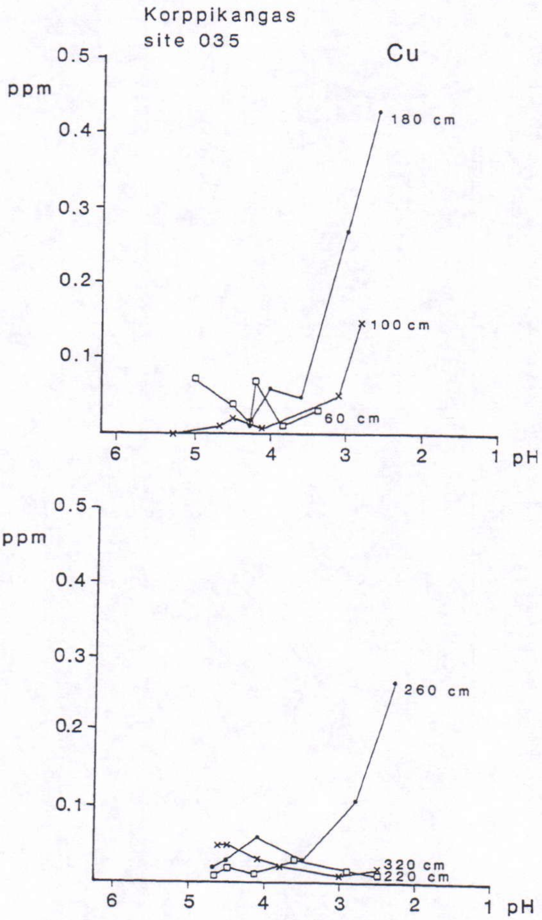

Figure 16. Dissolved Cu versus pH at different depths in the till profile at site 35, Korppikangas end moraine hill.

CONCLUSIONS AND DISCUSSION

The podzolisation processes have generally lowered the pH values down to a depth of 1 m in the till profiles, and the total element analyses show alterations to the same depth. The ANC values, which are more sensitive, show alterations which go deeper down, however, even below 2 m in places. The ANC values are higher in the uppermost parts of the till layers, where they represent the fast-working part of the neutralizing capacity and are attributable to the presence of hydrous Al and Fe oxides. Aluminium

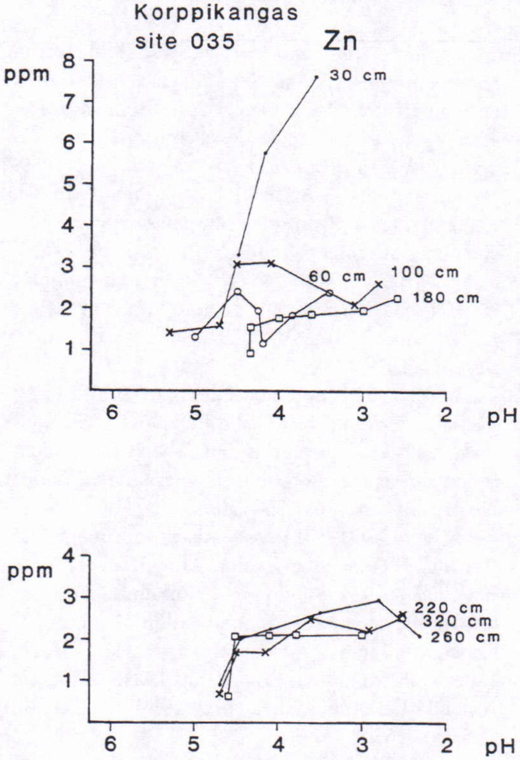

Figure 17. Dissolved Zn versus pH at different depths in the till profile at site 35, Korppikangas end moraine hill. In this case an enrichment of Zn has taken place in the upper part.

and Fe are dissolved from the upper parts of the tills in greater quantities and at a higher pH than deeper down (cf. Kennedy, 1986, p. 156). Magnesium, Ca, K and Sr have been leached out from the upper parts as a result of postglacial weathering, and Mn has also commonly been leached out, but it has been re-precipitated in places. Copper and Zn show no systematic trend in the analyses, but in some places enrichment into hydrous Fe and Mn oxides can be seen. When looking at the results, one should consider the different general groups of buffering reactions which exist in tills (cf.Ulrich, 1982; Alcamo *et al.*, 1985):

Buffer ranges	typical pH
Carbonate buffer range	8.0–6.2
Silicate buffer range	6.3–5.0
Cation exchange buffer range	5.0–4.2
Aluminium buffer range	4.2–3.0
Iron buffer range	< 3.8

Stress rates under natural conditions are usually low in Finland. Even though the buffering rates corresponding to some of the above buffer ranges can also be considered very low under these conditions, the buffers at each pH level are mostly able to neutralize the whole acid deposition. The lower pH-level buffers, do not predominantly start working before the higher ones have been exhausted (cf. Hettelingh and Hordijk 1987, p.45).

The present experiments more or less resemble acid rain conditions. Acid rain occurs commonly in Finland, but not all rain is equally acid (e.g. Järvinen and Haapala, 1980). Acid stress rates can be very high at times and the higher pH-level buffers are often unable to neutralize the acidity immediately, so that the lower pH-level buffering processes come into play. It seems that the critical soil pH level and related high amount of dissolved elements, some of them harmful (e.g. Al), which cause forest damage, can often be reached in these highly acid showers, and the surface waters also will suffer. However, the total buffering capacity of a thick till sequence is high (cf. Shilts et al., 1981, Shilts, 1984a,b), and the slowly percolating water will be buffered before reaching the groundwater table or soon afterwards. The groundwater is therefore not greatly endangered in areas with thick till deposits.

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