Quaternary palaeosols in Norway - examples from selected areas

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The aim of this contribution is to present an overview of the recorded palaeosols mainly older than the last glaciation (Late Weichselian) in Norway. No detailed classification of soils will be provided here. Only a pure record supported by stratigraphy and some chemical data will be considered, and the examples will be mainly from Sargejohka in Finnmark county, but some occurrences from other parts of Norway will also be mentioned (Fig.1). It has been known for a while that Tertiary weathered bedrock or, broadly speaking, traces of Tertiary palaeosols exist in a number of places in Norway, for example in western Norway (Roaldset et al. 1982), in southwestern, southern and southeastern Norway (Holtedahl 1953), and in northern Norway (Olsen 1988). However, the main occurrences of remains of both Tertiary and Quaternary palaeosols have been recorded recently in Finnmark (Olsen et al. *in prep.*).

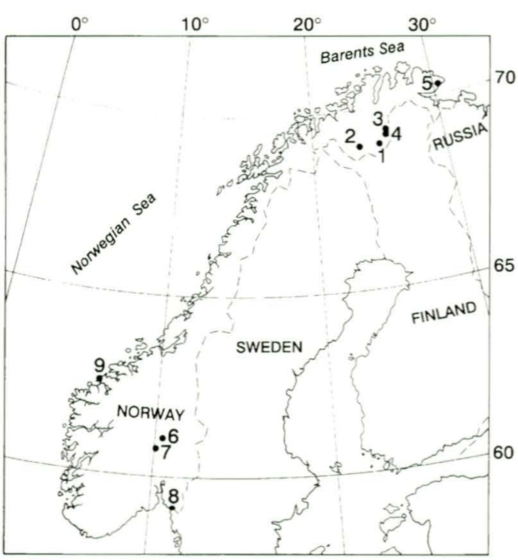

Fig.1. Map of Norway with location of palaeosol sites 1-9. Names of sites are given in the text.

Finnmark county

In the northernmost part of Norway, several palaeosols in the category buried soils have been recognised in the stratigraphy at Sargejohka on Finnmarksvidda (Fig.1: no.1). At this locality up to seven, different, buried zones of pedogenic activity have been found. This is based on stratigraphical evidence, morphology, structure, datings and some chemical analyses. Each set

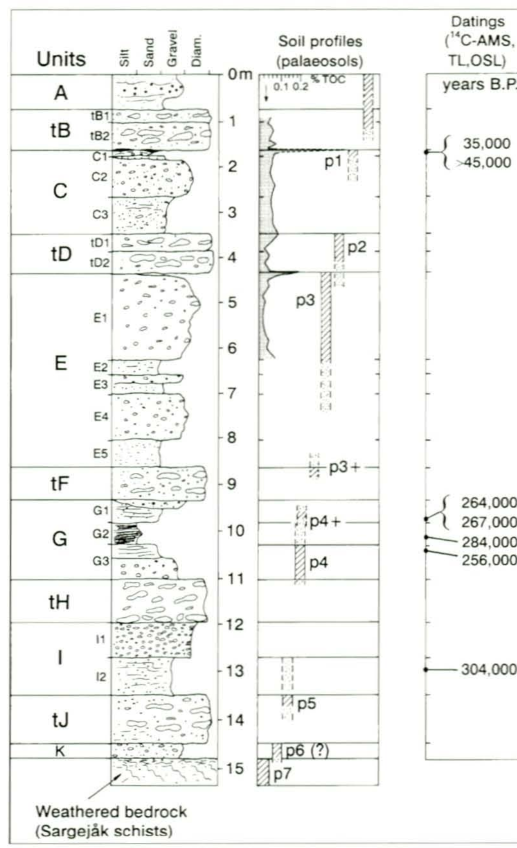

Fig.2. The Quaternary stratigraphy at Sargejohka, Finnmarksvidda, North Norway; simplified log with location of palaeosols 1-7 and datings. After Olsen et al.(*in prep.*). The content of total organic carbon (TOC) from the upper part of the stratigraphy covering palaeosols nos. 1-3 is also indicated.

Fig.3. Photo of palaeosol no.3 (p3), Sargejohka. It is thought to be a humo-ferric podzol developed in a warm and humid climate during the last interglacial period. The upper part of the palaeosol is severely altered by cryoturbation indicating a change to arctic tundra conditions. Scale: person lying on top of terrace.

of 'palaeopedons' is separated from the following overlying one by tills and glaciotectonic deformation events (Fig.2). This implies that the pedons represent really at least five, probably seven different palaeosols of different ages and are not repeated horizons at different depths of only one or two soil profiles (Olsen 1994, Olsen et al. *in prep.*). Several of these palaeosols are thought to be podzols, podzolic soils or similar soils. Conventional chemical analyses for pedogenic classification, for example according to FAO (1988), have not been carried out. The well developed red-yellow palaeosol, which is thought to be a podzol from the last interglacial, is illustrated in Fig.3. It is recorded as palaeosol no.3 (p3) counted from the present surface soil and successively downwards. As may be seen in Fig.3, younger cryoturbation has greatly altered the upper part of this paleosol, indicating a dramatic change in climate from temperate humid to arctic tundra conditions. The latter may have happened during the initial part of the Weichselian, but the stratigraphy and the datings give only evidence of a minimum age older than the middle Middle Weichselian for this cryoturbation.

The Tertiary weathered bedrock is supposed to represent palaeosol (sensu lato) no.7 at Sargejohka (Fig.2: p7). The horizon that is thought to be the oldest Pleistocene soil (p6) at Sargejohka is represented mainly by a glaciotectonised horizon consisting of abundant coatings and peds of iron oxids or iron- and manganese oxids. It is possible that this horizon may be attributed to diagenesis and not to pedogenesis. If this is correct, then the number of palaeosols represented at Sargejohka should be reduced to six. This number may, in fact, even shrink to five if p2, which is a soil-like profile thought to be the next youngest buried palaeosol, also turns out to be a pseudosoil or a false palaeosol. This is possible, although most properties recorded for p2 indicate a palaeosol, because the lateral record of p2 is poor, and at least parts of the recorded zonation may be explained by groundwater action or other processes associated to water transport through the sediments in a subsoil position. The final conclusion about the genesis of p2 has therefore not yet been reached. The remaining five old profiles are, however, real buried palaeosols that cannot be explained by diagenesis alone, although some alteration during a younger phase of diagenesis is believed to have occurred.

Remains of inferred palaeosols represented mainly by strong oxidation and/or rusty glaciotectonised horizons are also recorded, for example at Vuolgamasjohka (Fig.1: no.2), Gamehisjohka (no.3), Buddasnjarga (no.4; relict soil) and at Leirelva (no.5). The most reliable parameters for previous pedogenic activity, for example at Vuolgamasjohka and at Leirelva, are represented by organic matter in the uppermost parts of the palaeosol remnants. It is thought, however, that diagenesis has affected and altered parts of the buried horizons in most of the mentioned

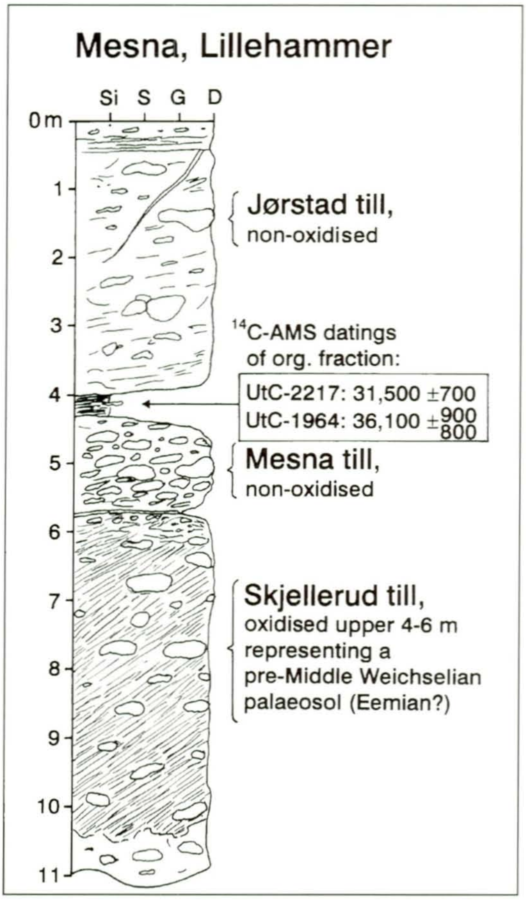

Fig.4. The Quaternary stratigraphy as recorded in the northwestern bluff of the Mesna river close to its outlet in lake Mjøsa at Lillehammer, southeastern Norway; simplified log with remains of a buried palaeosol and datings (yrs. B.P.) of a younger ice-free event. After Olsen 1985, and unpublished material.

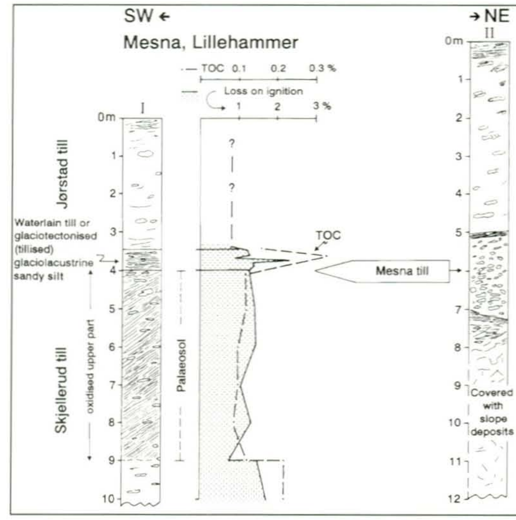

Fig.5. The Mesna stratigraphy; organic content represented by loss-on-ignition and total organic carbon (TOC) data indicated for the southern part of the section, column I. After Olsen 1985, and unpublished material. The generalised stratigraphy in Fig.4 represents a position between columns I and II which are located about 20-30 m from each other.

localities. For example, rusty horizons may at least partly have been caused by diagenesis and not, strictly, by pedogenesis. All these remains of possible palaeosols and diagenetic features are inferred to be of Late Pleistocene age. Traces of a Tertiary soil profile have, in addition, also been found at the latter locality (Olsen et al. *in prep.*).

Other parts of Norway

In the bluff of the river Mesna that runs through the town of Lillehammer in southeastern Norway, remains of the oxidised zone of a 5-6 m-deep palaeosol are recorded in a till underlying thick non-oxidised tills from the last glaciation (Fig.1: no.6; and Fig.4). The pedogenic activity is characterised mainly by strong oxidation, and chemical analyses support the visual evidence of a palaeosol (Figs. 5 and 6). It is realised that the depth of the oxidation is most likely much dependent on its position adjacent to the supposed former Mesna river which probably followed the same path as the present river. The generally most organic-rich upper part of a soil is in the case probably removed by erosion during younger erosive events, and the organic content in this remaining upper part of the old till is only slightly higher than that of the underlying also oxidised zone and it is lower than in the non-oxidised and non-leached parent material (Fig.5). The latter indicates that leaching with transportation out of the pedogenic zone has been more important than downward enrichment of organic matter in the represented part of the palaeosol. Inorganic material which is soluble in weak acids indicates mostly the opposite trend with peak values clustering at c. 1 m apparent soil depth (Fig.6). This indicates that younger erosion has probably not removed much more than the topmost part of the palaeosol. Based on the stratigraphy and the thickness of the palaeosol remnants it is thought that the palaeosol was developed mainly during the last interglacial, but it may have been influenced by, and further developed during, the relatively warm ice-free intervals in the Early and Middle Weichselian (Olsen 1985, *in prep.*).

Traces of possible Late Weichselian buried soils are recorded at Dokka and at Skjeberg in southeastern Norway (Fig.1: nos.7-8; Olsen

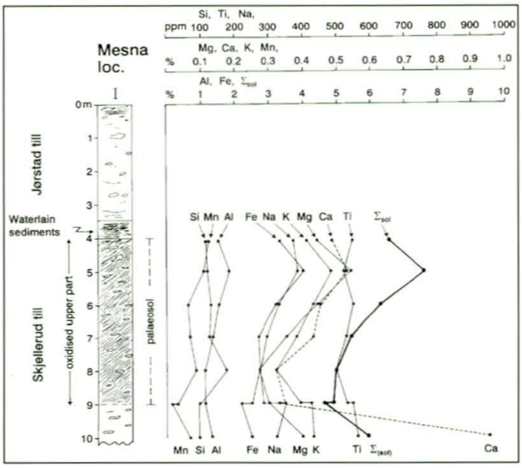

Fig.6. The Mesna stratigraphy; with some chemical (ICP) data indicated.

1989, 1993a). Both these inferred palaeosols have been dated to ages of around 19-19.5 ka (Olsen 1993a, *in prep.*).

Remains of a possible Late Weichselian palaeosol have also been recorded on the mountain Gamlemsveten in the coastal part of western Norway (Fig.1: no.9). The relict soil was found underlying boulders in a blockfield area, and it has been dated to c. 20 ka (J. Mangerud, unpublished data, 1981).

Conclusions

The occurrences of palaeosols provide evidence of very little subsequent erosion, and their existence is very important in understanding parts of the landscape-forming history in the area. The type of palaeosol may also give significant information about the climate that prevailed during the development of the soil profile. Particularly in areas where other climatic indicators, for instance pollen or fossils, are lacking or sparsely represented, the palaeosols may be especially valuable for the interpretation of the ancient climatic history. However, a precise pedogenic classification of the palaeosols is beyond the scope of this extended abstract.

Some climatic interpretations may be attempted though on the basis of the presence of these palaeosols. For example, some cannot have developed during tundra conditions, so that the climate during the associated ice-free intervals must have been warmer than in tundra areas. The average content of the weathering mineral kaolinite in the lowermost palaeosol at Sargejohka (p7) and at Leirelva indicates development during a Tertiary climate at these latitudes (Olsen 1993b, Olsen et al. *in prep.*). To obtain more climatic information from the palaeosols it is necessary first to do more detailed fieldwork with descriptions and soil sampling; and second to carry out at least some conventional chemical analyses, for example according to FAO (1988) and the paleopedology manual given by members of INQUA Commission 6 (Paleopedology) and others (Catt 1990).

References

Catt, J.A. (ed.) 1990: Paleopedology Manual. *Quaternary International 6*, 1-95.

FAO 1988: FAO/Unesco Soil Map of the World, Revised Legend. World Soil Resources Report 60, FAO. Rome.

Holtedahl, O. 1953: Norges Geologi. *Nor. geol. unders. 164, II*, 585-1118.

Olsen, L. 1985: Weichselian Till Stratigraphy in the Lillehammer Area, Southeast Norway. *Nor. geol. unders. Bull. 401*, 59-81.

Olsen, L. 1989: *Glasialgeologi og kvartærstratigrafi i to innlandsområder, Nordlige Mjøsregionen og Finnmarksvidda*. Dr. scient. thesis. University of Bergen, 21pp. + 9 printed papers.

Olsen, L. 1993a: Siste nedisning belyst med dateringer fra noen lokaliteter i fastlands-Norge. *Abstract, Geonytt 1/93*, 37.

Olsen, L. 1993b: Finnmark county, map of Quaternary stratigraphy, scale 1:1 million, with description (in Norwegian). *English summary. Nor. geol. unders.*

Olsen, L. 1994: Paleosols ved Sargejohka, Finnmarksvidda. 21. Nordiska Geologiska Vintermøtet i Luleå, 1994. *Abstract.*

Roaldseth, E., Pettersen, E., Longva, O. & Mangerud, J. 1982: Remnants of preglacial weathering in western Norway. *Nor. Geol. Tidsskr. 62*, 169-178.