Kirkhill

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Highlights

The sequence of deposits formerly exposed at Kirkhill Quarry, and proved by boreholes and pits to extend beneath adjacent fields, provides the longest and most complete record of Quaternary events in Scotland. It is a unique locality of the very highest importance for Quaternary studies, providing evidence of multiple glacial, interglacial and periglacial episodes.

Introduction

Kirkhill Quarry [NH 012 529] is located 14 km north-west of Peterhead. The interest of the site lies in the variety of environments recorded by a succession of sediments which spans a large part of Middle and Late Pleistocene time. The succession includes:

1. Two interglacial soils of possible Ipswichian and Hoxnian age.
2. Organic sands of possible late Hoxnian age.
3. Tills which record at least three separate phases of glaciation in this part of Buchan.
4. Evidence for at least four separate periglacial phases, two of which pre-dated the last interglacial and three of which involved soil development.

The site represents the most complete Middle Pleistocene sequence known in Scotland and is of key importance in the controversy over the extent and timing of Devensian glaciation in north-east Scotland (Hall, 1984b; Sutherland, 1984a). The sediments have been described in a series of papers by Connell, Hall and co-workers (Connell *et al,* 1982; Connell, 1984a, 1984b; Connell and Romans, 1984; Hall, 1984a; Connell and Hall, 1987; Hall and Connell, 1991); Lowe (1984) has critically reviewed the available pollen data. The quarry is now filled, but the succession has been proved beneath the fields to the south and east (Hall *et al.,* 1989b) and at Leys Quarry, 0.6 m south-west of Kirkhill (Hall and Connell, 1986).

Description

The sediment succession is up to 10 m thick and occurs in a number of bedrock channels or basins. The lithostratigraphy is summarized in (Figure 8.4). Terminology is after Connell and Hall (1987).

Deposits below the Lower Buried Soil

The base of the sequence is composed of blocky talus and gelifluctate deposits derived from frost shattering of the channel margins. These sediments comprise Gelifluctate Complex 1 and are overlain by, and interstratified with, up to 4.5 m of bedded sand and gravel of fluvial or glaciofluvial origin. The gelifluctate and the base of the sand and gravel contain occasional erratic pebbles, which suggest, together with the existence of bedrock channels probably carved by meltwater, an early phase of glaciation at this site.

Recent work at nearby Leys Quarry indicates that the Kirkhill Lower Sands and Gravels rest on, or are a facies of the bouldery Leys Gravels, carried by meltwater from the east (Hall and Connell, 1986). Beneath the latter and resting on bedrock lies a further till, the Leys Till, derived from the west. The erratics in the Lower Sands and Gravels are presumably derived from the Leys Till.

The Lower Buried Soil

The lower deposits are truncated by an erosion surface on which is developed the Lower Buried Soil. The soil comprises a distinctive, upper, light-grey, bleached horizon and a lower, grey-brown, mottled horizon, with a basal iron pan (Figure 8.5). Analytical data are given in Connell and Romans (1984). The Lower Buried Soil is of podsolic type and it developed under humid temperate conditions (Connell *et al.,* 1982), but micromorphological evidence of silt droplet fabrics indicates subsequent climatic deterioration (Connell and Romans, 1984).

Deposits between the Lower and Upper Buried Soils

The Lower Buried Soil is truncated and draped by a 0.02 m thick layer of laminated organic mud, deposited in shallow ponds. The mud contains pollen of Gramineae, together with a marked arboreal component of mainly *Pinus* and *Alnus* (Connell *et al.,* 1982). Initial radiocarbon dating of the organic mud gave finite radiocarbon dates for three samples of 45,630 +1740/−1430 BP (SRR–1635), 44,900 +1580/−1320 BP (SRR–1637) and 33,810 +630/−590 BP (SRR–1636), but contamination was suspected (Connell *et al.,* 1982). Later dating of a much larger sample (Connell, 1984b) gave a date of >47,360 BP (SRR–2416) and confirmed that the sediments are beyond the range of radiocarbon dating (Hall, 1984b).

The organic mud is succeeded by 0.1–0.7 m of poorly-organic sands containing frost cracks. Pollen analysis shows a reduction in arboreal pollen and an increase in grasses and *Calluna,* possibly reflecting the establishment of an open, treeless environment. The organic sediments indicate erosion and recycling of organic deposits, possibly including the upper horizons of the Lower Buried Soil, from neighbouring slopes under deteriorating climatic conditions. The organic sands are overlain by sediments belonging to Gelifluctate Complex 3 and then by the Lower Till, containing erratics transported from the north-west.

The Upper Buried Soil

The Upper Buried Soil is developed on the Lower Till. Diagnostic features of soil development include mottling, clay translocation, alteration of clasts and down-profile changes in colour and clay mineralogy (Connell and Romans, 1984). The Upper Buried Soil bears many similarities with Holocene gleyed brown-earth profiles in north-east Scotland and is therefore considered to have formed during an interglacial. Countable pollen dominated by *Alnus* was recovered from one sample in the weathered till but its significance is uncertain.

Deposits above the Upper Buried Soil

The A horizon of the Upper Buried Soil is missing due to erosion. The truncated soil surface is cryoturbated and overlain by Gelifluctate Complex 4. This depositional surface then stabilized, ice wedges developed and periglacial soil formation began. Renewed glaciation then took place across the permafrost surface, with deposition of the brown Upper Till, derived from the west. Of interest is the discovery of a single Norwegian erratic in the Kirkhill Upper Till. In the northern part of the quarry the Upper Till underlies a large erratic mass of dark grey silty clay containing Jurassic and Cretaceous dinoflagellate cysts, which was originally derived from the Moray Firth. West of the quarry, excavations have shown that this material grades into dark tills at least 5 m thick in places and containing fragments of shell (the East Leys Till). The Kirkhill Upper Till and the East Leys Till are overlain by glaciofluvial sands and gravels and by periglacial slope deposits of Kirkhill Gelifluctate 5. This is the last depositional event recorded at the site prior to Holocene soil development.

Interpretation

Kirkhill Quarry contains an extraordinary range of sediments, which provide an unrivalled record of Quaternary environmental change in Scotland. The site is considered to include evidence of two interglacials, at least three glacial phases and at least four periglacial phases. No firm dates, however, exist for sediments in the Kirkhill sequence. The simplest view is that the Upper Buried Soil represents the Ipswichian and that the Lower Buried Soil represents the Hoxnian. On this basis, the glacial and periglacial sediments above the Upper Buried Soil would be Devensian, there was one period of regional glaciation preceded by periglacial conditions between the Ipswichian and the Hoxnian, and the latter interglacial was preceded by one period of glaciation as well as periglacial conditions of unknown duration.

Kirkhill Quarry clearly has great potential as a regional reference site, but this potential has not yet been realized owing to the shortage of age determinations and the lack of firm stratigraphic correlations with Pleistocene sediments elsewhere in north-east Scotland. Sands and gravels below the Lower Buried Soil have been tentatively correlated with gravels at Leys Quarry (Hall and Connell, 1986), but no other deposits of comparable age are known in Buchan (Hall and Connell, 1991). Equally, the Lower Buried Soil currently stands alone in the regional stratigraphy as a presumed pre-Ipswichian deposit. The Lower Till may correlate with other weathered pre-Devensian tills of inland derivation at Kings Cross, Aberdeen (Synge, 1963) and Boyne Quarry, Portsoy (see below) (Peacock, 1966). If these correlations are justified, then these tills represent a major advance of inland ice (Hall and Connell, 1991). Acceptance of an Ipswichian age for the Upper Buried Soil invites correlation with the weathered tills above and with the buried interglacial soil at Teindland (FitzPatrick, 1965; Sutherland, 1984a).

The deposits below the Upper Buried Soil point to a complex sequence of pre-Devensian events in Buchan. An early, possibly Anglian ice-sheet transported the erratics in the basal Gelifluc-tate Complex 1 and deposited the basal till at Leys. Subsequently, ice-sheets covered this area at least in two later, separate periods, probably during a pre-Ipswichian cold period and during the Devensian. In addition, the sediments record at least two pre-Devensian periglacial phases, and the thickness of periglacial sediments in the sequence suggests important periglacial slope modification in the Middle Pleistocene (Connell and Hall, 1987). Finally, the Lower Buried Soil and the overlying organic sediment appear to represent an interglacial phase and a subsequent climatic deterioration. This interglacial was probably the Hoxnian. The only other organic sediments in Scotland for which a Hoxnian age has been claimed are from Fugla Ness, Shetland (Birks and Ransom, 1969; Lowe, 1984) (see above), and Dalcharn near Inverness (Merritt, 1990a) (see above).

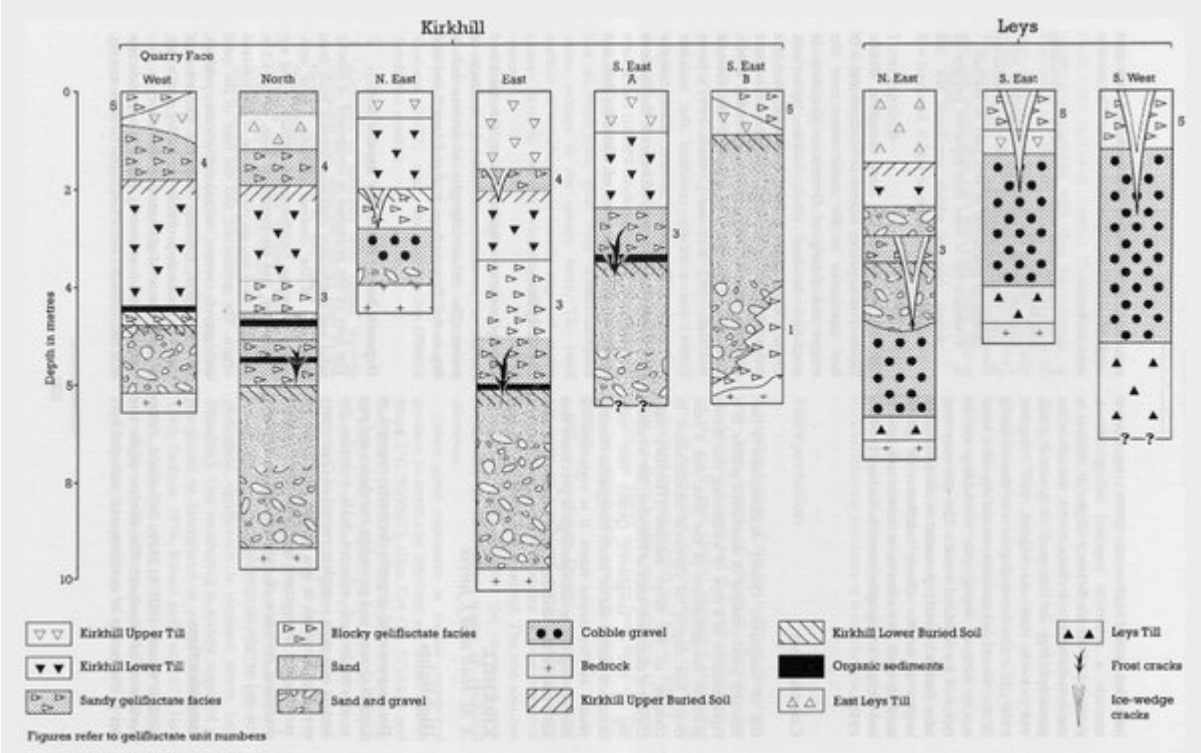
The Upper Till has been correlated with other tills of inland derivation, the Inland 'Series' (Hall, 1984b), which represent the last glaciation of central Buchan. The Upper Till at Kirkhill provides an upper limiting age of post-Ipswichian for the Inland 'Series'. At Crossbrae, Turriff, a peat containing pollen of interstadial character and with radiocarbon dates of 26,400 ± 170 BP (SRR–2041a) and 22,380 ± 250 BP (SRR–2041b) rests on till correlated with the Inland 'Series' and is overlain by periglacial solifluction deposits (Hall and Connell, 1991). The combined evidence from Kirkhill and Crossbrae indicates that the last glaciation of central Buchan was during the Early or Middle Devensian and that an ice-free area existed there in the Late Devensian (Sutherland, 1984a; Connell and Hall, 1987). The Kirkhill site thus has crucial bearing on the problems of the timing, number and extent of Devensian glaciations in Scotland (Clapperton and Sugden, 1977; Hall, 1984b; Sutherland, 1984a; Bowen *et al.,* 1986; Hall and Connell, 1991).

The details of the stratigraphic succession at Kirkhill seem assured after over a decade of sediment logging. The quarry is now infilled with refuse, but geophysical and trial pit investigations (Hall *et al,* 1989b) *indicate* that the sequence extends to the east of the former quarry, and recent work at Leys Quarry has further expanded the basic stratigraphic sequence established at Kirkhill. Several problems remain outstanding, however: the status of the Lower Buried Soil is not yet resolved (Connell and Romans, 1984) and published pollen data are scanty (Lowe, 1984). Crucially, also, the sediments at Kirkhill are not yet firmly dated. None the less, the Kirkhill succession is the longest known in Scotland and offers potential for correlations, both on land and offshore.

Conclusion

Kirkhill is a unique site of the highest importance for Quaternary studies in Scotland. Its sequence of deposits provides evidence for two interglacial phases, three separate glaciations and at least four periglacial episodes. Kirkhill has the longest succession of Quaternary deposits in Scotland (extending back over approximately 450,000 years) and is therefore a critical reference site for establishing a better understanding of the sequence and timing of glacial and non-glacial climatic episodes.

References



(Figure 8.4) Kirkhill and Leys: lithostratigraphy.

(Figure 8.5) Kirkhill Quarry, south-east face B (1984). Developed in the Kirkhill Lower Sands and Gravels is the Kirkhill Lower Buried Soil, with its striking bleached horizon. The soil is truncated and overlain by laminated organic muds and sands, and then by periglacial slope deposits of Kirkhill Gelifluctate 3. These rubble layers have been partly reworked to form the Kirkhill Upper Till. The section is about 6 m high. (Photo: J. Jarvis.)