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# MOSS OF CRUDEN

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## Highlights

The Moss of Cruden is a key locality for a suite of flint gravels of pre-Quaternary origin. Like the quartzite gravels at Windy Hills, the syn- and post-depositional sedimentary characteristics of the flint gravels are a unique source of evidence for interpreting the history of landscape evolution in north-east Scotland during the late Tertiary and Quaternary.

## Introduction

The Moss of Cruden site (NK 028403) occupies an area (0.85 km<sup>2</sup>) at the top of a broad ridge orientated south-west to north-east, approximately 10 km south-west of Peterhead. The ridge, which reaches a maximum altitude of 139 m OD is the most important locality for the Buchan Ridge Formation, part of the Buchan Gravels Group (McMillan and Merritt, 1980). These gravel deposits are notable for:

1. the presence of Chalk flints;
2. a highly distinctive lithology of flint and quartzite clasts with a matrix of kaolinitic sand;
3. the advanced degree of post-depositional alteration.

Flint gravels in Buchan were first described by Christie (1831) and subsequently generated considerable scientific interest (Ferguson, 1850, 1855, 1857, 1877, 1893; Salter, 1857; Jamieson, 1858, 1865, 1874, 1882b, 1906; Wilson, 1886; Flett and Read, 1921). Despite much recent work (Koppi and FitzPatrick, 1980; McMillan and Merritt, 1980; Kesel and Gemmell, 1981; McMillan and Aitken, 1981; Merritt, 1981; Gemmell and Kesel, 1982; Hall, 1982, 1983, 1984c; Merritt and McMillan, 1982; Saville and Bridgland, 1992), the age and origin of the Buchan Gravels remain controversial, but there is no doubt that these deposits are of key importance for understanding Tertiary and early Pleistocene environments in north-east Scotland. Recent and continuing excavations at Moss of Cruden (Hall *et al.*, unpublished data) have added to the interest of the site by the discoveries of a small outlier of sandstone of probable Devonian age adjacent to the flint gravel margin and two masses of weathered Lower Cretaceous sandstone, apparently *in situ* and underlying the Buchan Ridge gravels.

## Description

The Buchan Ridge Formation comprises deposits of flint gravel found at altitudes of 75 m to 150 m OD discontinuously capping the summits of a broad ridge running south-west from Den of Boddam (NK 115415) to Hill of Dudwick (NJ 979378). These gravels probably reach their maximum extent at Moss of Cruden, where a thickness of at least 25 m has been recorded (McMillan and Aitken, 1981). Present exposures, however, are poor and infrequent.

The deposit at Moss of Cruden comprises white, clay-bound, coarse gravels with minor sandy and silty units. The gravel ranges from granule to boulder size and is composed mainly of flint with metaquartzite and vein quartz. Flint and metaquartzite clasts are generally well-rounded and bear numerous chatter marks. The deposits originally contained small numbers of less siliceous clasts, which have decomposed to balls of white, kaolinitic, sandy clayey silt (McMillan and Merritt, 1980).

Sandy units are composed of quartz and flint with seams of muscovite. Both sand and gravel units are bound and, in places, supported by white, sandy clayey silt consisting of well-ordered kaolinite with minor illite (Hall, 1982). The base of the gravels rests on kaolinized granite and gneiss (McMillan and Merritt, 1980; Hall, 1983, 1987; Hall *et al.*, 1989a).

Recent excavations (A. M. Hall *et al.*, unpublished data) on the north-western edge of the ridge

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have shown that the flint gravel margin approaches to within a few hundred metres of a small, concealed outlier of red-brown arkosic sandstone of probable Devonian age. The Moreseat locality on the south-eastern margin of the ridge is famous for the occurrence of large masses of Lower Cretaceous greensand, previously interpreted as erratics transported to the site by ice from the Moray Firth (Jamieson *et al.*, 1898; Hall and Connell, 1982). Recent work has revealed, however, that the Lower Cretaceous sandstones are more extensive beneath the lower slopes of the Moss of Cruden than previously thought, and that these rocks are probably *in situ*. Evidence for this interpretation includes the manner in which mottled, red silts, representing highly weathered Lower Cretaceous sediments, pass below the north-west margin of the Buchan Ridge gravels north of Smallburn (NK 019407).

On the crest of Moss of Cruden, the Buchan Ridge Formation is overlain by a variable thickness of white to grey, gravelly till incorporating occasional erratics of fresh Peterhead granite (Figure 8.2). To the north of the ridge, a sheet of soliflucted flint gravel, up to 2 m thick, extends well downslope on to sandy, weathered granite. North of Moreseat, recent excavations have shown that the gravels are locally overlain by two tills, which are separated by a peat of interglacial or interstadial origin.

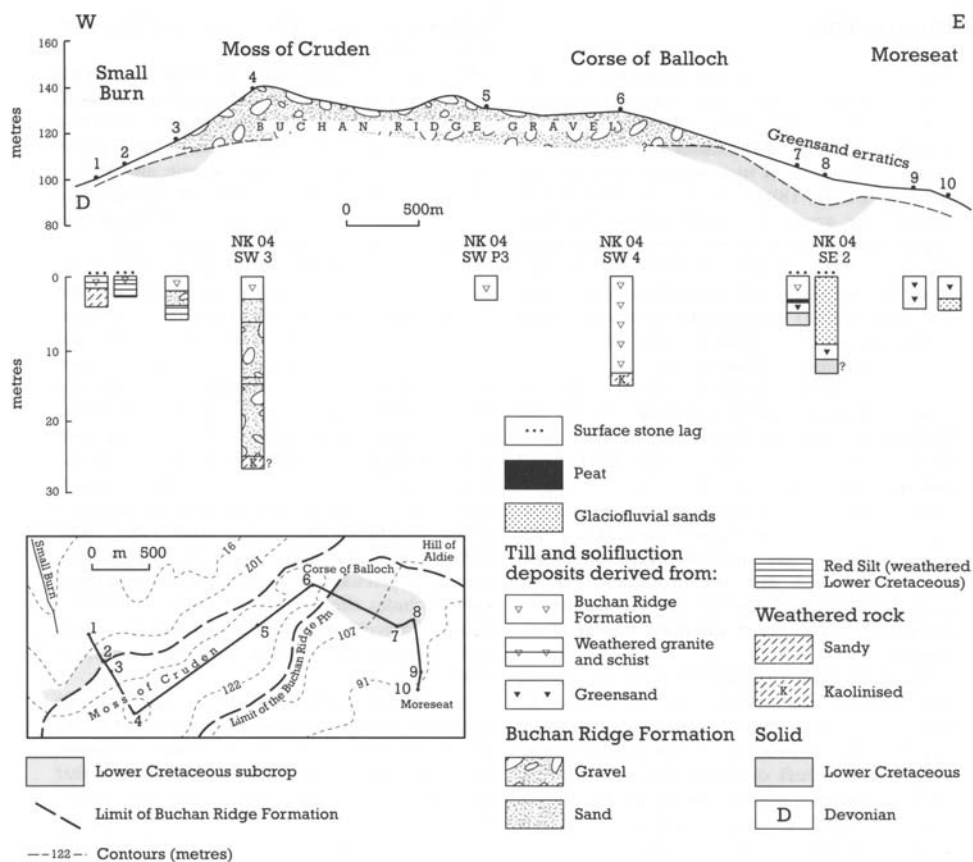


Figure 8.2: Schematic cross-section through the Moss of Cruden ridge. Borehole and pit data are from McMillan and Aitken (1981), Hall and Connell (1982) and A.M. Hall *et al.* (unpublished data).

## Interpretation

The presence of flint gravels in the Buchan area was first described by Christie (1831). Ferguson (1850, 1855, 1857, 1877, 1893) noted the rounded character of the clasts and suggested an origin as a beach, an idea initially supported by Jamieson (1858, 1882b). Jamieson (1865, 1874) thought the gravels to be pre-glacial, but later suggested deposition by ice moving south from the Moray Firth (Jamieson, 1906). More detailed study of petrology and sedimentology led Flett and Read (1921) subsequently to favour earlier interpretations of the gravels as pre-glacial beach deposits, possibly of Pliocene age.

Several studies have added much new information about these distinctive deposits (Koppi and FitzPatrick, 1980; McMillan and Merritt, 1980; McMillan and Aitken, 1981; Merritt, 1981; Kesel and Gemmell, 1981; Hall, 1983), but their origins remain highly controversial (Merritt and McMillan, 1982; Gemmell and Kessel, 1982; Hall, 1982, 1984c). Three main areas of recent discussion can be identified: first, the provenance of the gravel constituents; second, the mechanism or mechanisms of transport; and third, the age of the deposits.

The three main components of the gravels are flint, quartzite and kaolinitic silts and sands. The origin of each of these components has been disputed. The two sources of flint that have been proposed are: Chalk outcrops beneath the Moray Firth, transported southwards as glacial erratics (Jamieson, 1906; Kesel and Gemmell, 1981); or Tertiary weathering of a former Chalk cover (Wilson, 1886), with concentration into later fluvial (Hall, 1982, 1983) or marine gravels (Koppi and FitzPatrick, 1980; McMillan and Merritt, 1980). The recent discovery of little-worn, nodular flint in gravels at the Moss of Cruden indicates that some of the flints are not far-travelled and is consistent with reworking of a nearby remanié flint deposit. This interpretation is also consistent with the discovery that the gravels locally rest on Lower Cretaceous sandstone.

According to Flett and Read (1921), the quartzite clasts are distinct in character from the Dalradian quartzites of north-east Scotland, but recent mineralogical study has demonstrated many similarities (Kesel and Gemmell, 1981). An overlooked possible additional source is the Old Red Sandstone (Hall, 1984c), whose basal conglomerates contain large amounts of well-rounded Dalradian quartzite cobbles (Read, 1923; Peacock *et al.*, 1968).

The kaolinitic sand matrix has been interpreted as the result of secondary infilling of an openwork sandy gravel by kaolinitic fines due to alteration and breakdown of some clasts in the gravel (McMillan and Merritt, 1980; Merritt and McMillan, 1982), or glacial transport and deposition of clay-rich facies of the gravels as till (Kesel and Gemmell, 1981; Gemmell and Kesel, 1982).

The origin of the Buchan Ridge Formation has been variously interpreted. Evidence adduced for a beach origin includes the presence of chattermarked clasts (Flett and Read, 1921; Koppi and FitzPatrick, 1980), the presumed original openwork character of the deposit (McMillan and Merritt, 1980) and the geomorphological setting of the deposit (Flett and Read, 1921). In contrast, a fluvial origin has been invoked to explain the sedimentary structures, clast rounding and quartz grain surface textures, and the association with a deeply weathered land surface (Hall, 1982, 1983, 1986, 1987). The third proposed origin is as a glacial or glaciofluvial deposit. Supporting evidence includes the presence of matrix-supported beds of gravel and the breakage of previously well-rounded quartz grains (Kesel and Gemmell, 1981).

The presence of kaolinized clasts throughout the entire known thickness of the Moss of Cruden gravels and the evidence of topographic inversion since deposition, have allowed agreement that the flint gravels are older than all known Pleistocene deposits in Buchan. Following on from their interpretation of the gravels as early glacial or glaciofluvial deposits, Kesel and Gemmell (1981) suggested a Pliocene or early Pleistocene age. Flett and Read (1921) also originally proposed a Pliocene age based on long-range height correlations with marine deposits in southern England. McMillan and Merritt (1980) suggested that the degree of post-depositional weathering indicates prolonged alteration under warm climates in the middle to late Tertiary; Hall (1982, 1983, 1985) proposed a Neogene age based on comparisons with types of deep-weathering cover recognized by him in Buchan. However, firm dating of the flint gravels is not yet possible from the evidence available.

The Buchan Ridge Formation is a unique deposit in Scotland. The review above reveals that many questions about the provenance, origin and age of these gravels remain unanswered, and further advances may await the opening of deep sections. However, it is clear that the flint gravels have a bearing on several important problems of Scottish pre-Pleistocene and Pleistocene landscape history including:

1. the former extent of Cretaceous cover in north-east Scotland;
2. the nature of Tertiary weathering environments in Buchan and landscape evolution in the

region (Hall, 1985, 1986);

3. the timing of the onset of regional glaciation in Scotland (Hall, 1984c; Sutherland, 1984a).

The Moss of Cruden site sheds important new light on long-term rates of denudation in this part of Scotland. The Peterhead granite, which partly underlies the Moss of Cruden, is of Caledonian age; it intrudes Dalradian metasediments. It was unroofed by Devonian times and later buried by Devonian sediment. This Old Red Sandstone cover was almost completely removed at the site, apart from a thin remnant now represented by the small outlier of arkosic sandstone, prior to marine transgression and deposition of sandstone in the Early Cretaceous. Further burial by Late Cretaceous Chalk is demonstrated by the presence of nodular Chalk flints in the basal layers of the Buchan Ridge Gravels. The Cretaceous cover was probably largely stripped in response to early Tertiary uplift, and the survival of the small remnants of Devonian and Cretaceous sediments at Moss of Cruden are undoubtedly a result of their subsequent burial by the Buchan Ridge Gravels in the (?) late Tertiary. The granite and metasediments at Moss of Cruden have therefore been protected from erosion for the last c. 350 Ma. It is unlikely, however, that these igneous and metamorphic rocks were ever deeply buried and this allows the possibility of a highly complex weathering history in these rocks.

The only outcrop of the Buchan Ridge Formation of comparable dimensions to the Moss of Cruden deposit lies beneath the Hill of Aldie (NK 059414), but exposure is extremely poor. Fieldwork there suggests the existence of a flint gravel deposit extending over an area of about 1 km<sup>2</sup> and reaching depths of at least 17.8 m (McMillan and Aitken, 1981). Smaller deposits occur at Whitestones Hill (NJ 979389), Sandfordhill (NK 115416) and Den Muir (NK 105406), but the possibility of glacial and periglacial disturbance is much greater, particularly at the last two localities.

The Windy Hills Formation consists of quartzite gravels with occasional flints and shows many similarities with the Buchan Ridge Formation (see Windy Hills). However, these two gravel bodies are lithologically distinct and may be of different origin and age (McMillan and Merritt, 1980; Kesel and Gemmell, 1981; Hall, 1983).

## Conclusions

Moss of Cruden is the type area for the unique flint gravels of Buchan. These deposits include weathered material and are locally overlain by till. Although acknowledged to be pre-Quaternary in age (see Windy Hills above), their origin is still arguable and has been ascribed to marine, river and glacial processes. The Moss of Cruden gravels are different in their composition from those at Windy Hills and the two deposits may be of different age and origin. Like the gravels at Windy Hills, those at Moss of Cruden provide unique evidence for interpreting the long-term evolution of the landscape during the Quaternary ice ages and earlier.

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