Letters to the Editors

THE 'PLIOCENE' GRAVELS OF BUCHAN: A REAPPRAISAL

SIRS—Kesel and Gemmell’s recent reappraisal (1981) of the distinctive flint and quartzite ‘Pliocene’ gravels of Buchan presents new data, including examination of sand grains under the Scanning Electron Microscope (SEM), which may assist in elucidating the age and origin of these enigmatic deposits. Although they agree with our interpretation (McMillan and Merritt 1980) that the deposits at Windyhills [NJ 801 399] and at the ‘Buchan Ridge’ represent lithologically distinct units, and that the Windyhills gravels are in situ and of fluviatile origin, they reject our explanation of the ‘Buchan Ridge Gravels’. Here we use our (1980) term Buchan Ridge Gravels to define the in situ clay-bound flint and quartzite gravels forming the ‘Buchan Ridge’ (Flett and Read 1921) which extends from Den of Boddam [NK 114 415] to Hill of Dudwick [NJ 979 378].

Our interpretation is based largely on field and borehole evidence from recent IGS surveys (Merritt 1981; McMillan and Aitken 1981). Kesel and Gemmell examined, in some detail, near-surface deposits from natural and temporary sections. Broadly similar interpretations are offered for the Windyhills Gravels, partly because existing pit-faces reveal a representative thickness of the deposit. However, for the deposits at the Buchan Ridge there are radically different explanations mainly because Kesel and Gemmell were unable to collect samples representative of material at depth which we (1980) defined as Buchan Ridge Gravels. Without boreholes it was not possible for them to appreciate the total thickness of the deposit. For example, in figure 3 of their paper, profile B shows that pits at the Moss of Cruden [NK 027 404] reached less than 5 m whereas IGS borehole 04SW3 (McMillan and Merritt 1980, fig. 2, borehole E), drilled nearby, failed to bottom kaolinitic clay-bound gravels and interbedded sands at a depth of 25 m.

Kesel and Gemmell state that the deposits which they name the Cruden Flint Gravels (i.e. Buchan Ridge Gravels) comprise till and fluvioglacial material ‘carried landward by glacial activity’ from the floor of the Moray Firth or North Sea. We disagree as we believe the sections available to them are not representative of the full thickness of deposits at the Buchan Ridge. We accept that the upper part of the sequence has been glacially modified but contend that the bulk of the deposit is in situ and formed as a beach shingle. Although we examined no sections at the Buchan Ridge showing a contact between reworked and in situ deposits we are prepared to accept that this is the case. At Windyhills a fluvioglacial sand and gravel unconformably overlies in situ ‘Tertiary’ gravels, both deposits being...
capped by a matrix-supported cryoturbated layer up to 1·5 m thick (McMillan and Merritt 1980, fig. 1, locality C).

In addition to sampling difficulties at the Buchan Ridge we suspect that Kesel and Gemmell have paid insufficient regard to diagenetic modification of the deposits. Comparisons are made with the work of Friedman (1967) who described distinctions between fluvial and beach sands in terms of a number of statistical parameters. In relating modern with ancient sediments, however, Friedman emphasised the effects of diagenetic changes such as secondary overgrowths, solution and the introduction of interstitial material on size frequency distribution of sands. The flint and quartzite gravels of Buchan are highly weathered, and, in their present state, cannot be related simply to modern sediments whether of beach or fluvial origin.

The SEM micrographs of grains portrayed by Kesel and Gemmell allow a further line of investigation but the results are ambiguous, either because of unrepresentative sampling or as a result of shortcomings of such analytical work in general as has been noted, for example by Brown (1973). It is particularly difficult to distinguish the features attributable to glacial and high-energy aqueous environments. In any case it is not surprising to find glacial features on grains taken from surficial deposits on the Buchan Ridge but it is perhaps more significant that samples collected at depth from IGS borehole 04SW3 (McMillan and Merritt 1980, fig. 2, borehole E) exhibited no generally accepted glacial features but only those compatible with severe post-depositional weathering.

Kesel and Gemmell argue that the ‘Tertiary’ gravels underlying the Buchan Ridge were ‘brought onshore by glacial action’, but it is not clear whether they consider these deposits to have been ice-rafted. If so, none of the rafted blocks referred to approach the mass of the Buchan Ridge Gravels (about 27 million m$^3$, Merritt 1981). Is it plausible that ice of a late-Pliocene or early-Pleistocene glaciation which has left no other identified traces in Scotland transported these gravels more than 30 km from the floor of the Moray Firth to a position over 110 m above sea-level?

Kesel and Gemmell reject our interpretation that the Buchan Ridge Gravels are largely open-work beach gravels with a secondary infill of sandy kaolinitic clay because they find sharp contacts between beds of sand and gravel and beds of matrix-supported gravel which they believe to be till. Certainly, large parts of the Buchan Ridge Gravels are matrix-supported. We state (1980) that some of the kaolinitic matrix must have been derived from previously deeply weathered bedrock and was incorporated during deposition. However, if much of the original beach sand and shingle gravel comprised locally derived granite and metasediments, we maintain that the constituent minerals other than quartz, muscovite and heavy minerals would have decomposed to the sandy kaolinitic clay which now forms a supporting matrix to the more durable flint and quartzite clasts. It follows, that many of the very angular or deeply etched sand grains observed by Kesel and
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Gemmell may have come directly from decomposed granite clasts and, as they show no indication of the abrasion that might otherwise be expected in beach or fluviatile sand, might be considered to be of glacial origin.

Kesel and Gemmell prefer a late-Pliocene or early-Pleistocene date for both the Windyhill and Buchan Ridge Gravels and refer to flint and quartzite gravels in Suffolk and Germany with which they believe the Buchan deposits show ‘marked similarities’. However, if analogies are to be made then they should be between gravels of broadly similar original composition such as the various Tertiary gravels of Devon, Cornwall and Pembrokeshire (Hamblin 1973; Edwards 1973; Wilson 1975; Allen 1981 and Isaac 1981) which comprise a variety of quartzo-feldspathic igneous rocks, hornfels and sedimentary rocks in addition to quartzite and flint. Weathering observed in the Buchan Ridge Gravels and Windyhills Gravels is much more severe, for example, than that in the St Erth Beds of Cornwall dated on fossil evidence to be late-Pliocene to early-Pleistocene, but matches more closely that observed in the Bullers Hill Gravels of Devon, which are possibly Eocene.

Finally, we are not convinced that the Buchan Ridge Gravels are of glacial origin and maintain our (1980) view that they are mainly in situ beach deposits in which the kaolinitic sandy clay matrix results from extensive, post-depositional weathering of granite and metasedimentary clasts during the Tertiary. The flints in the gravels are either derived directly from the Chalk or from a residual deposit similar to the Tower Wood Gravels or Peak Hill Gravels of South Devon.

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Letters to the Editors

The 'Pliocene' Gravels of Buchan: A reappraisal: Reply.

SIRS——Although supporting our (Gemmel and Kesel 1979) contention that the ‘Pliocene’ gravels of Buchan can be divided into two lithologically distinct units, the Windy Hills gravels and the Cruden Flint gravels, McMillan and Merritt (1980) and Merritt and McMillan (1982) disagree with our interpretation (Kesel and Gemmell 1981) of the genesis of the Cruden Flint gravels (their Buchan Ridge gravels). They suggest that as we were not privy to borehole data, we were unable to appreciate the full thickness of the deposit. This we dispute, for we declared (Kesel and Gemmell 1981, p. 190) that . . . ‘the thickness of the unconsolidated deposits is possibly as much as 15–20 m’.

McMillan and Merritt (1980) note that the upper part of the Cruden Flint gravels have been glacially modified, but admit (1982) that no contact between reworked and in situ deposits has been identified. They suggest however that the pits available to Kesel and Gemmell (1981) were not representative of the character of the full deposit. Against this idea, bore logs (McMillan and Aitken 1981) from the Cruden Flint gravels indicate that the closest borehole (McMillan and Merritt 1980, fig 2, E) to our (1981) pits on Moss of Cruden reveals Cruden Flint gravels outcropping at the surface. In addition, our highest pit on Cruden Moss lies within the area mapped by McMillan and Merritt (1980, fig 2) as ‘concealed Buchan Ridge gravels’ rather than ‘concealed Buchan Ridge gravels’. We thus contend that we have used valid samples of the Cruden Flint gravels in our analyses.

Having established that we are indeed examining the Cruden Flint gravels, we cannot support the opinion of Merritt and McMillan (1982) that the deposit is largely open-work beach gravel with subsequent matrix infill. The gravel is, as they concede, matrix-supported. They consider the clay matrix to be the product of the weathering of granitic or metasedimentary clasts held within the gravels. We would agree that extensive decomposition of such clasts has taken place, but the good exposures obtained in the pits reveal that the clasts form coherent ‘ghosts’, have not disintegrated and are themselves matrix-supported. This demonstrates that some matrix material predates the decomposition of the clasts, and therefore must be considered a characteristic of the original deposit. Our pits (e.g. Kesel and Gemmell 1981, pl. 1B) also reveal alternating discrete sand and cobble beds. Such a bedding pattern cannot be a secondary product of diagenesis and translocation of sediment (McMillan and Merritt 1980, p. 23), and must be considered an original facet of the deposit.

Open-work beach gravels are highly permeable, and fines will readily pass

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through them. Under conditions such as those described by McMillan and Merritt, fines produced by the kaolinsation of included clasts would be washed downwards. Infilling will take place, if at all, from the base of the deposit upwards. At higher levels, cobbles of flint and quartzite would come into contact as the interstitial fines wash away. Thus the mechanism suggested by McMillan and Merritt just might produce a matrix-supported situation in the basal layers, but, as a corollary, all higher levels would be clast-supported. Such a situation has been revealed neither in our pits, nor in the borehole logs of Merritt (1981) and McMillan and Aitken (1981). We therefore find the suggestion that the Cruden Flint gravels are a beach deposit unacceptable.

The sedimentary analyses performed in our (1981) paper indicate that sand beds in both the Windy Hills gravel and the Cruden Flint gravel are fluvial according to Friedman's (1967) indices. Although we are aware of the problems of diagenesis, our conclusions were supported by sedimentary bedding and structures, data not readily available from boreholes. It is interesting here that Merritt and McMillan raise no dispute about our interpretation of the Windy Hills gravel despite presumed diagenetic effects. It is hard to see why criteria acceptable in one case should not also be so for the Cruden Flint gravels.

The crux of Merritt and McMillan's argument as to the genesis of the Cruden Flint gravels rests on SEM analysis of grain surface textures. Their statement that '. . . it is not surprising to find glacial features on grains taken from surficial deposits on the Buchan Ridge.' (Merritt and McMillan 1982) might be fair comment were it not for the fact, as shown above, that our (1981) micrographs were of grains taken from levels that IGS bore logs confirm as 'Buchan Ridge gravels'. Accordingly, we maintain that SEM analyses support our suggestion that the gravels have undergone glacial transport and deposition.

Kesel and Gemmell (1981) cite the presence of ice-rafted material in north-east Scotland (e.g. Cumming and Bate 1933) as evidence that it is feasible for ice to have transported material into Buchan from the bed of the North Sea. We contend that this is a more plausible source for the gravels than a postulated chalk cover, no trace of which can now be found. If the Cruden Flint gravels were an ice-rafted block, we would anticipate finding glacial characteristics only on grains taken from the contact zone between the gravels and the transporting ice. Our evidence suggests that glacial characteristics are found throughout the body of the gravels. We therefore believe the gravels to be true glacial deposits.

As Merritt and McMillan note, gravels similar to the Cruden Flint gravels and the Windy Hills gravels have been recorded from a wide range of locations. The ages attributed to these gravels range from Eocene to early Pleistocene (for references, see Merritt and McMillan 1982; Kesel and Gemmell 1981). Kaolinsation was widespread in Europe during the Mesozoic and the Tertiary (Lidmar-Bergstrom 1982), and possibly even occurred in the early Pleistocene (Bakker 1967). It is thus entirely feasible for Quaternary glacial and fluvial agencies to have
incorporated kaolinitic material into their deposits. We therefore reject the implication of Merritt and McMillan that the presence of large amounts of kaolinitic matrix material in the Windy Hills and Cruden Flint gravels requires these deposits to be of Tertiary age.

We reaffirm our (1981) conclusions as to the origin and age of the Windy Hills gravel and of the Cruden Flint gravel.

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Letters to the Editors

THE ‘PLIOCENE’ GRAVELS OF BUCHAN: A REAPPRAISAL: DISCUSSION

SIRS—Recent studies by Kesel and Gemmell (1981) and others (Koppi and Fitzpatrick 1980; McMillan and Merritt 1980) have provided much new information about the flint and quartzite ‘Pliocene’ gravels of Buchan, yet no consensus has emerged as to their origin. In view of the current interest in the Buchan gravels I wish to present some additional observations on these distinctive deposits.

The Buchan gravels are basically composed of metaquartzite and flint clasts, quartz sand and kaolinitic fines. Post-depositional weathering has been severe and has obscured their original composition.

In all outcrops stable metaquartzite, vein quartz and flint clasts are predominant. Other less resistant clasts are kaolinised (Koppi and Fitzpatrick 1980) but comprised no more than 10% of the original cobble fractions. The sand fractions are dominated by quartz, with some flint and muscovite, although the rare presence of strongly corroded alkali feldspars suggests a formerly more diverse sand mineralogy. However, impregnated sections of closely-packed sands from Windyhill show few clay-filled cavities indicative of the former presence of unstable minerals.

The kaolinitic clay and silt matrix is mainly of detrital origin. Although the degree of clast alteration decreases with depth at Windyhills and Moss of Cruden (McMillan and Merritt 1980) the matrix clays remain homogeneous. At Windyhills the matrix clay mineralogy of b-axis disordered kaolinite, with minor illite is unchanged throughout the entire 15 m of deposit. At Moss of Cruden the crystallinity index values (Hinckley 1954) for well-ordered kaolinite matrix clays vary only between 0·84 and 1·20 in 23·5 m of deposit. The uniformity of clay mineralogy over such depths demonstrates a mainly detrital origin for the kaolinite.

These highly stable components were probably derived from a deeply weathered landsurface. However the gruss-type weathering covers found throughout NE Scotland were not a major source for the Buchan gravels. These saprolites show a low degree of chemical alteration, with low clay contents and diverse clay mineralogies. A more feasible source lies in older kaolinitic regoliths, remnants of which may exist at a few locations. A further possibility is re-cycling of pre-existing Tertiary gravels and the dome-like precipitation surfaces found on certain rounded quartz grains are evidence for previous stabilisation in environments of high silica mobility (van der Waals 1967).

Perhaps the most distinctive feature of the Buchan gravels is the abundance of
flint in the Buchan Ridge gravels and the rare presence of flint and chert in the Windyhills gravels. The flints contain Cretaceous fossils (Salter 1857). It has been suggested that the flints were transported by ice from Cretaceous rocks offshore (Jamieson 1906; Kesel and Gemmell 1981). However the other components of the gravels are of undoubted terrestrial and probably westerly (Kesel and Gemmell 1981) origin and it is unclear how any flints carried by ice from the north and NE could have been incorporated into the deposits.

Derivation from a former Cretaceous cover is more feasible (Ferguson 1893; McMillan and Merritt 1980). Cretaceous rocks outcrop extensively in the Moray Firth (Chesher and Bacon 1975) and may well have locally overstepped onto basement around the basin margins. Kaolinitic remanié deposits derived from weathering of these rocks (cf. Hamblin 1973) would provide flint and chert clasts for later fluviatile sediments.

The severity of post-depositional alteration indicates prolonged weathering of the gravels. The reconstructed original composition suggests formation prior to development of gruss-type weathering covers, formed under interglacial or preglacial temperate enviroments (Basham 1974; Wilson and Tait 1977). The Buchan gravels bear many similarities to Eocene deposit in S.W. England (Hamblin 1973) and to Neogene and early Pleistocene sediments around the eastern margins of the North Sea basin (Wirtz and Illies 1951; van den Broek and van der Waals 1967; Spjeldnaes 1975; Friis 1976).

However evidence of fracture and breakage of rounded quartz grains from the Windyhills deposits and the upper zones of the Buchan Ridge gravels may indicate episodes of glacial transport (Kesel and Gemmell 1981). At Windyhills the proportion of grains affected is small and breakage may be a result of cobble-to-cobble impact during high energy acqeous transport. At Moss of Cruden fracturing is more widespread. In I.G.S. borehole 04SW3 (McMillan and Merritt 1980, fig. 2, borehole E) fractured grains extend down to 24 m and in places clasts are matrix-supported, with broken pebbles and splinters of flint. If these characteristics are not drilling artefacts then the Moss of Cruden deposit must have been through a final phase of glacial transport.

Available evidence indicates that the Windyhills gravels are fluviial deposits of Neogene or early Pleistocene age. The Moss of Cruden and Den of Boddam deposits appear to be locally transported glacial erratics of similar origin and age.

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