# Ground stability and foundation conditions, Cainozoic of north-east Scotland



Merritt, J W, Auton, C A, Connell, E R, Hall, A M, and Peacock, J D. 2003. Cainozoic geology and landscape evolution of north-east Scotland. Memoir of the British Geological Survey, sheets 66E, 67, 76E, 77, 86E, 87W, 87E, 95, 96W, 96E and 97 (Scotland). Contributors: J F Aitken, D F Ball, D Gould, J D Hansom, R Holmes, R M W Musson and M A Paul.

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## Contents



## Engineering properties of glacigenic sediments

It is well known that glacial deposits often present problems to the ground engineer owing to their inherent variability and the complex sequences in which they lie. Observations on modern glaciers have enabled the development of a process-based model (Boulton and Paul, 1976) that has been found applicable to several areas of lowland Britain (Paul and Little, 1991). This model distinguishes erosion and transport processes, which are responsible for the grading and plasticity of the sediments, from depositional and postdepositional processes, which are responsible for the packing and strength of the materials. At the larger scale, the model identifies a number of recurrent landform-sediment associations, which describe the geomorphology and facies architecture of the glacigenic sequences as a whole.

Based on the analysis of commercial site investigation data held at the British Geological Survey, it is possible to classify foundation materials in the study area into three broad assemblages.

> i Relatively thin (usually less than 5 m) glacigenic sequences, which lie on bedrock and may be weathered or glacially tectonised. They usually extend to surface, and comprise coarse glacial tills, sands and gravels. These sequences are normally found in upland areas and may be locally extensive.
> ii Thick (5–10 m or more), generally complex glacigenic sequences of interdigitated tills, glacioflu vial sands, and glaciolacustrine/glaciomarine silts and clays, typically found as local valley or low ground embayment infills.

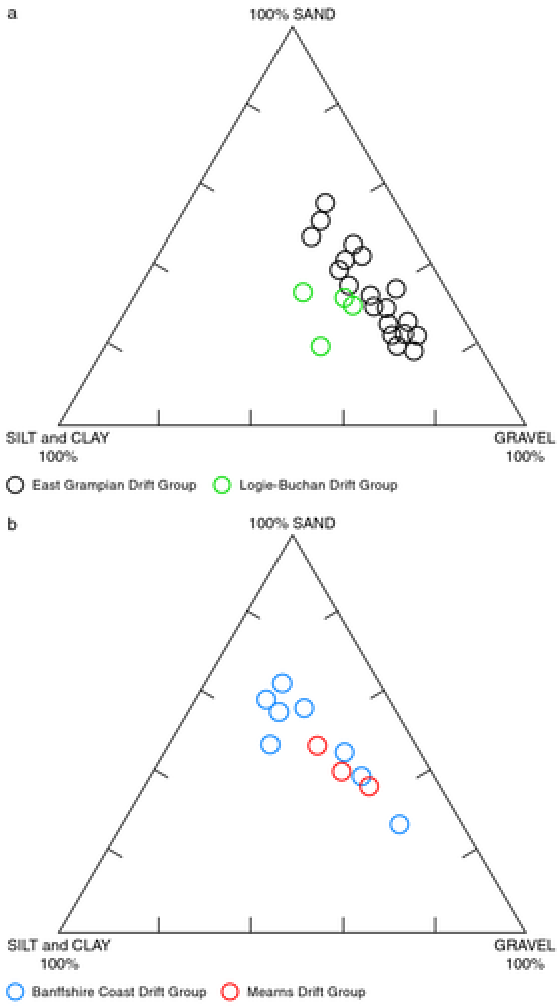
iii Thick (over 10 m), postglacial sequences of clays, silts and sands, together with interbedded peats, which overlie glacigenic sequences, found locally in bedrock depressions.

File:P915251.png
Generalised flow-lines of ice during the Main Late Devensian glaciation. P915251.

Assemblage i is widespread across the area and appears to be present in the outcrop of each of the drift groups shown in P915251 and described in Quaternary lithostratigraphy and correlation. It seems common within the outcrops of the Central Grampian, East Grampian and Banffshire Coast drift groups, where it has been encountered in excavations for several road improvement schemes. Assemblage ii, by contrast, is more restricted in extent, being confined to the coastal lowlands and the lower parts of the adjacent valleys. To the west and north of Aberdeen excavations in the Don and Ythan valleys have shown local development of this assemblage involving sediments of the Logie-Buchan Drift Group. Similarly, excavations in the Feugh valley to the south-west of Aberdeen have revealed analogous sequences in sediments of the East Grampian Drift Group. Assemblage iii has been reported only rarely, mainly from coastal settings. In the Peterhead area, excavations to 20 m depth have revealed peats, sands and gravels resting on glacial deposits of both the Banffshire Coast and Logie-Buchan drift groups. Around St Fergus, similar sequences have been reported extending to 15 m depth.

Most of the geotechnical properties described below deal with glacigenic successions, dominated by glacial diamictons (tills) and sampled from shallow boreholes and trial pits. A more detailed study of engineering properties of glacial sediments from sites throughout northeast Scotland (Ramsay, 1999) shows, however, that at any particular location, site investigations are required to adequately characterise the geotechnical properties of specific Quaternary sequences. Geotechnical information is not presented for the Central Highland Drift Group owing to the sparse, and unrepresentative coverage of site investigation data within its area of outcrop in the district.

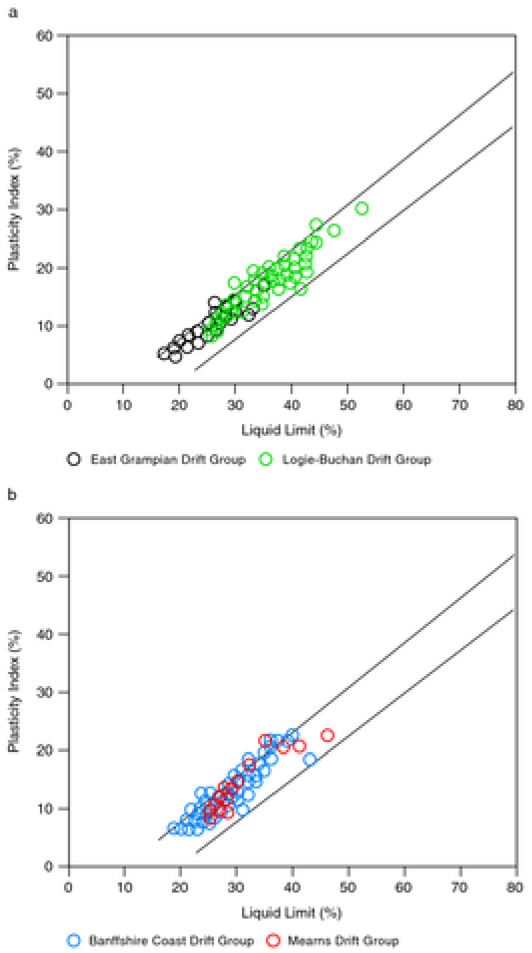
## Particle size




Grain size plots for four of the drift groups in north-east Scotland. P915258.

Ternary composition plots (P915258) show that the glacial and glaciofluvial deposits within all of the drift groups are broadly sandy gravels, with an admixture of fine (silt and clay) particles. They are thus classified as clast-dominant to well-graded diamictons in the scheme of McGown and Derbyshire (1977). In detail, the sediments of the East Grampian Drift Group have a relatively constant proportion of fines (15–20%), although the proportions of sand and gravel can vary greatly. The sediments of the Mearns Drift Group appear indistinguishable from those of the East Grampian Drift Group on granulometric criteria alone. By contrast, sediments of the Logie-Buchan and Banffshire Coastal drift groups differ granulometrically both from those of the other two and from one another. Those of the Logie-Buchan Drift Group contain up to 40 per cent fines and around 30 per cent each of sand and gravel, whereas those of the Banffshire Coast Drift Group, although sandy, generally contain less gravel (less than 40 per cent) and have a fines content in the range 20 to 40 per cent.

## Liquid and plastic limits



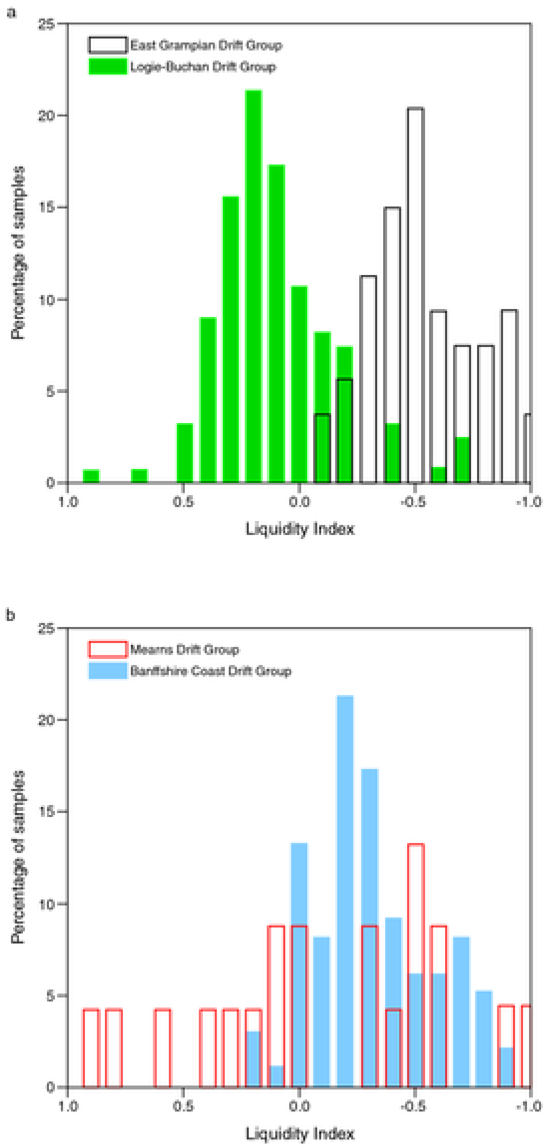

Plots of Plasticity Index versus Liquid Limit for four drift groups in north-east Scotland. P915259.

Glacial tills show a relationship between their liquid limit (LL) and plasticity index that arises from their characteristic particle-size distributions, which are themselves, in part, the result of crushing processes and subsequent modification (Dreimanis and Vagners, 1971; McGown, 1971), and also reflect the provenance of the deposits. This relationship is expressed on the plasticity chart as a straight line (the T-line of Boulton and Paul, 1976). Plasticity charts for glacial sediments from four of the north-east Scotland drift groups considered here (P915259) illustrate that they conform to this linear relationship. Comparison of these charts shows a number of differences between the drift groups, which reflect the differences in their grain-size and source material. Sediments of the East Grampian Drift Group (P915259a) are of relatively low plasticity (LL 20–30%) and values are scattered around the T-line, probably owing to their low fines content, and the possible inclusion of some weathered bedrock in the 'till' category. The field of values for sediments sampled from the Mearns Drift Group (P915259b) overlaps that for samples from the East Grampian Drift Group, which is expected from the apparently similar granulometry and clay-size mineralogy of both sets of samples.

The sediments of the Banffshire Coast Drift Group (P915259b) also plot along the T-line. Those from the Lhanbryde area are of generally low plasticity (LL 25–35%), which reflects their sandy character and incorporation of material from the local sandy bedrock. In fact, the tills at Lhanbryde are probably representative of the Central Grampian Drift Group. Those from St Fergus have a generally greater range of liquid limits (25–50%), possibly reflecting their derivation from offshore clayey strata, and also as a result, in some instances, of a concentration of fines by resedimentation processes. In a similar manner, sediments of the Logie-Buchan Drift Group (P915259a) also have generally high liquid limits (25–50%), presumably as the result of their large fines content. The probable inclusion of a number of glaciomarine and glaciolacustrine silts and clays, clayey deformation tills and resedimented deposits ('flow tills') in this group, in addition to lodgement tills, may be responsible for the spread of points below the T-line.

The mineralogy and grading of the sediments exert the fundamental control on their plasticity. P915259 indicates that the sediments of the Logie-Buchan Drift Group are the most plastic of the four groups examined and those of the East Grampian Drift Group the least. Hall and Jarvis (1995) have reported the clay mineralogy of glacial sediments in the Ellon area, and have shown that the Hatton Till Formation of the Logie-Buchan Drift Group is dominated by illites and mixed illite smectites. By contrast, the Pitlurg Till Formation of the Banffshire Coast Drift Group, near its southern limit, contains a mixture of illites, illitesmectite and kaolinite. Although their composition has not been reported in the literature, the East Grampian and Mearns drift groups, which contain largely locally derived lodgement and deformation tills, may be expected to be dominated by kaolinite and quartz flour. This is supported by a study of the clay mineralogy of soils developed on the Logie-Buchan and Mearns drift groups (Glentworth et al., 1964), which showed that the latter contain higher proportions of kaolinitic clays and vermiculite and lower proportions of illite. If all of these results, taken together, are broadly representative of the groups as a whole, then at a given clay content, sediments of the Logie-Buchan Drift Group should behave more plastically than those of the Banffshire Coast Drift Group. The sediments of the East Grampian and Mearns drift groups will be less plastic still. The results shown in P915259 confirm these comparisons.

## Water content and liquidity index



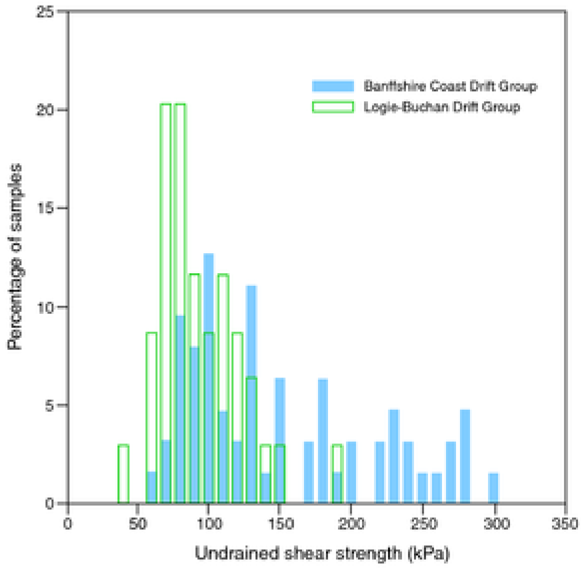

Histograms of Liquid Index of four drift groups in north-east Scotland. P915260.

The in situ water content of a fine-grained sediment is determined by its stress history (the sequence of load changes in terms of effective stress) and is thus indicative of its geological origin and subsequent postdepositional history. In general, subglacial sediments have experienced larger loading events than those from ice-marginal settings and so, for a given composition, their water contents are normally lower. This is not to imply that the stress history of a glacial sediment is a simple function of the superincumbent weight of ice: it is now recognised (e.g. Boulton and Dobbie, 1993) that pore-water pressure plays a complex role in the control of subglacial stress and that for ice-marginal sediments, episodes of drying or freezing are often the most significant events in their stress histories (Boulton and Paul, 1976).

For a given stress history, the water content of a sediment is determined by the quantity and type of its clay content, which is reflected by its liquid and plastic limits. They are generally compared in terms of their liquidity index, a normalised value of water content that is relative to their liquid (LI=1) and plastic (LI=0) limits. A review of glacigenic deposits (Paul and Little, 1991) has shown that, in many areas of Britain, subglacial lodgement tills usually have liquidity indices in the range – 0.1 to – 0.5, whereas resedimented ice-marginal diamictons normally have higher liquidity indices in the range 0.5 to 0. Thus, sediments of ice-marginal origin appear to be typically wetter and softer than their sub-glacial counterparts, a not unexpected situation, in view of the differing stress histories of these classes of sediment.

Comparison of liquidity indices across the four drift groups for which adequate data exits (P915260), shows significant differences. The sediments of the East Grampian and Banffshire Coast drift groups have relatively low liquidity indices (mostly in the range 0 to -1.0), which is consistent with a subglacial origin, whereas those of the Logie-Buchan Drift Group are higher (+ 0.5 to – 0.3), which suggests a mixed suite of both subglacial and ice-marginal deposits. The results from the Mearns Drift Group are more difficult to interpret, but may also suggest a bimodal distribution with both subglacial and ice-marginal components.

## Undrained shear strength




Histograms of Undrained Shear Strength for the Banffshire Coast and Logie-Buchan Drift Groups. P915261.

The undrained shear strength of a remoulded clay sediment is determined by its liquidity index according to a logarithmic relationship (Skempton and Northey, 1952). At the plastic limit (LI=0) remoulded clays have an undrained strength around 170 kPa; at LI=0.5 their strength is around 7 kPa and at LI= – 0.3 it is around 400 kPa, although the latter is difficult to determine accurately and may be reduced by fissuring. Thus naturally remoulded sediments, such as glacial tills, may, in the case of subglacial tills, be expected to have undrained strengths around 200 to 400 kPa and, in the case of ice-marginal flow tills, to have undrained strengths around perhaps 50 to 100 kPa. Data from two drift groups (P915261) supports these suggestions. Sediments of the Banffshire Coast Drift Group, of presumed subglacial origin, possess strengths up to 300 kPa with a modal value of 100 to 150 kPa. Those from the Logie-Buchan Drift Group, formed in a more ice-marginal setting, have strengths in the general range 50 to 150 kPa with a modal value 50 to 75 kPa. In both cases there is an expected relationship between liquidity index and undrained strength, although the absolute values of strength are less than those expected, possibly as a result of fissuring or other difficulties in testing.

## Relationship to depositional and postdepositional history

File:P915251.png
Generalised flow-lines of ice during the Main Late Devensian glaciation.

P915251.

The glacigenic deposits of north-east Scotland are divisible into five drift groups on the basis of lithology and provenance (P915251). They were deposited by three major ice streams, involving both subglacial and ice-marginal processes. The engineering properties of the sediments within each group generally reflect their differences in composition, their mode of deposition, and the degree and type of postdepositional modification (weathering, cryoturbation, solifluction etc) that has affected each unit.

Although the data is somewhat limited and scattered geographically, a general model emerges when the area is considered as a whole. The ice streams deposit subglacial till at their base, with sedimentation of flow till and melt-out till (including associated glacio-aqueous sediments) at their margins, especially where ice locally abutted against reverse slopes. This leads to the observed association of low liquidity index and high undrained shear strength in assemblages from coastal regions, where basal tills dominate, and to the association of higher liquidity index and lower shear strengths in marginal valleys plugged by mixed sedimentary infills.

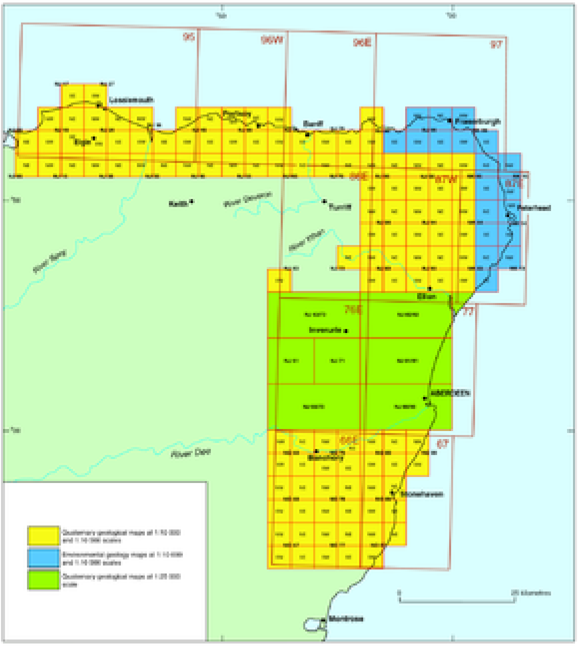
The diamictons of the East Grampian Drift Group are mostly subglacial in origin and, being derived from weathered crystalline or arenaceous bedrock, have a low liquidity index and low plasticity. The liquidity index data suggest that subglacial (deforming bed) tills also dominate the Banffshire Coast Drift Group. The Logie-Buchan Drift Group contains both subglacial and ice-marginal elements, as implied by the liquidity index and shear strength data. It suggests that ice that moved inland from the North Sea deposited basal tills along the coast, but there was supraglacial (flow till) sedimentation into the valleys at its western margin. At the few sites examined here, the Mearns Group appears to contain diamictons deposited in both ice marginal and subglacial settings.

## Deeply weathered bedrock, periglacial and postglacial deposits

The widespread development in north-east Scotland of deep weathering profiles on bedrock has important implications for ground stability conditions in the district. The nature, distribution and age of these weathering covers are discussed fully in Palaeogene and Neogene deep weathering and soil development.

The postdepositional remobilisation of glacial diamictons has been widespread within the district, but it can only be recognised at a few sites, notably where the remobilised material rests on Windermere Interstadial and Loch Lomond Stadial organic sediments. These sites demonstrate the former instability of low-angle till slopes, particularly during the Loch Lomond Stadial and their identification is important because such sites are liable to be rendered unstable by engineering works.

## Made, landscaped and worked ground, and landfill




Coverage of large-scale Quaternary geological maps of the district. P915298.

Only the largest, well-defined areas of made and worked ground are shown on the published 1:50 000 scale geological maps of the district. Many of the smaller areas are only shown on 1:10 000 and 1:25 000 scale geological maps dealing with the Drift deposits. The coverage of these larger scale maps is shown in P915298. Most of the examples of made, landscaped and worked ground, quoted below, come from recently surveyed sheets (77, 76E, 67 and 67) in the southern part of the district. Knowledge of the extent of these deposits and workings in the remainder of the district is, at best, patchy and requires revision. However, many of the observations on types of workings and man-made deposits appear typical of similar excavations and areas of made ground in the less well known northern parts of the district.

Made ground is ubiquitous within some parts of the larger built up areas, but many of the deposits are less than 1 m in thickness and their precise nature and distribution is difficult to determine by traditional geological mapping alone. The composition, thickness and extent of individual deposits can only be determined in areas where adequate site investigation records exist. For example, site investigations indicate that thick man-made deposits overlie undisturbed bedrock and Quaternary strata around the harbours of the larger coastal settlements, with jetties and breakwaters commonly constructed on reclaimed ground. Several of the larger road and railway embankments shown on Sheet 66E Banchory and Sheet 77 Stonehaven are underlain by made ground up to 15 m thick.

Embankments are generally composed of naturally occurring Quaternary sediments (soils, tills, sands and gravels etc) which have been excavated and mixed together; embankment drains are infilled with coarse crushed rock aggregate. Made ground in urban areas (particularly areas of housing and industrial regeneration) is commonly composed of mixtures of artificial inert material (builders rubble, ash and slag) and disturbed Quaternary sediments. In major civil engineering projects made ground is commonly composed of graded hard rock aggregate from local bedrock quarries, which has been faced and capped by reinforced concrete.

Spoil heaps associated with bedrock quarrying and sand and gravel workings are widespread in rural areas. Piles of granite blocks up to 20 m in height have accumulated on the valley sides adjacent to disused granite quarries on Sheet 76E Inverurie around Tillyfourie (NJ 645 124) and Raimoir (NJ 702 003), and the working quarry at Corrennie (NJ 641 119); many of the blocks are several metres in diameter. The quarries themselves are many tens of metres deep. Similar spoil tips have also developed around the quarry in the basic/ultrabasic igneous intrusion at Belhelvie (NJ 944 181) on Sheet 77 Aberdeen. Spoil associated with sand and gravel working is generally finer grained and commonly comprises mixtures of overburden (generally topsoil and till) and waste partings (tills, silts and clays) together with boulders. Much of this material is stored within worked-out areas of active pits or has been used to backfill worked-out and abandoned sites.

The most widespread sand and gravel workings in the district are found on Sheet 77 Aberdeen between Corby Loch and the coast north of Bridge of Don (Bulk mineral resources). Some pits were excavated to depths of more than 20 m. Most are now disused and many have been backfilled with inert domestic and industrial waste; some less inert domestic refuse, agricultural waste and chemicals used in paper making have also been placed in landfills. Most of these landfill sites are in highly permeable strata and only the more recent are lined. The waste is commonly covered by less permeable spoil from the former workings which is often capped by replaced topsoil. Partial infilling of abandoned areas within active pits is commonplace, with final reinstatement occurring when extraction has ceased. Several large landfill sites have been landscaped and returned to agriculture. Disused sand and gravel workings have been landscaped and incorporated into golf courses, turned into nature reserves or built over. For example, industrial units have been erected in open disused pits at Blackdog (NO 957 143) and Upper Tarbothill (NO 951 134).

Red clayey diamicton (Hatton Till Formation) has been dug at a site near Teuchan (NK 0839 3896) since 2000 for burying domestic waste at the new Stonyhill landfill site, south-west of Peterhead.

Many abandoned bedrock quarries have been used as landfill sites. For example, a quarry in felsitic microgranite at Kirkhill (NK 011 528) has been infilled with domestic waste from nearby Peterhead. Similar tipping of domestic waste has taken place in Burnside Quarry (NJ 775 126), a disused quarry in the Crathes Granodiorite, south-east of Kintore. Tipping of inert domestic and building waste on top of lowland peat mosses has been widespread also, particularly north of Aberdeen. Many tips are now disused and have been graded and landscaped, but several remain active, for example the large tip (NJ 916 457) near Maud. Numerous smaller enclosed depressions in bedrock and till have been completely infilled by farmers, with rocks cleared from nearby fields, subsoil and farm waste. The fill is covered by top soil and the ground returned to agriculture. Around Aberdeen, larger scale excavations and hollows in bedrock and till have been infilled, for example around Westhill (NJ 830 870), Loirston Loch (NJ 940 010) and Portlethen (NO 920 970), where extensive building developments have taken place on the reclaimed ground.

Many of the recent large-scale industrial developments on the outskirts of Aberdeen, at Bridge of Don, Dyce and Nigg, for example, have involved widespread modification of the ground surface, with millions of tons of loose material being removed or remodelled using mechanical excavators. The extent of these spreads of landscaped ground is currently being mapped as part of ongoing continuous revision of Sheet 77. Smaller areas of landscaped ground associated with industrial and commercial developments around Portlethen and housing developments in Stonehaven are shown on Sheet 67. A housing development on the southern bank of the River Dee, 1 km upstream of the Bridge of Dee (NO 697 952), and the Invercannie Water Treatment Works, on the northern bank, 2 km farther upstream are both sited on landscaped ground associated with former sand and gravel workings.

## Landslips


Back scar of a landslip in the Kirk Burn Silt Formation near Macduff. P104100.

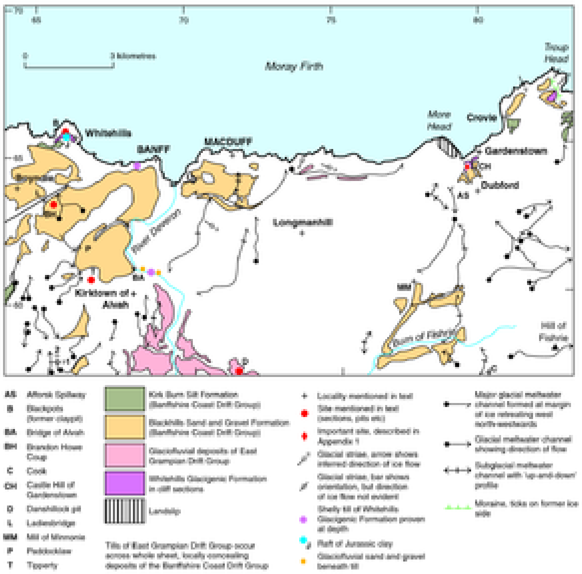
Landslips are widely developed in coastal areas where steep rock cliffs are being eroded by the sea. Slips are widespread along the rocky shoreline of the Moray Firth, between Buckie and New Aberdour and along the North Sea coast south of Aberdeen, where resistant Dalradian metamorphic rocks and Devonian sandstones and conglomerates reach the sea. Small slips are widely developed in the Kirkburn Silt Formation, especially where the deposits are exposed on the sides of deeply incised valleys that reach the coast around Troup Head (NJ 826 673), immediately east of Crovie (NJ 809 658) and in the vicinity of Macduff (P104100; P915373). Slips are also developed in reddish brown clayey diamictons of the Mill of Forest Till Formation and clays of the Ury Silts Formation Evidence of the mobilisation and probable solifluction of glacial diamictons is widespread in the lowlands of north-east Scotland. Few of the landslips are extensive enough to be shown on the published 1:50 000 geological maps, but some are shown on 1:10 000 and 1:25 000 scale geological maps of the district. Many of these small slips are wholly developed within Quaternary sediments. Dating of organic material incorporated in one example, at Knockhill Wood near Glenbervie, suggests that the earliest movement occurred either during the Loch Lomond Stadial (about 10–11 ka 14C years BP) or at the beginning of the Holocene (Knockhill Wood).

Another good example of an old landslip was observed in 1995 during the realignment of the A941 road near Rothes (NJ 277 498). The excavations revealed lenses of organic sediment containing wood fragments within a unit of interbedded grey clayey silt, pale greyish brown sandy silt and sand. The unit rested on gravel and was overlain by 2 m of reddish brown, pebbly sandy diamicton. A radiocarbon age of about 11 110 BP (see table below) from a fragment of willow demonstrated that disturbance observed towards the top of the organic sequence postdated retreat of ice from the area. Furthermore, the presence of sand blocks within the silt unit indicated that the disturbance and mass movement took place across at least partly frozen sediment. This, together with the degree of disturbance, suggests that the slip was a detachment slide of an ‘active layer’ that had formed under permafrost conditions during the Loch Lomond Stadial (compare with Ballantyne and Harris, 1994).

Radiocarbon dates from Late-glacial sites in the district

| Site | Grid reference | Laboratory number | Age (year BP) | Dated material and setting | Reference |
|---|---|---|---|---|---|
| Rothes cutting | NJ 277 498 | Beta 8653 | 11 110 ± 70 | peat under remobilised till | Appendix 1 |
| Garral Hill, Keith | NJ 444 551 | Q-104 | 10 808 ± 230 | peat under remobilised till | Godwin and Willis (1959) |

| | | | | | |
|---|---|---|---|---|---|
| Garral Hill, Keith | NJ 444 551 | Q-103 | 11 098 ± 235 | peat under remobilised till | Godwin and Willis (1959) |
| Garral Hill, Keith | NJ 444 551 | Q-102 | 11 308 ± 245 | peat under remobilised till | Godwin and Willis (1959) |
| Garral Hill, Keith | NJ 444 551 | Q-101 | 11 888 ± 225 | peat under remobilised till | Godwin and Willis (1959) |
| Garral Hill, Keith | NJ 444 551 | Q-100 | 11 358 ± 300 | peat under remobilised till | Godwin and Willis (1959) |
| Woodhead, Fyvie | NJ 788 384 | SRR-1723 | 10 780 ± 50 | peat under remobilised till | Connell and Hall (1987) |
| Howe of Byth | NJ 822 571 | SRR-4830 | 11320 | peat beneath gravel | Hall et al. (1995) |
| Moss-side, Tarves | NJ 833 318 | I-6969 | 12 200 ± 170 | peat under remobilised till | Clapperton and Sugden (1977) |
| Loch of Park | NO 772 988 | HEL-416 | 10 280 ± 220 | kettlehole infill | Vasari and Vasari (1968) |
| Loch of Park | | HEL-417 | 11 900 ± 260 | kettlehole infill | Vasari and Vasari (1968) |
| Mill of Dyce | NJ 8713 1496 | SRR-762 | 11 550 ± 80 | kettlehole infill | Harkness and Wilson (1979) |
| Mill of Dyce | NJ 8713 1496 | SRR-763 | 11 640 ± 70 | kettlehole infill | Harkness and Wilson (1979) |
| Glenbervie | NO 767 801 | GX-14723 | 12 460 ± 130 | peat under remobilised till | Appendix 1 |
| Glenbervie | NO 767 801 | SRR-3687a. (humic) | 12 305 ± 50 | peat under remobilised till | Appendix 1 |
| Glenbervie | NO 767 801 | SRR-368Th (humin) | 12 340 ± 50 | peat under remobilised till | Appendix 1 |
| Brinzieshill Farm | NO 7936 7918 | SRR-387 | 12 390 ± 100 | peat under remobilised till | Auton et al. (2000) |
| Rothens | NJ 688 171 | SRR-3803 | 10 680 ± 100 | kettlehole infill | Appendix 1 |
| Rothens | NJ 688 171 | SRR-3804 | 11 640 ± 160 | kettlehole infill | Appendix 1 |
| Rothens | NJ 688 171 | SRR-3805 | 11 760 ± 140 | kettlehole infill | Appendix 1 |



Glacial and glaciofluvial features and the distribution of glacigenic deposits on Sheet 96E Banff. P915373.

A number of other sites have been reported where solifluction deposits rest on organic sediments dated to the Windermere Interstadial and Loch Lomond Stadial. Examples include Garral Hill, near Keith (Godwin and Willis, 1959), Woodhead, Fyvie (Connell and Hall, 1987), Moss-side Farm, Tarves (Clapperton and Sugden, 1977) and sites near New Byth (information from G Whittington, St Andrews University, 2002). These sites demonstrate the instability of low-angle till slopes during the Loch Lomond Stadial and the widespread occurrence of foot-slope accumulations of periglacial diamicton. The frequency of former active layer detachment slides in the region is unclear, but they are liable to be rendered unstable by engineering works.

The largest landslip affecting solid rocks in the district is developed in steeply dipping, interstratified semipelites and psammites of the Southern Highland Group on the western side of Gamrie Bay (P915373); the slip is almost 800 m long and up to 300 m wide. Another major slip in Dalradian gritty psammites and semipelites occurs in the 150 m-high cliff (NJ 798 649) immediately south-east of Morehead. The largest area of landslip in the southern part of the district occurs on the southern flank of Strathfinella Hill (Sheet 66E), north of Westmoston (NO 683 761). Five individual slips have been recognised (Carroll, 1995a), all of which are developed in Lower Devonian Strathfinella Conglomerate. The slipped material, which can be up to 70 m thick in places, extends for a distance of some 300 m along the hillside. Each slip has a prominent cuspate back scarp and reorientation of bedding within the slipped masses suggests that the slips are principally rotational failures.

## References

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