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A review of significant Quaternary Geology sites in the Western Midland Valley of Scotland: targets for the Quaternary methods and training programme

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A review of significant Quaternary Geology sites in the Western Midland Valley of Scotland: targets for the Quaternary methods and training programme

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Figure 1 Localities described in the report

Summary

This report reviews the potential for trial pitting the geologically significant Quaternary sites in the western Midland Valley of Scotland. The practice and methodologies of trial pitting to depths of 5-6 m are to be developed within BGS. Initially pitting is to be targeted on the important Quaternary sites in the Ayrshire area as important scientific information is to be gained in the trials. Ayrshire was chosen partly because of the debate about the origins of the shelly till as either in situ glaciomarine deposits or as glaciotectonised rafts and also because fieldwork is currently continuing in central Ayrshire. In particular, sites where there is evidence of a lower shelly till or clay overlain by interglacial deposits and/or an upper till are examined. Eleven sites together with their present state of scientific knowledge are reviewed and the potential for pitting at each site is assessed.

As a scientifically interesting site for trial pitting, Afton Lodge would appear to be the most likely to produce results in a safe environment. Besides the relationships of the clay to the adjacent till/s, there could be shell or plant material available for analysis or radiocarbon dating. If access to Afton Lodge was not available, similar sites near Bogend Burn or Raith Burn could be considered.

1 Introduction

Trial pitting and the associated methodologies are recognised in BGS as important methods that must be promulgated to staff and recorded as best practice. Pitting is to be targeted on the important Quaternary sites in the Ayrshire area. In particular at localities where there is evidence of a lower shelly till or clay overlain by interglacial deposits and/or an upper till. Initially, Ayrshire was chosen partly because of the debate about the origins of the shelly till as either in situ glaciomarine deposits or as glaciotectonised rafts and also because fieldwork is currently continuing in the area of Sheets 14W (Ayr) and 14E (Mauchline). Trial pitting would probably be able to go to depths of 5-6 m.

Sites that could be considered are described below. Initially the most significant site was considered to be Sourlie [NS 3380 4139] but the sections there were in a deep opencast coal pit; these workings are now restored and the locality is likely to be buried to depths in excess of 6 m. Other potential sites include several classic Scottish Quaternary localities such as Kilmaurs/Dreghorn, Cowdon Glen, Afton Lodge, Nith Bridge (New Cumnock) and Greenock Mains. Some of the old localities were temporary exposures which could be considered as targets whereas others occur in steep unstable cliffs incised by rivers.

Most of the sites are closely associated with the presence of ‘shelly till’ and some, such as Afton Lodge with shelly clay which Eyles et al., (1949) considered represented ‘erratics’, brought in from the coast by Highland Ice. Previously Smith (1898) had considered that the shelly units were marine deposits indicating submergence below the sea to levels that are at present 1061 feet (c. 323 m) above sea-level. Bailey (1930 p. 321) (cf. Bell, 1896, Gregory, 1927) argued that the shelly tills were absent at lower levels than these in the Southern Uplands, which would be hard to explain if they were marine deposits. However, if the presence of an ice cap over the Southern Uplands prevented ice from the Highlands entering areas to the south, then the erratic model would make sense. Holden (1977) reopened the debate, arguing that the shelly clay deposits represent a pre-Late Devensian sea-level stand between 115 m and 150 m above OD. Sutherland (1981) supported this view and suggested that these high-level marine deposits were the product of isostatic downwarping in front of an expanding ice-sheet possibly during the Early Devensian. The relationship between these shelly clays, and adjacent overlying and underlying tills is therefore crucial to any further modelling of the glacial history of Ayrshire.

2 Potential Sites

Potential sites reviewed in the report include Sourlie, Kilmaurs, Dreghorn, Cowdon Glen, Afton Lodge, Merkland Burn, Sorn Mains, Nith Bridge, Greenock Mains, Tayburn and Croy. The location of the sites reviewed is illustrated on Figure 1.

2.1 SOURLIE [NS 3380 4139]

This locality lies in the Irvine district (Monro, 1999) where there are several localities in which two tills are separated by beds which include a terrestrial fauna. However, only at Sourlie can the fauna be shown conclusively to be in situ (Jardine et al., 1988). This site proved that glaciation took place not only in late Devensian times but also in pre-Devensian times. Jardine et al. (1988)

had access to temporary opencast coal excavations in 1986 and examined a sequence of 7 to 8 m of organic-rich silts which lay between two lodgement tills. The upper one was measured as over 12 m in thickness and the lower one as up to 7.5 m thick. The intervening silts contained part of an antler of the reindeer *Rangifer tarandus* in situ [NS 3380 4139]. The authors also found bones of the woolly rhinoceros *Coelodonta antiquitatis*, together with more antler fragments in tip heaps left by the excavations of the site. The microflora recovered from the intervening beds includes grasses, sedges, Caryophyllaceae and *Myriophyllum* (water milfoil). The macroflora includes *Chara* (Stonewort), *Potamogeton* (pondweed), *Ranunculus* section *Batrachium* (water buttercup) and *Salix* (willow) as well as various genera of mosses. Samples of the reindeer antlers and plant debris from localities nearby yielded radiocarbon ages ranging between 29 290 and 33 270 years BP. It was concluded that west central Scotland was free from ice between these dates. At the base of the upper lodgement till a thin pink-brown diamicton, interpreted as a flow till, was found to contain cold water marine molluscs. These, although not dated at the time, are presumed to be younger than the dated material. The shells identified by J D Peacock were *Natica pallida* [= *Lunatia pallida*], *Turritella communis*, *Astarte borealis*, *Arctica islandica*, *Astarte montagui* and *A. elliptica*. Material examined for the memoir (Monro, 1999) showed the bivalve *Macoma calcarea* to be particularly abundant, with *Mya truncata*, *Hiatella artica* and *Nuculana pernula* all relatively common.

Finds of fossil Quaternary mammals are relatively rare in Scotland although isolated fragments of wholly rhinoceros *Coelodonta antiquitatis* were found in gravels near Bishopbriggs in Lanarkshire (Rolfe, 1966). A radiocarbon date of 27 550 years BP was obtained from one of these bone fragments which meant that either the bone was derived from earlier deposits or the Kelvin valley sands and gravels are pre-Dimlington Stadial in age. The latter situation is considered to be correct (Hall et al., 1998).

2.1.1 Potential for pitting

This site has now been restored and in a letter from Graham Jardine he considered it to be too deep to be intersected by trial pitting methods. This is particularly the case since the upper till alone is of the order of 12 m thick.

2.2 KILMAURS [NS 405 395] AND DREGORN [NS 3631 3998]

Several localities in the Kilmaurs-Dreghorn area have been recorded as having interglacial deposits.

At Woodhill Quarry [NS 405 395] an upper till overlies fossiliferous beds containing tusks of the mammoth *Mammuthus [Elephas] primigenius*. These deposits were first described by MacKenzie (1818, p. 62) and more fully by Bald (1822, p. 63). Bryce (1865, p.213) later discovered further elephant remains and reindeer antlers. Marine shells said to come from this locality were not identified.

A history of investigations into the Woodhill Quarry site was given by Bishop and Coope (1977, pp. 68-72), who compared and tentatively correlated the sequence examined in 1865 with one excavated in 1966. According to these authors the thickness of the till overlying the clay in which the remains of the mammoth and reindeer were found would be more compatible with an age greater than the 40 000 BP date which was obtained on a large fragment of reindeer antler (Shotton et al., 1970), than with the radiocarbon date of 13 700 (+1300/ -1700) BP obtained from a mammoth tusk (Sissons, 1967).

A mammoth tusk was recovered from Drummuir No. 5 Pit [NS 3631 3998], 4.8 km west of Woodhill Quarry. Craig (1888) recorded the fragment of tusk of *Mammuthus [Elephas] primigenius* as well as some molluscs, foraminifers, ostracods, fish scales, plant and insect remains from the sinking of pit No. 5 on the farm of Drummuir, Dreghorn. This locality was said by Craig to be 'nearly 3 miles south-west of the old quarry at Greenhill where so many tusks of the Mammoth were discovered about sixty years ago'.

The section at pit No.5 was recorded as:

Boulder clay 76 feet (23 m)(top)

Stratified interlaminated sand and clay 2 feet (0.6 m)

Sand, about 4 feet (1.2 m), the Mammoth and shell bed.

Sands and gravels, unfossiliferous, 20 feet (6 m)

Craig did not find it possible to separate beds containing the marine shell and mammoth remains.

Cold-water marine shells recovered during the sinking of No. 9 Pit Woodhill Colliery [NS 4132 3946], 0.8 km east of Woodhill Quarry were listed by Young and Craig (1869), p.315). At another locality near Kilmaurs, the sinking of the No. 1 Pit Greenhill Colliery [NS 4053 3881] revealed marine shells above and below a horizon containing mammoth tusks. This was interpreted by Anderson (in Richey et al., 1930, p. 329) as indicating a transition from marine to estuarine or terrestrial conditions and back again. Anderson regarded the generally good preservation of the fossils as evidence that significant transport had not occurred but Gregory and Currie (1928, pp. 393-395) pointed to the presence of glacial striae on one of the mammoth tusks. The fauna from this locality includes foraminifers, molluscs and ostracods. Among these are the cold-water taxa such as the bivalves *Chalmys islandica*, *Macoma calcarea*, and *Nuculana pernula*, presently found only in more northerly latitudes. From a sample of clay associated with a mammoth tusk, Bennie (1885, p.451) extracted a microfauna which was interpreted as indicating an essentially arctic environment.

2.2.1 Potential for pitting

The Kilmaurs localities are unlikely to be suitable for pitting as they were recorded from quarries and shafts at considerable depths (c. 20 m).

2.3 COWDON GLEN [NS 4655 5714]

Along a railway cutting in Cowdon Glen [NS 4655 5714], just east of the Irvine district and on the Kilmarnock sheet, James Geikie (1868, pp. 393-395) recorded an occurrence of bones (skull and horn core) belonging to the ox *Bos primigenius*. These bones were described as being from crumpled stratified lacustrine mud and sand, with lenses of gravel and peat, between two tills. However, Craig (1868, pp. 486-487) argued that the deposits above the stratified muds were not true till but probably landslips into the lake. Craig also noted the discovery of part of a horn of an extinct Irish elk, *Megaceros hibernicus* and a few bones of the horse *Equus caballus*. Subsequently Geikie (1869) described the crumpling of the bedded sand, clay and gravel and Mahony (1869), recorded species of desmids, diatoms, mosses, flowering plants seeds and tree leaves, sponge spicules, crustacea, annelida, and insecta from the beds. Craig (1869) described in more details his interpretation of the lake deposits and the slumped upper till. The upper till was again referred to by Geikie (1870) who insisted that it was in situ. On the basis of further

examination and collection Bennie (1891, pp.213-225) gave a fuller account of the flora and fauna of this locality, interpreted the fossiliferous deposits as interglacial lake deposits and supported the view that there were two genuine tills present.

According to MacPherson et al., (2000), the dispute over the status of the upper till is unresolved and it is possible that the upper slumped till overlies lacustrine deposits of probable Flandrian age.

Since this locality [NS 458 567] lies in a narrow drift filled glen with drift-free slopes of Clyde Plateau basalt to the north and south, soliflucted drift deposits could be possibility, but Geikie (1870) had discounted landslippage.

2.3.1 Potential for pitting

This is a potentially interesting site but in a narrow glen close to a railway and not easy to access.

2.4 AFTON LODGE [NS 417 259]

The best-exposed locality of the shelly marine clay was described from in a stream at Afton Lodge, 1.5 miles south-west of Tarbolton (Eyles, 1922). The section there is:-

Red Boulder Clay up to 16 feet (4.9 m)

Laminated greyish variegated clay 5 feet (1.5 m)

Stiff blue to black stoneless shelly clay, base not seen, 2 feet (0.6 m)

This shelly deposit was described as continuous over a distance of 350 yards (300 m) at a height of between 250–300 feet (76 - 91m) above sea-level. The list of mollusc shells was given modern names by J D Peacock. These shells are:-

Tridonta montagui

Astarte sulcata

Arctica islandica

Chlamys islandica

Nuculana pernula

Tectonatica clausa

Oenopota turricula

Boreotrophon clathratus

and *Hydrobia ulvae*.

Gordon (1993a) describes the sections as including a high-level shelly clay with a fossil marine fauna. The site at Afton Lodge [NS 417 259] comprises a series of exposures along the Ladykirk Burn, 8 km north-east of Ayr, at an altitude of about 85 m OD. The origin of these marine clays has been subject of debate similar to that of the deposits of Clava in north-east Scotland (Merritt, 1992). Originally the deposits were interpreted as in situ marine sediments but later they were

interpreted as ice-rafted blocks of frozen seafloor sediments. Holden (1977) reopened the debate, arguing that the deposits represent a pre-Late Devensian sea-level stand between 115 m and 150 m OD. The section measured by Holden (1977) recorded the following deposits: -

Sand and gravel comprising angular clasts up to 0.3 m in a red-brown, coarse, sandy open textured matrix 3m

Coarse gravel, dipping east-south-east at 5° 0.3 m

Stiff, black, shelly, silty clay containing bivalves and foraminifers 5 m.

Holden considered that the uppermost bed was not a till as suggested by Eyles et al. (1949) but a slope-wash deposit. The typical till of the area did not overlie the shelly clay, but is its lateral equivalent and could be traced upstream from it. There was a sharp vertical contact between the two units but in fact they were interdigitated. Abd-Alla (1988) considered that the shelly clay was a marine deposit that could be distinguished on the basis of grain size distribution and geochemistry from the shelly till at locations elsewhere in Ayrshire. Holden described stratification in the upper part of the black clay with layers of coarse sand. Lower down the silty clay was homogenous. Mollusc shells in the clay were nearly perfectly preserved; small ones were whole, larger ones fragmented. Foraminifers and ostracods were identified by M. Keen who reported that the assemblage was one which could be found in the Firth of Clyde today between 15 m and 50 m depth. Holden argued that the black shelly clay was in situ. He also concluded that ice movement had all been offshore and in his study of central Ayrshire he found no evidence of ice movement from the west. He considered the northern part of central Ayrshire was glaciated by Highland ice moving south, then bifurcating to the east and west as it encountered ice from the Southern Uplands. The topographic location of Afton Lodge, in the lee of a ridge and so protected from ice moving from the north-east, was considered admirably suited to the preservation of a marine deposit. Since there was no evidence of a Late Glacial or Holocene submergence of the required magnitude, and the fauna at Afton Lodge was warm temperate, Holden concluded that the shelly clay represented a pre-Late Devensian sea-level stand of between 115 m and 150 m. Sutherland (1981), also argued that the high-level shelly clays in Scotland were in situ. He suggested that these high-level marine deposits were the product of isostatic downwarping in front of an expanding ice-sheet possibly during the Early Devensian and that the ice-sheet could have been sufficiently great to explain the altitudes at which the marine clays now occur. The shell beds were compatible with the evidence of Ruddiman et al. (1980) that relatively a mild oceanic climate in the North Atlantic accompanied the build up of ice-sheets in the Northern Hemisphere. The date of this build up and the age of the shells in the clay are still not known.

Also within this general area, 1.5 miles north-west of Afton Lodge, there were two exposures close together at about 260 feet (79.25 m) above sea-level. One of these was in Raith Burn, which feeds the reservoir from the east, about 300 yards (c. 91 m) above the service road leading to the farm. The other exposure is in the smaller stream west of the farm at a point 200 yards (c. 61 m) north of where it enters the reservoir. The deposit in both cases is described as grey, almost stoneless, clay (cf. Afton Lodge) and contains complete specimens of *Astarte*, *Cyprina* and *Trophon*. It is distinct from the red stony boulder clay which surrounds it and in which the grey clay is believed to be included. In a resurvey of part of this area Sowerbutts and Smith (1999) noted a section in Raith Burn [NS 4043 2722] with a pocket of grey brown till with shell fragments about 1 m thick which overlies 0.8 m gravel above a red-brown till. Since the grey-brown shelly till appears to be found only in certain places it was interpreted as an exotic block/s deposited on or within the red-brown till. The lower grey shelly till documented by Mykura (Geological Survey of Great Britain, 1966) is no longer exposed.

At another locality occurring south of Catrine, in Bogend Burn [NS 5263 2516], about 150 yards (137 m) upstream from the railway viaduct at a height of 330 feet (100 m) above sea-level. Here boulder clay with shell fragments overlies up to 2 feet (0.6 m) of blue-grey silty clay heavily charged with shell fragments including *Leda sp.* In this respect it is unlike the other exposures of clay. The base of the clay was not seen.

2.4.1 Potential for pitting

This site has apparently relatively little relief and the shelly clay is at about 3m depth. It would be interesting to see if a trial pit could get to the base of the shelly clay. The debate about the overlying till being in situ may be resolved and the observation that the marine shelly clay interdigitates with till. If Afton Lodge itself was not available for pitting there are comparable localities such as Raith Burn and Bogend Burn.

2.5 MERKLAND BURN [NS 5908 2716]

Merkland Burn is a tributary of the River Ayr and at [NS 5908 2716], Abd-Alla (1988) recorded a section:

- 5 upper red till 5 m
- 4 sand and gravel 1 m
- 3 shelly till up to 6.5 m
- 2 sand and gravel 0.5 m
- 1 lower red till 1.5 m (base not seen)

2.5.1 Potential for pitting

Since the shelly till is at least 6 m depth and the section is in a dangerous cliff face. This is not a good site to try pitting.

2.6 SORN MAINS [NS 537 280]

Abd-Alla (1988) sampled 3 locations in exposures along the banks of the Burn o'Need (a tributary of the River Ayr). Locations NS 5369 2802 and NS 5371 2793 were recorded as having up to 1 m of soil resting on up to 15 m of shelly till. At a third location [NS 5385 2815], sand and gravel 1.5 m thick overlies a grey till 1.0 m thick then a red till at least 0.5 m thick.

2.6.1 Potential for pitting

If pitting were to be solely targeted at shelly till this locality is a possibility but the section is quite deeply cut by the burn and the Quaternary deposits are locally variable.

2.7 NITH BRIDGE [NS 594 141]

The south-west river-bank section [NS 594 141] at Nith Bridge near New Cumnock exposes a multiple till sequence (Sutherland, 1993). These are interpreted as showing that ice from sources in the Highlands and the Southern Uplands crossed the area during the main Late Devensian glaciation (about 18 000 years ago). The sequence of tills and glaciofluvial deposits was described by Holden (1977) and Holden and Jardine, (1980). The sequence was summarised as:-

5. Till, grey, coarse-grained and gravelly up to 3.5 m
4. Gravel <0.5 m
3. Till, brown less compact and more clayey than bed 1 and containing shell fragments 2 m
2. Gravels and minor sand bodies c. 2 m
1. Till, purple, stiff and sandy at least 1.5m (base not seen)

Bed 1 occurs immediately above river level. Beds 2 and 3 are truncated and unconformably overlain by Bed 4. However, when examined in the field, Bed 4 appears to be a line of stones in the till.

Holden (1977) investigated the particle size, lithology and clast fabric of the tills. He concluded that the lower two tills had a similar provenance, from the Highlands, probably having crossed the Firth of Clyde area. The uppermost till in contrast, has a southern provenance and Holden (1977) concluded that Southern Uplands ice had succeeded the Highland ice. Other than locally, there was no evidence for a break in deposition between the deposits and it was therefore concluded that the ice deposition related to differences in pressure exerted by the Highland and Southern Uplands ice masses during the progress of the last ice-sheet glaciation. This conforms to the models developed elsewhere in Ayrshire (e.g. Eyles et al., 1949).

2.7.1 Potential for pitting

The section described is in a bank of the River Nith, so unless a site can be found away from the river, it would not be suitable.

2.8 GREENOCK MAINS [NS 635 277]

At the site at Greenock Mains [NS 635 277] along the Greenock Water, 8 km west of Sorn, intercalated sand and gravels occur between two tills. It was described by Smith (1898), Holden (1977) and Gordon (1993b) who considered it represented a local readvance of the Late Devensian ice-sheet.

Smith (1898) recorded 47 feet (14.3 m) of upper till stratified in part overlying 32 feet (11.1 m) of sand, gravel and lower till. He recorded that the upper boulder clay was shelly in part. Holden (1977) and Abd-Alla (1988) have made more recent studies. The basic sequence comprises:

3. Red-brown sandy till with clasts of sandstone, shale, and igneous rocks up to 6 m
2. Sand and gravel up to 20 m

1. Chocolate-brown, sandy till with shells and clasts of sandstone, shale, igneous and metamorphic rocks; locally with dark grey, silty-clay matrix up to at least 7 m.

Abd-Alla (1988) found that one section of the lower till closely resembled the shelly till present at other localities in Ayrshire. In another section the till was comparable in properties to the shelly clay at Afton Lodge. Within the sand and gravel bed Holden (1977) recognised channel forms, arched bedding, poor-sorting of materials and the presence of large cobbles, all suggestive of high-energy fluvial regimes such as a sandur. Palaeocurrent analysis indicated water flow from the north-east. Holden recorded no shells in the upper till, but apart from this and colour, the two tills were similar in particle size composition and their relatively high percentage of clasts of local composition (i.e. little Highland provenance contribution).

2.8.1 Potential for pitting

This site is along steep cliffs of the Greenock Water. The shelly till is exposed at the base, practically at the river's edge, so it is not a likely site for pitting shelly till or possible shelly clays.

2.9 TAYBURN [NS 510 433]

At Tayburn, to the north-east of Kilmarnock, Abd-Alla (1988) sampled two exposures [NS5107 4345 and NS5095 4333] in the banks of the Hareshawmuir Water. They both contained grey till overlying red till at depths of 2.5 – 6 m. Although the tills are described as having different characteristics, neither is recorded as shelly.

2.9.1 Potential for pitting

This is a potential site for pitting but since it doesn't contain shells and it is away from the main field areas, it is unlikely to prove as scientifically rewarding as others.

2.10 CROY AREA, AYRSHIRE [NS 2472 1340]

On the Ayrshire coast north of Croy [at NS 2472 1340] Smith (2000) noted cliffs locally slipped exposing over 6 m of dark brown till containing clasts of local rock such as basaltic andesite and red-brown sandstone as well as vein quartz, coarse-grained quartzose sandstone and wacke sandstone. Shell fragments are sparse but indicate movement of the ice sheet onshore and it is considered, with the presence of clasts from the Scottish Highlands, as evidence for the north-westerly derivation of the detritus in the till. Separate tills could not be distinguished at the site.

2.10.1 Potential for pitting

This is a possible site for pitting shelly till but it would have to be done well away from the unstable cliffs.

3 Conclusions

As a scientifically interesting site for trial pitting, Afton Lodge would appear to be the most likely to produce results in a safe environment at depths of c. 5 metres. Besides the relationships of the clay to the adjacent till/s, there could be shell or plant material available for analysis or radiocarbon dating. If access to Afton Lodge was not available, similar sites in the vicinity, near Bogend Burn or Raith Burn, could be considered. If the target was simply shelly till, then Croy or Sorn Mains would be potential sites. Sourlie is a restored opencast site and the upper till is in the order of 12 m thick, and therefore not suited to pitting. Cowdon Glen, another potentially interesting site, is in a railway cutting through Quaternary deposits flanked by drift-free hill slopes so again is not suited to pitting. Greenock Mains would be interesting to re-examine possibly by hand digging when the river was low.

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Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

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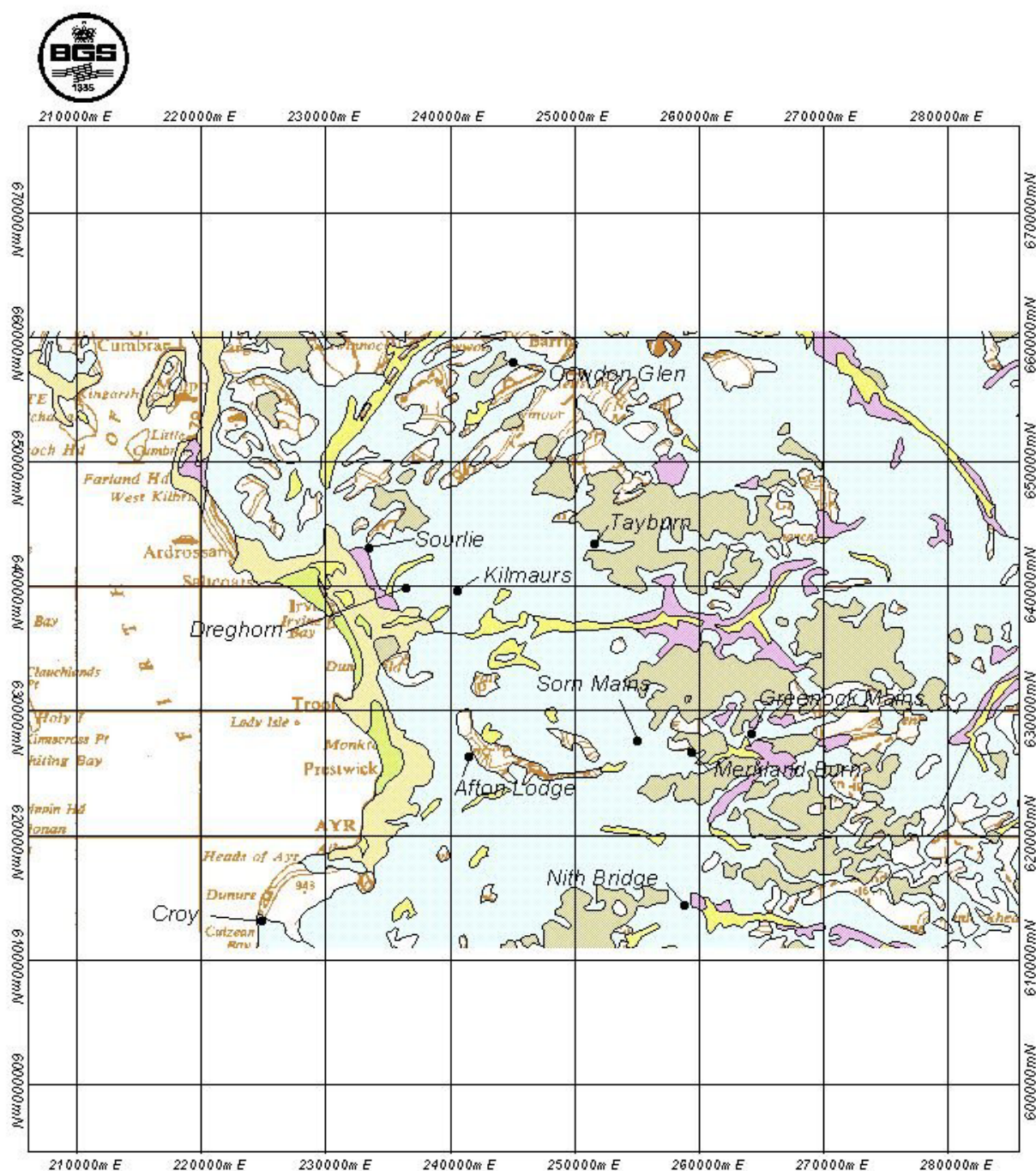
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LEGEND:

- | | | |
|---|--|---|
|  Landslip |  Raised Beach and marine deposits |  Crag |
|  Blown sand |  Glacial sand and gravel |  No Data |
|  Peat |  Boulder clay and morainic drift | |
|  Lacustrine clays, silts and sands |  Sand and gravel of uncertain age or origin | |
|  Alluvium (including River Terrace Deposits in Scotland) |  Clay with flints | |
|  River Terrace deposits (mainly sand and gravel) |  Brickearth, mainly loess | |

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Figure 1
Localities described
in the report