British Geological Survey
Expert | Impartial | Innovative

Physical properties and micromorphology of till deposits from Talla Earth Observatory, Southern Uplands, Scotland

Engineering Geology and Infrastructure Directorate

Open Report OR/19/063

BRITISH GEOLOGICAL SURVEY

ENGINEERING GEOLOGY AND INFRASTRUCTURE DIRECTORATE

OPEN REASEARCH REPORT OR/19/063

Physical properties and micromorphology of till deposits from Talla Earth Observatory, Southern Uplands, Scotland

D P Boon, E R Phillips, M Kirkham, C A Auton

Contributors

K Northmore, K McNeillie (Nuffield Student), T Bradwell

BGS Science Editors

A Finlayson, D A Gunn

Keywords

Talla Earth Observatory, Particle Size, Geotechnical, Micromorphology, Glacial, Quaternary, Southern Uplands, Scotland, Langholm Till Formation..

National Grid Reference

SW corner 314000,619400
Centre point 314600,620000
NE corner 315200,620400

Geological Map

Sheet 16W, 1:50 000 scale,Moffat

Front cover

Excavation of trial pit for geotechnical sampling of Quaternary deposits at Talla Moss, Scotland, in July 2007. Taken by D P Boon.

Bibliographical reference

BOON, D., PHILLIPS, E. R., KIRKHAM, M., AUTON, C A, 2019. Physical properties and micromorphology of till deposits at Talla Earth Observatory, Southern Uplands, Scotland. *British Geological* Survey Open Research Report, OR/19//063. 36PP.

Keyworth, Nottingham British Geological Survey 2019

BRITISH GEOLOGICAL SURVEY

The full range of our publications is available from BGS shops at Nottingham, Edinburgh, London and Cardiff (Welsh publications only) see contact details below or shop online at www.geologyshop.com

The London Information Office also maintains a reference collection of BGS publications, including maps, for consultation.

We publish an annual catalogue of our maps and other publications; this catalogue is available online or from any of the BGS shops.

The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as basic research projects. It also undertakes programmes of technical aid in geology in developing countries.

The British Geological Survey is a component body of UK Research and Innovation.

British Geological Survey offices

Environmental Science Centre, Keyworth, Nottingham NG12 5GG

Tel 0115 936 3100

BGS Central Enquiries Desk

Tel 0115 936 3143
email enquiries@bgs.ac.uk

BGS Sales

Tel 0115 936 3241
email sales@bgs.ac.uk

The Lyell Centre, Research Avenue South, Edinburgh EH14 4AP

Tel 0131 667 1000
email scotsales@bgs.ac.uk

Natural History Museum, Cromwell Road, London SW7 5BD

Tel 020 7589 4090
Tel 020 7942 5344/45 email bgslondon@bgs.ac.uk

Cardiff University, Main Building, Park Place, Cardiff CF10 3AT

Tel 029 2167 4280

Maclean Building, Crowmarsh Gifford, Wallingford OX10 8BB

Tel 01491 838800

Geological Survey of Northern Ireland, Department of Enterprise, Trade & Investment, Dundonald House, Upper Newtownards Road, Ballymiscaw, Belfast, BT4 3SB

Tel 01232 666595
www.bgs.ac.uk/gsni/

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon SN2 1EU

Tel 01793 411500 Fax 01793 411501
www.nerc.ac.uk

UK Research and Innovation, Polaris House, Swindon SN2 1FL

Tel 01793 444000
www.ukri.org

Website www.bgs.ac.uk
Shop online at www.geologyshop.com

Foreword

This report is the published product of a ground investigation to ascertain the physical and geotechnical properties of the Langholm Till Formation and other Quaternary deposits in the Talla Moss Earth Observatory catchment site, located in the Scottish Southern Uplands, UK. The study was funded by BGS-NERC under the *Physical Properties & Behaviour of UK Rocks & Soils* and *Talla Earth Observatory* projects in 2007. This report describes the ground investigation, geotechnical and thin-section sampling methods, laboratory testing, results, and conclusions. The data and information generated is of relevance to upland catchment-scale environmental and flood modelling, construction and drainage engineering, geohazards studies, renewable energy projects, as well as wider earth science related research and training.

Contents

FIGURES

TABLES

Summary

This factual report describes the 2007 field program at BGS' Talla Earth Observatory, in the Scottish Southern Uplands, UK. The work involved 12 trial pits with logging of pit walls, soil sampling for particle size analysis and undisturbed sampling for thin sections and micromorphological analysis of a till and a hard pan in moranic deposits.

The tills of the Langholm Till Formation (of McMillan & Merritt, 2012) are technically 'coarse soils' from a BS5930:1999 ground engineering perspective; typically very dense/hard, very well-graded silty sandy gravels with a matrix dominated by silt and sand. In thin section the till sand-matrix-supported gravel clasts show a preferred alignment orientated suggesting a micro-fabric indicative of a subglacially deposited till. Clast lithology includes sandstone, siltstone and mudstone, and are consistent with the local bedrock lithology. Cobbles and boulders are often 'very strong' from a geotechnical perspective, but may have weaker 'rotten' crust in valley floor settings. The work provides new data on the geotechnical properties of Scottish tills and enhances our understanding of the physical and hydrological properties of commonly encountered Quaternary deposits that occur in the Talla Burn and nearby upland catchments.

1 Introduction

The work described in this report forms part of a wider long-term multidisciplinary study of British till deposits being carried out by the Geo-engineering Properties & Processes Team. The study formed part of Task 1 of the *Physical Properties & Behaviour of UK Rocks & Soils* project and *Talla Earth Observatory* project in 2007/8. The main objective of this BGS/NERC-funded project was to develop a better understanding of the physical property variability and engineering geology of glacial till deposits in lowland and upland catchments across Great Britain.

The particle size distribution and fabric (stone orientation, layering, fissuring and jointing) are significant features of the engineering and hydrogeological properties and behaviour of tills, but these are seldom studied in a quantitative or representative manner in remote upland catchment areas of the UK. This study aims to better characterise the engineering properties of the Tills found in the Scottish Southern Uplands through geotechnical classification tests on representative sample sizes augmented with detailed field descriptions. The geotechnical data produced from this project has been entered into the BGS National Geotechnical Properties Database. This database forms the main tool for the geotechnical attribution of BGS' digital 3D geological models and is a prime information source for academic and applied research and internal/external enquiries. This factual report follows description and terminology from the British Standards (BS5930:1999) for consistency with UK ground investigation and geotechnical practice.

The field work was undertaken in July 2007 in conjunction with a multidisciplinary investigation into an upland catchment at the Talla Earth Observation Site. The main driver for this ground investigation was to determine the thickness, extent, geotechnical properties, and variability of mapped glacial deposits in order to construct a 3D geological model of the catchment to provide a framework for landscape evolution and to support future flooding and catchment management by government agencies and other organisations (e.g. Tweed Forum). The initial results of the work at Talla Earth Observatory, including mapping, drilling, shallow geophysical surveys (ERT and GPR), LiDAR, and 3D geological modelling, are published in Scheib et. al. (2008).

1.1 SITE LOCATION AND GEOLOGY

1.1.1 Background to the geology

This study was specifically aimed at characterising the basic physical properties of the till deposits at the Talla Earth Observatory site. Stratigraphically, the tills are part of the Langholm Till Formation (of McMillan & Merritt, 2012) and are of Late Devensian age. However, other Quaternary deposits including hummocky (moundy) glacial deposits, peat and alluvium are present across the Talla Moss stidy site and their physical properties are also of great importance to practical geology, such as ground and drainage engineering and hazard mitigation, energy infrastructure development, and catchment-scale flood management. The local bedrock geology is Silurian greywacke of the Gala Group. It includes folded and faulted, well-indurated meta-sandstone, meta-siltstone, and meta-mudstones cut by later basaltic dykes. Within the Scottish Southern Upland terrain the extent of till deposits is mapped largely based on landform evidence. At the Talla Moss site the deposits have been mapped on both sides of the valley (Figure 1). The physical properties of these till deposits was poorly understood prior to this study because there have not been any previous intrusive subsurface investigations done at the site. There is dam located down stream to the west at Talla Linfoots.

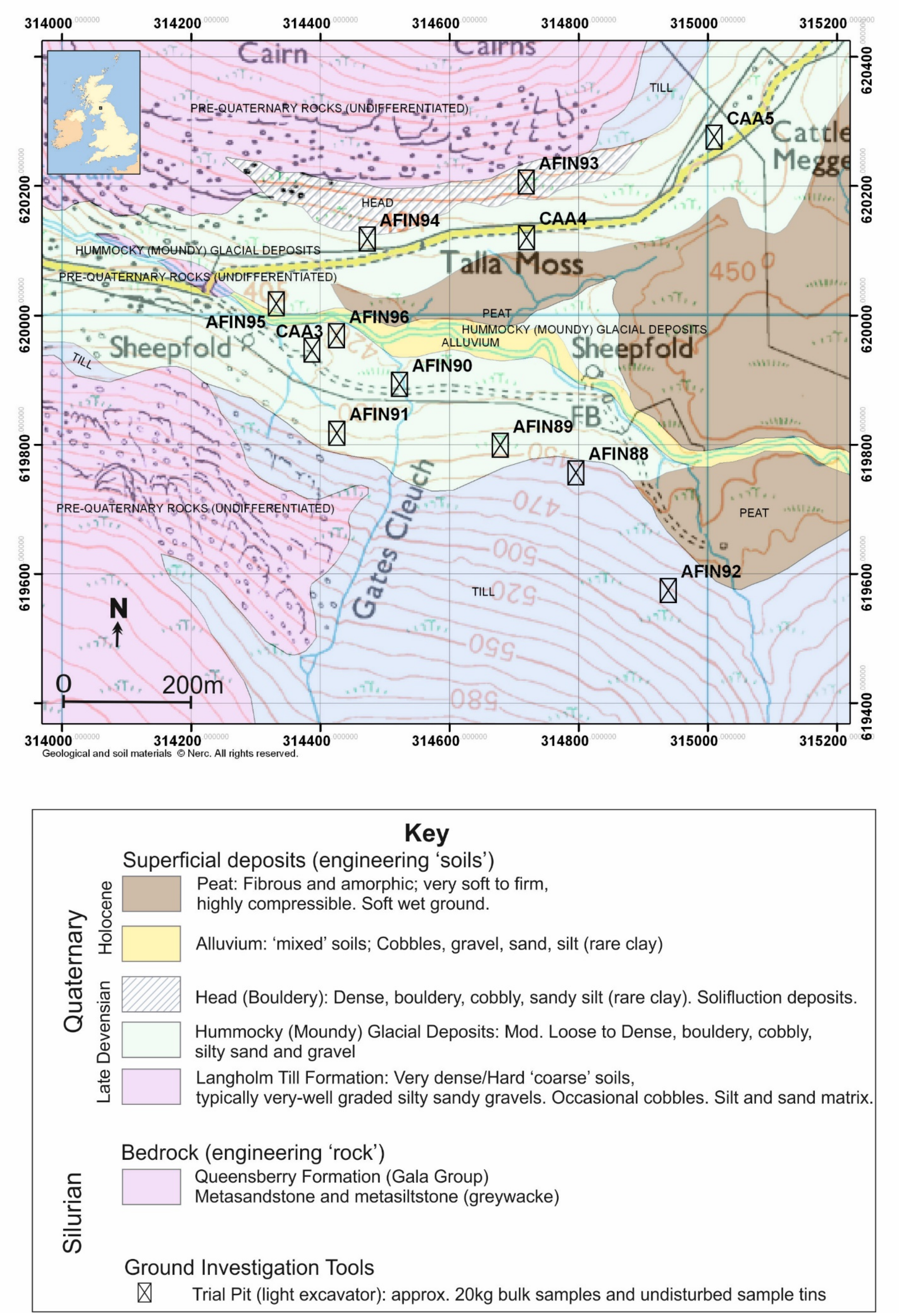


Figure 1 Unpublished 1:10 000 scale geology map of Talla Moss with location of trial pits. Coordinate system is British National Grid.

2 Ground Investigation

2.1 TRIAL PITS

Trial pitting was undertaken to expose a range of glacial deposits and offered an opportunity to sample and characterise them. Twelve trail pits (TP) were excavated across the site in a range of soil types. The aim of the trial pits was to describe the geological and geotechnical characteristics of the sediments to gain an understanding of the variability of materials and their relation to associated landforms for 3D geological modelling purposes. The location of the trial pits is provided in Table 1. Two of the TP (AFIN88 and AFIN92) were purposely located on mapped till deposits (Figure 1). Trial pits were excavated using a 6.3 tonne Kubota KH191 backhoe excavator (see cover photo). Trial pits dimensions were typically 1 m wide by 3 m long, and up to 2.7 m deep. All TPs were backfilled with the excavated soil and ground level reinstated.

Engineering geological logs and descriptions were made in six of the twelve trial pits. Summary logs and several photographs of the trial pits are included in Appendix B. Logging of trial pit walls was carried out to BS5930:1999 standards to provide easily-digestible information aimed at the UK geotechnical community. Detailed geological descriptions of the encountered soil profiles, sedimentary structure and water conditions were made and soil samples were collected for laboratory testing. The trial pit naming convention used throughout in this report (e.g. AFIN, CAA) relates to the name of the supervising survey geologist with an ID number (i.e. Andrew Finlayson, Clive Auton).

Table 1 Location of trial pits.

Trial Pit name	Grid reference (BNG)	Elevation (m aOD) (Mid slope)
AFIN 88	314799, 619754	453.57
AFIN 89	314680, 619799	446.61
AFIN 91	314423, 619820	440.26
AFIN 90	314522, 619892	425.61
AFIN 92	314938, 619580	480.02
AFIN 93	314710, 620211	456.26
AFIN 94	314470, 620116	430.78
AFIN 95	314324, 620022	410.88
AFIN 96	314425, 619968	421.47
CAA 3	314386, 619946	417.56
CAA 4	314719, 620120	437.86
CAA 5	315009, 620275	453.70

2.2 SOIL SAMPLING

Sampling and storage procedures followed British Standard BS 1377:1990 - Methods of test for soils for civil engineering purposes: Parts 1 & 2, respectively.

The samples were taken from representative till units directly from the wall of the excavation in an attempt to retain the fine fraction. The soils from different layers were placed in separate spoil piles to avoid mixing. The material was generally in a dry condition and so loss of fines during sampling was minimal. Sample bags were tied and labelled immediately after collection. A representative unit is defined here as material containing similar textural, compositional and colour characteristics based on field observation.

The bulk sample size was determined based on the maximum grain size of the matrix. Approximately 20 kg of sample was collected (except AFIN92) to ensure representative volume sampling due to the presence of coarse grained materials (cobbles <10%), in accordance with BS1377: Part 1:1990, Table 5. Cobble-size grains were included, but boulders were not sampled for obvious practical reasons. Where boulders were encountered, they are described and recorded on pit logs and a sub-sample was collected. An estimate of the % weight of boulders of the total weight was made. The bulk samples were returned to BGS Keyworth geotechnical laboratory for index testing under supervision of D P Boon and M Kirkham.

2.3 MICRO-MORPHOLOGY

Undisturbed samples were collected by C A Auton in AFIN 93 and AFIN 96 to provide material for specialist investigation into the micro-structure of till. The sample method involves careful hand excavation of a block of soil by first cutting a trench around the sample leaving it proud, followed by gradual encapsulation of the block in an aluminium Kubiena tin to contain the sample and minimise physical disturbance. The orientation of the sample and sample ID is recorded on the tin. Samples were sent to BGS Edinburgh for resin impregnation and thin-section preparation under the supervision of Dr E R Philips.

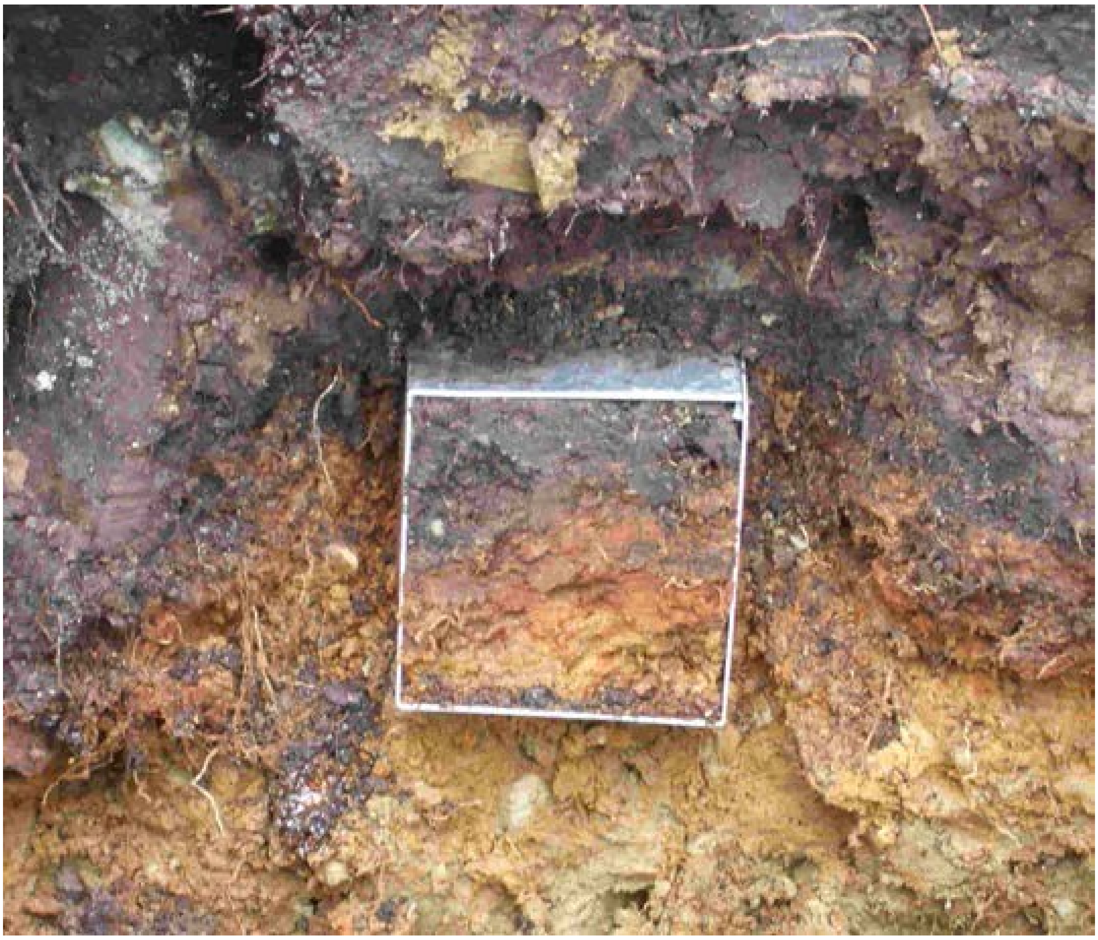


Figure 2 Example of a Kubiena sampling tin containing an undisturbed soil sample in the final stages of excavation from trial pit AFIN 96.

3 Laboratory Testing

The bulk soil samples obtained from the trial pits were analysed by Mr M. Kirkham in the BGS geotechnical laboratory. Tests include:

- Particle size analysis (dry sieving and sedigraph)
- Natural moisture content (fine soils only)

Sample storage and testing procedures followed British Standard BS 1377:1990 - Methods of test for soils for civil engineering purposes, and Head (1980).

3.1 PARTICLE SIZE ANALYSIS

Particle Size Analysis was undertaken by M. Kirkham on all the bulk samples collected from trial pits listed in Table 2. Cobble-sized material was separated by hand in the laboratory and weighed for later correction. Standard sieves were then used on the remaining fine to coarse soil fractions. The remaining fine fraction (<0.063mm) was then analysed in an X-ray sedigraph to accurately measure clay and silt content.

3.2 MOISTURE CONTENT

The sub-samples separated for sieving were further sub-sampled for separate moisture content determination of the sand and gravel fraction. Samples were weighed, oven dried, then weighed again to calculate moisture content following the procedures described in British Standard BS 1377:1990 - Methods of test for soils for civil engineering purposes.

4 Results

In total, twelve trial pits greater than 2 m deep were dug, logged, and photographed through July 2007 with bulk samples taken for testing. Graphic logs of the trial pits are included in Appendix B. The base of the till was not encountered in any of the trial pits. The tills were generally dominantly silty and sandy. They are hard to dig by hand and hence assumed to be very dense, probably due to glacial compaction. The tills encountered between 0-2 m depth were typically dense cobble-rich silty SAND and GRAVEL (diamictons) with occasional thin (<10cm) slope parallel lenses of water-bearing sands and gravels.

Several trafficability issues arose during the investigation due to soft/wet ground and compressible sub-soil conditions (basin peat bogs), steep uneven slopes, river crossings, narrow tracks, large boulders above and below ground, and other environmental considerations.

4.1 PARTICLE SIZE DISTRIBUTION

The results of particle size analysis for tills and the other superficial deposits are summarised in Table 2 and Figures 3 and 4.

The grading curves for all till samples are shown in Figure 3. These data suggest the tills can be classified as well-graded coarse granular soils, generally composed of 1-5% clay, 5-15% silt, 20-35% sand, 40-60% gravel and 2-28% cobbles. Boulders weighing approximately 2 tonnes were encountered. The matrix component of the tills is typically 3 – 10% clay, 15 – 35% silt, and 60 – 80% sand.

The Hummocky (moundy) glacial deposits can be split into two main groups - those with 20 – 35% sand: sand and gravels, and those with 40 – 60% sand: sandy gravels. In all samples the sand and gravel content varies more than fines content. This may be due to natural variability and volume scale effects as the shape of a PSD curve is more sensitive to the mass of coarse grains. The plot of Hummocky (moundy) glacial deposits (Figure 4) shows significant data scatter and suggests that grading curves can be variable. The number of samples collected is insufficient to characterise this variability using statistical techniques, but the data does provide a general sense of the variation. The matrix of the Hummocky (moundy) glacial deposits is generally a fine soil; typically <20% clay, 15-35% silt, and 50 to 80% sand.

Head (Boulder lobe) deposits are generally composed of 1 to 5% clay, 9 to 14% silt, 20 to 30% sand, with 45 to 50% gravel and 2 to 15% cobbles, not accounting for commonly encountered boulders.

The matrix of the sandy Alluvial Fan layers is generally 5% clay, 15% silt, 80 – 90% sand, and is the most uniform of all soils tested at Talla. Water flow (permeability) will probably be preferential in the coarser gravel-rich layers.

Table 2 Particle size distribution.

Mapped (surface) deposit Quaternary unit	Classification	Trial Pit ID	Sample depth (m)	Clay % (<0.002mm)	Silt % (0.002–0.063mm)	Sand % (0.063–2mm)	Gravel % (2–63mm)	Cobble % (63–200mm)
Till (Langholm Till Formation, Late Devensian)	Till	AFIN 92	0.32 – 1.50	3.0	13.6	28.9	51.7	2.8
	Till	AFIN 88	0.50 – 1.20	2.4	11.6	26.7	42.1	17.1
	Till	AFIN 93	0.45 – 1.25	4.3	13.4	33.3	45.6	3.4
	Till	AFIN 93	1.25 – 1.70	4.5	13.9	28.5	50.9	2.2
	Till	CAA 4	0.76 – 1.66	2.0	11.9	28.6	55.2	2.3
	Till	CAA 5	0.75 – 1.16	0.9	11.0	18.7	41.4	28.1
	Till	AFIN 94	0.75 – 1.30	4.3	11.1	34.4	50.2	0.0
	Till (saturated)	CAA 3	0.41 – 1.10	1.5	4.5	24.5	61.5	8.0
Head (Boulder lobe)	Head	AFIN 94	0.40 – 0.75	5.8	8.4	32.6	53.2	0.0
	Head (bouldery)	AFIN 93	0.25 – 0.45	0.8	9.1	21.6	52.6	15.9
Hummocky (moundy) glacial deposits. Includes moranic drift, ice contact, till.	HMGD	AFIN 89	0.29 – 1.30	2.2	9.6	23.5	60.0	4.8
	HMGD	AFIN 91	0.44 – 0.76	6.0	14.2	23.4	50.9	5.5
	HMGD	AFIN 96	0.60 – 0.75	4.3	19.4	34.5	41.9	0.0
	HMGD	AFIN 96	0.75 – 1.00	3.8	8.8	38.5	48.9	0.0
	HMGD	AFIN 95	0.59 – 0.95	4.6	6.8	13.7	57.6	17.3
	HMGD	AFIN 95	1.06 – 1.29	2.6	2.9	14.9	71.6	7.8
Alluvial Fan	ALF (gravel)	AFIN 90	0.35 – 1.00	0.5	3.4	16.1	72.4	7.6
	ALF (sand)	AFIN 90	1.00 – 1.10	4.8	6.9	62.3	26.1	0.0
	ALF (gravel)	AFIN 90	1.35 – 1.57	1.5	3.8	18.1	67.6	9.0

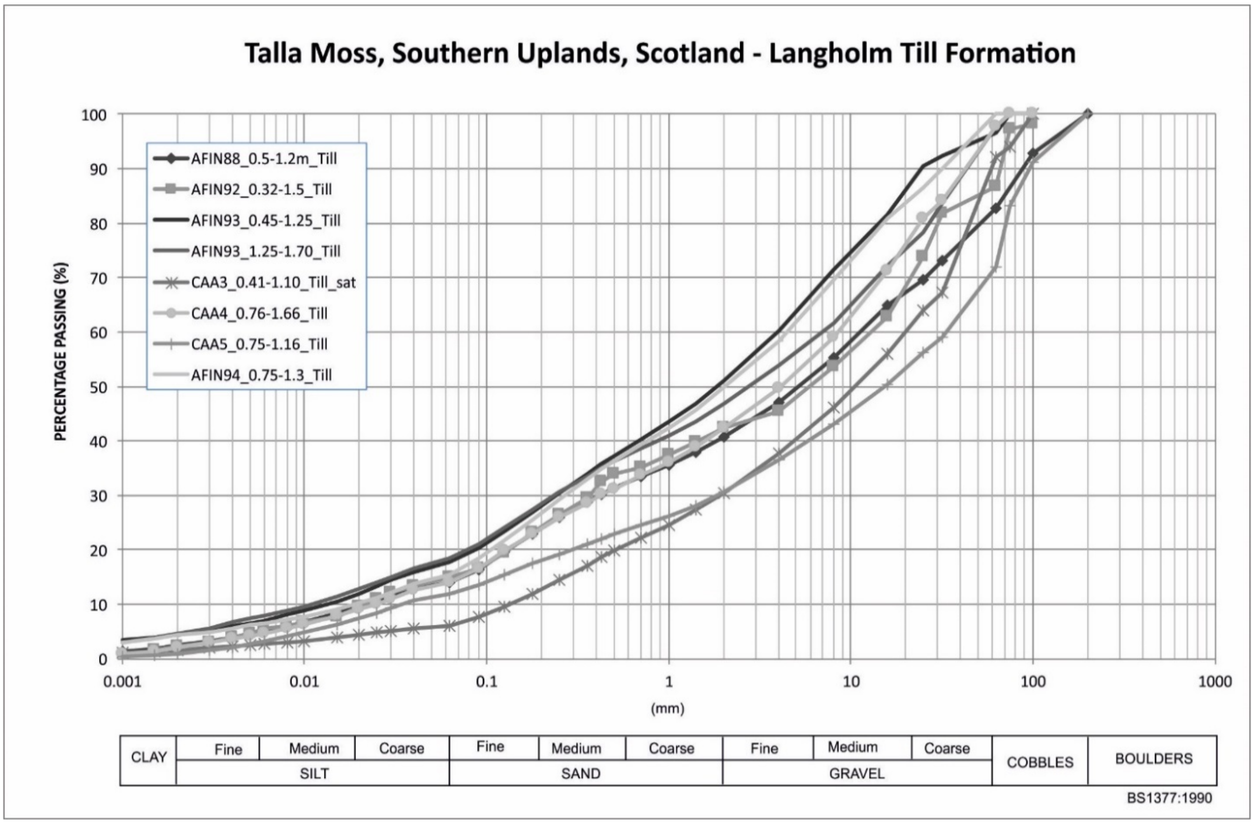


Figure 3 Particle size distribution of Langholm Till Formation deposits from Talla Moss.

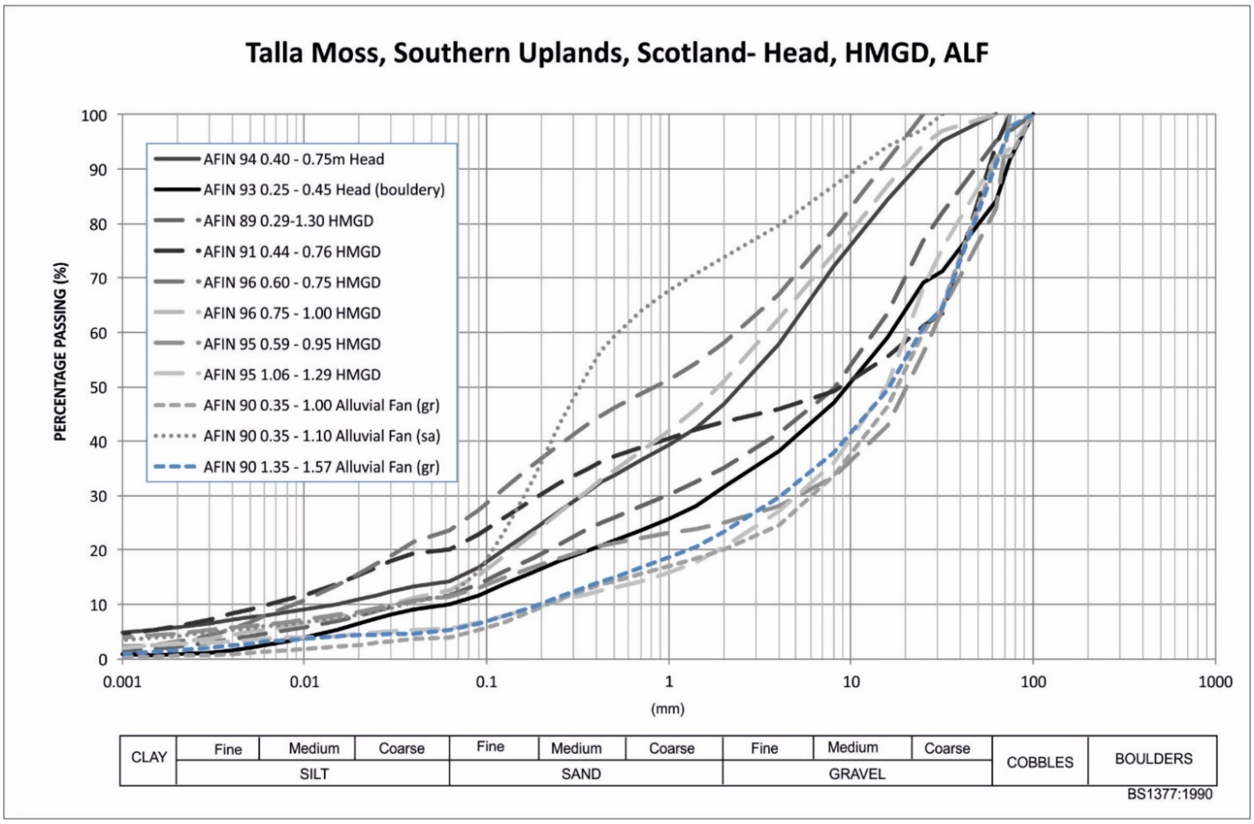


Figure 4 Particle size distribution of non-till superficial deposits from Talla Moss. HMGD is Hummocky (Moundy) glacial deposits (morranic).

4.2 MOISTURE CONTENT

The moisture content relates to the inter-granular porosity of the soil which is a function of grain size and relative density. The results of the natural moisture content (NMC) determination is summarised in Table 3 and shown graphically in Figure 5. The plot of moisture content against depth shows that the tills typically have a NMC of around 10% (+/-3%). The tills sampled were mostly in a partially saturated condition lying above the water table. By comparison, the saturated till sample, collected from below the water table shortly after (hours) heavy rain, had a moisture content of 17%.

The Hummocky (Moundy) Glacial Deposits (HMGD) show a high variability in moisture content and range from 6% to 57%. This wide range reflects the high variability in grain size and porosity. Some of those deposits mapped as HMGD may include tills, moranic deposits and ice contact (sandy and gravely outwash) deposits. The two alluvial fan (ALF) gravels beds are consistently 19% NMC while the sandy bed is 27% indicating better water retention properties in some layers. Head (Bouldery) NMC is consistently 19% and the matrix was silty in both deposits.

In the unsaturated zone the NMC of all near-surface sediments will of course fluctuate seasonally influenced by air temperature, humidity, wind speed, groundwater levels, rainfall and snow melt.

Table 3 Natural moisture content of superficial deposits from Talla Moss.

Deposit type	NMC % (Mean Av)	*n*
Till (above water table)	10	7
Saturated till (below water table)	17	1
Alluvial Fan (gravel)	20	2
Alluvial Fan (sand)	27	1
Head	19	2
Hummocky (moundy) glacial deposits	22*	6

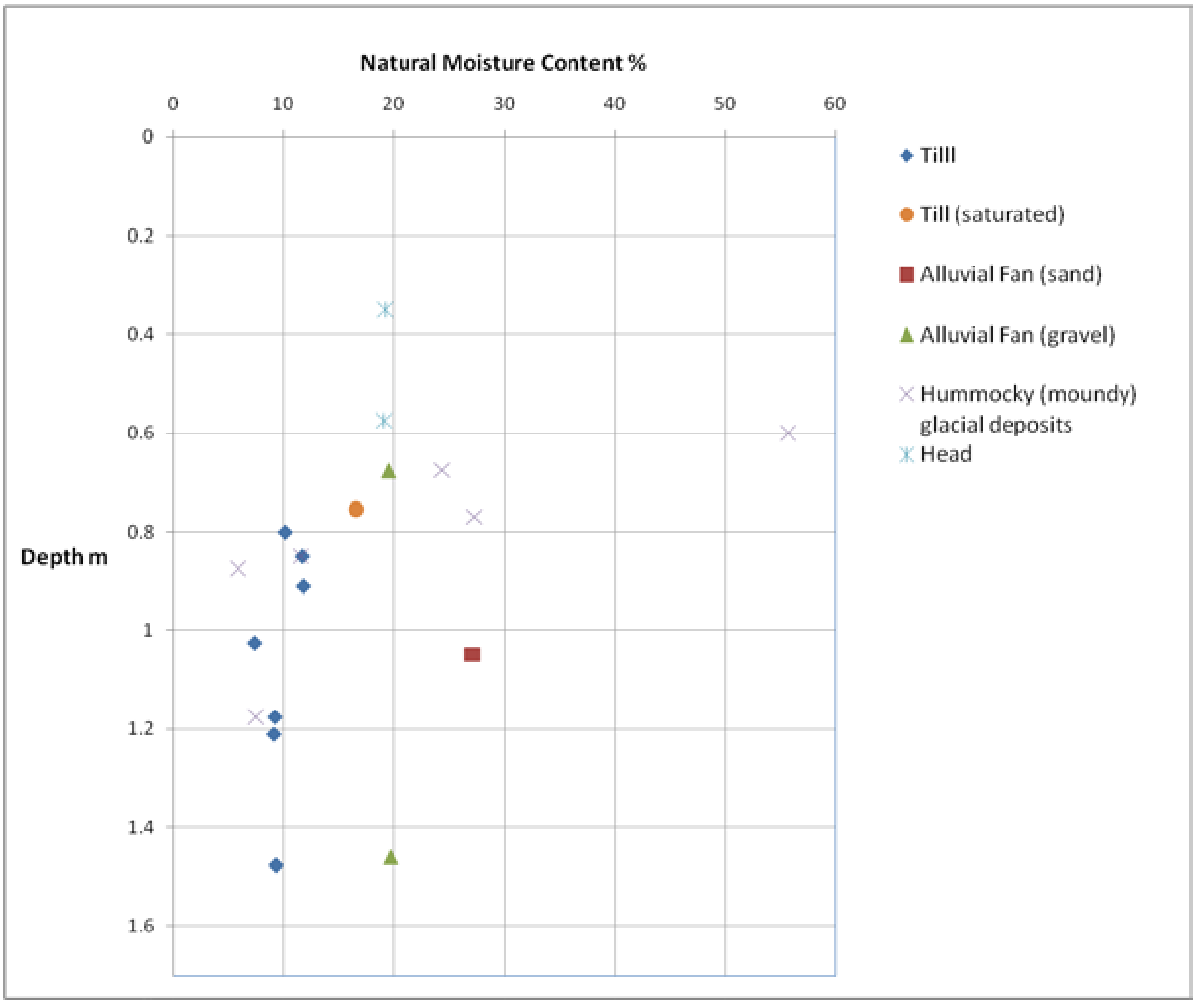


Figure 5 Plot showing variation in NMC with depth (all deposits).

4.3 MICROMORPHOLOGY

4.3.1 AFIN93

Registered number: N10971.

Location: Trial pit, sheet 16W [NT 314718 620206], location AFIN93. (see Figure 1)

Sample details: soil sample, resin blocked for large format thin section.

Lithology: massive silty gravelly sand.

Soil series unit: Denbigh Soil Series.

Geological map unit: Solifluction deposits (head) overlying Till.

Sample depth: Thin section taken from approximately 0.90 m depth below ground surface in Till unit.

The sample for thin section was taken from the thick (c. 1.2 m thick) clast- to matrix- supported diamicton present as the lowermost unit in trial pit AFIN93 (Figure 6) which was proved to a total depth of 1.70m (unbottomed). This thin section is of a poorly to very poorly sorted, texturally and compositionally immature, massive silty gravelly sand which possesses an open packed matrix-supported texture (Figure 7). No obvious primary sedimentary (bedding, lamination, cross-lamination) or glacitectonic features have been noted within this thin section.

Coarse sand, granule to small pebble sized clasts are subrounded to rounded in shape with a low sphericity. The shape of a number of these granule to small pebble sized clasts indicates that they represent broken fragments of much larger pebbles and are therefore polycyclic in origin. The clasts are mainly composed of locally derived sedimentary/low-grade metasedimentary rock fragments including quartzose litharenite, wacke sandstone, very fine-grained sandstone, siltstone and occasional mudstone. The quartzose nature of the sandstone rock fragments is consistent with their derivation from the underlying Gala Group rocks. Rare chloritised basaltic igneous rock fragments are also present. The mudstone rock fragments possess a variably developed lamination and bedding parallel fabric (cleavage) defined by optically aligned clay minerals and detrital micas. This cleavage represents the regional tectonic foliation present within the bedrock and not related to any imposed glacitectonism or mass movement related deformation processes.

The matrix to this gravelly sand is massive in appearance and composed of a fine- to medium-grained silty sand. Sand to coarse silt-grade clasts are angular to rounded in shape with a low to moderate sphericity. Overall the composition of the matrix is similar to that of the included sandstone fragments and, therefore, appears to have been largely locally derived from disaggregated bedrock. The sand-grade detrital grains are mainly composed of monocrystalline quartz with subordinate plagioclase and sedimentary/metasedimentary rock fragments. Minor to accessory detrital components include biotite, polycrystalline quartz, opaque minerals, chlorite, K-feldspar, microcline, micrographic intergrowth/granitic rock, epidote, felsite/chert and rare lamprophyre rock fragments. Other than traces of biotite and chlorite, other detrital ferromagnesian minerals are absent. However, rare detrital clinopyroxene was noted in one of the sandstone lithic clasts.

Irregular to rounded voids within the matrix are a combination of primary porosity (vesicles/pore spaces) and secondary features (plucking) formed during the thin section making process. The primary void spaces tend to be more rounded in form and lined or partially filled by a bright orange to orange-brown, highly birefringent clay cutan. A thin coating of fine silt or clay was noted lining some voids.

The most distinctive feature present within this thin section is the presence of a number of well-developed fine silt to clay-grade caps developed upon the upper surfaces of granule to pebble sized clasts (Figure 7a). Internally the silt to mud caps range from massive, to graded, to weakly laminated where the grading shows that the caps fine upwards. Consequently, they can be used as a way-up indicator and demonstrate that the sediments at Talla are the right-way-up. Clasts within this gravelly sand define a gently inclined clast microfabric (Figure 7b). The laminae within the silt caps developed upon these inclined clasts locally lap onto and rarely appear to 'climb-up' the margins of the pebbles. Elsewhere the lamination appears to drape over the tops of the clasts. This microtextural evidence indicates that the inclined clast fabric formed early (syndepositionally) and that there has been very little or no subsequent disturbance (e.g. mass movement, periglacial disturbance) of the sediment. A rarely developed possible cross lamination is developed in one of the silt caps.

In a small number of the silt caps the fine-grained sediments and lamination are cut by a number of very small, rounded voids lined or partially filled by very finely laminated, highly birefringent clay cutan. The cross-cutting relationships displayed by these clay cutan filled features indicate that this phase of fluid flow post-dated the formation of the silt cap. The bright orange colour of the cutan indicates that it is relatively 'old'. Clay cutan undergoes a maturing process with age as the clay takes up iron and manganese within the groundwater/pore water. Consequently, the darker the colour the cutan the older its formation. This indicates that the clay cutan present within this sample from Talla did not form as a result of 'recent' pedogenic processes.

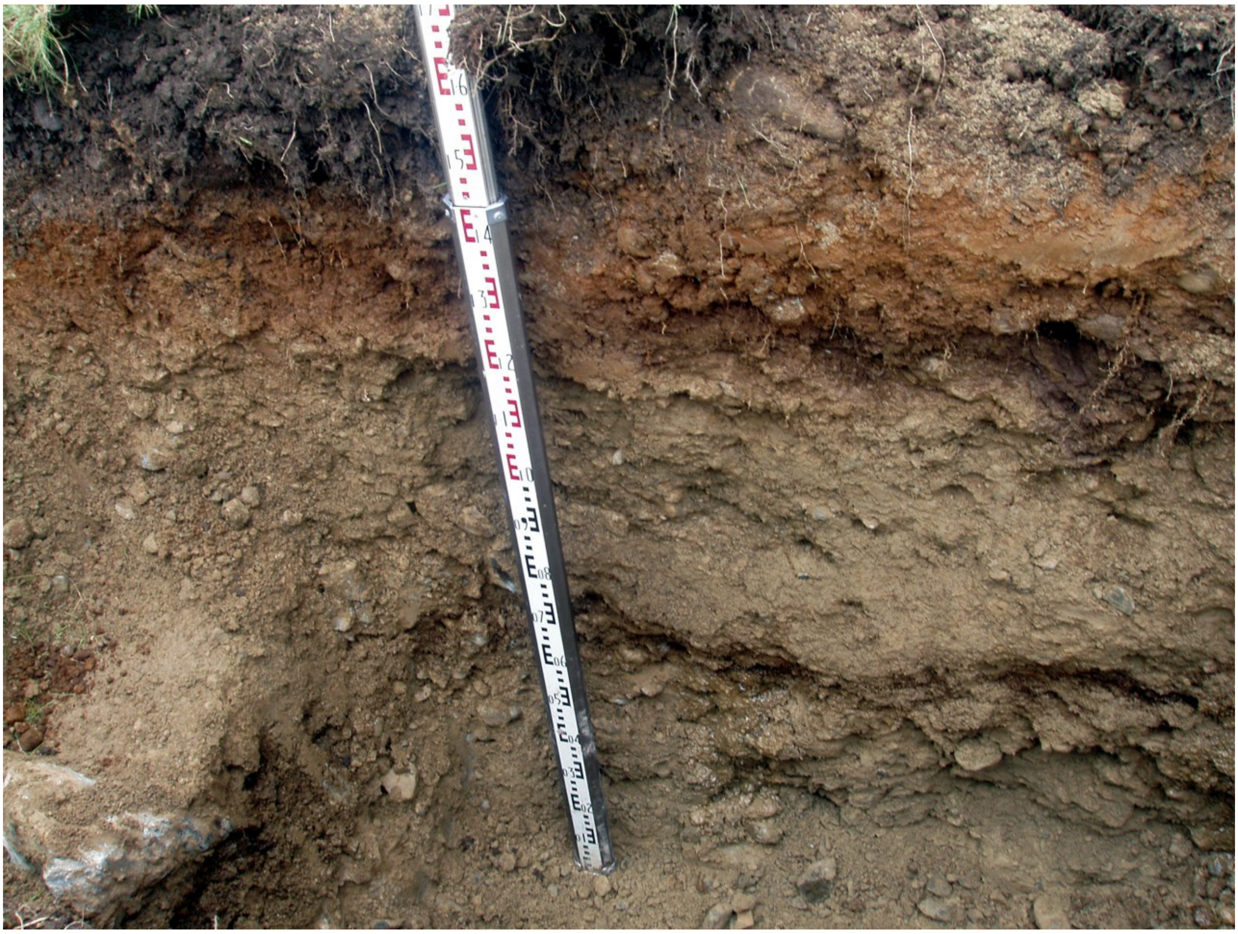


Figure 6 Photograph of trial pit wall on south facing slope (AFIN93). Head deposits (0 - 0.5 m) with a dark red base rest on light brown Langholm Till Formation till deposits (0.5 – 1.7 m).

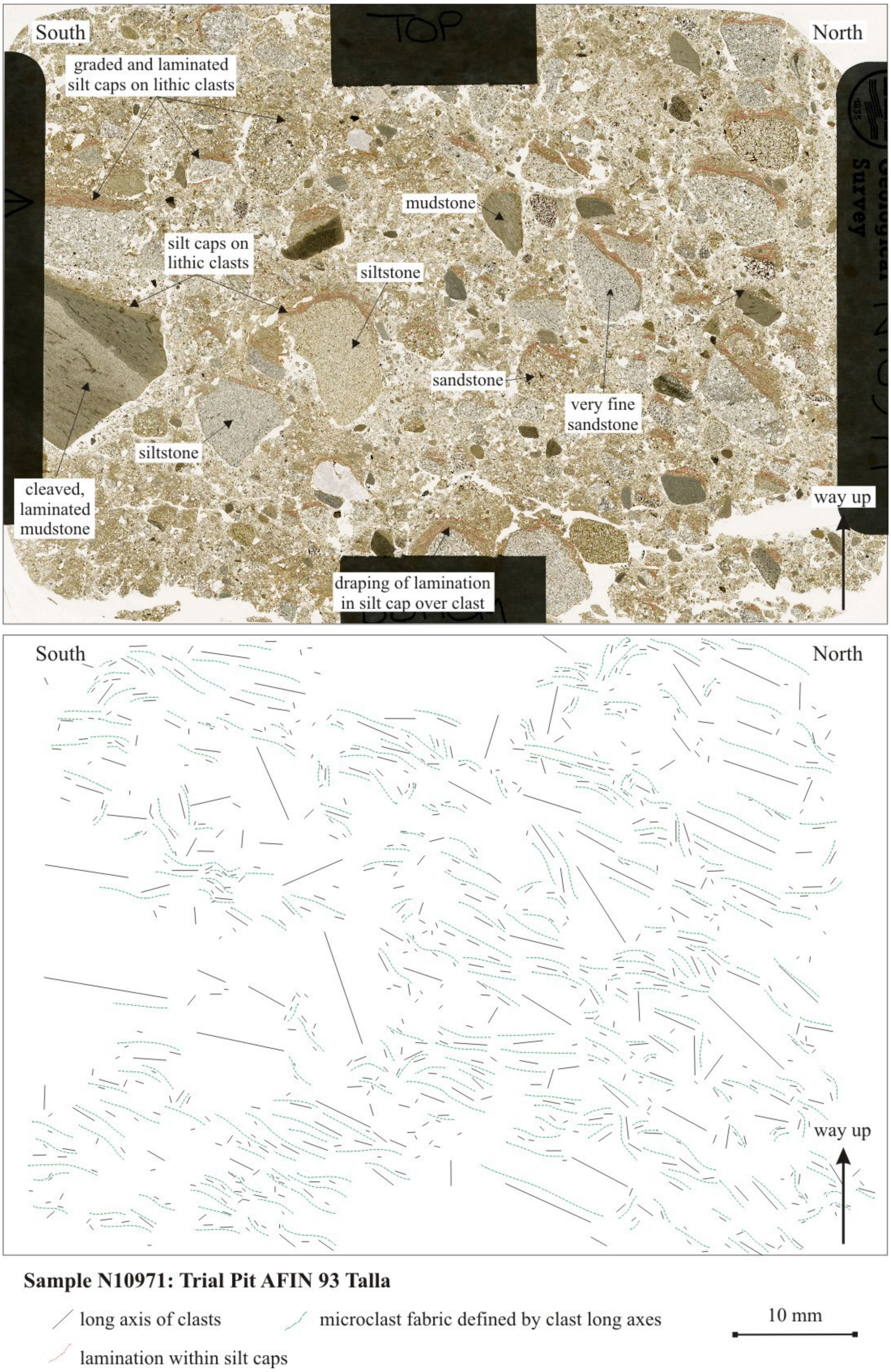


Figure 7 (a) Annotated scan of till thin section N10971 from 0.9m depth in trial pit AFIN93. (b) Diagram showing the orientation of the long axes of coarse sand to pebble sized clasts within sample N10971.

4.3.2 AFIN96

Registered number: N10972.

Location: Trial pit, sheet 16W [NT 314422 619967], location AFIN96. (see Figure 1)

Sample details: soil sample, resin blocked for large format thin section.

Lithology: Hematised pebbly sandy silt.

Soil map unit: Wilcocks/Hafren/Hiraethog.

Geological map unit: developed on Hummocky (moundy) Glacial Deposits (HMGD). These were proved to a total depth of 2.10 m (unbottomed).

Sample depth: Thin section taken from the top of these deposits 0.44 – 0.54 m below ground level.

The sample for thin section was taken from a prominent iron-rich horizon (iron pan) present in the side of trial pit AFIN96 (Figure 8) in HMGD. This thin section is orange-brown to red-brown coloured, highly altered, hematised, weakly pebbly sandy silt with an open packed, cement-supported texture (Figure 9).

A small number of granule to pebble sized clasts present within this hematised sediment are angular, subangular to subrounded in shape with a low sphericity (Figure 9). The clasts are composed of locally derived quartzose wacke sandstone, litharenite and siltstone. No obvious hematisation of the lithic clasts has been recorded. Sand to coarse silt-grade clasts are angular to subangular in shape with a low sphericity. No etching of the grain boundaries of these detrital grains during hematisation has been noted. The silt and sand-grade clasts are mainly composed of monocrystalline quartz and sedimentary lithic fragments. Minor to accessory detrital components include polycrystalline quartz, plagioclase, opaque minerals, oxidised biotite, chert/felsite, zircon and garnet. Variably hematised plant fragments are also relatively common.

The bulk of the thin section is composed of a sandy silty clay (Figure 9) which has been preferentially replaced by an amorphous to very finely crystalline, massive to weakly banded, isotropic to weakly birefringent hematitic oxide or oxidised clay mineral. In detail this Fe-rich material forms very fine-grained granular aggregates which coalesce to form a sponge-like framework enclosing the sand and silt particles. Dusty relicts of fine silt and clay-grade material are locally included within the Fe-rich aggregates. This sponge-like frame work locally possesses a fragmented or brecciated appearance with angular ‘clast’ separated by a network of fine planar to irregular ‘veinlets’ of clear orange-brown, banded to massive hematitic material. In the upper part of the thin section these ‘veinlets’ form a ramifying network which pervades the originally silty matrix to the sediment.

The degree of hematitic replacement within the sample is variable with the most intense alteration occurring in the upper part of the thin section. In this part of the sample, replacement resulted in the development of a moderately well-developed, subhorizontal banding, visible in Figure 9, which records changes/fluctuations in the position of the former oxidation front. The darker bands correspond to a greater degree of iron replacement and may denote periods of time when the oxidation front was relatively stable and remained in one position for a prolonged period. The zone of iron replacement occurs approximately 150 mm beneath a peat layer within a slightly gravelly, silty sandy diamicton (Figure 8). Consequently, one possibility is that iron replacement occurred at the interface between reducing water percolating downwards from the peat and oxygenated water which saturated the underlying diamicton.

No obvious primary sedimentary stratification has been noted within this sample.

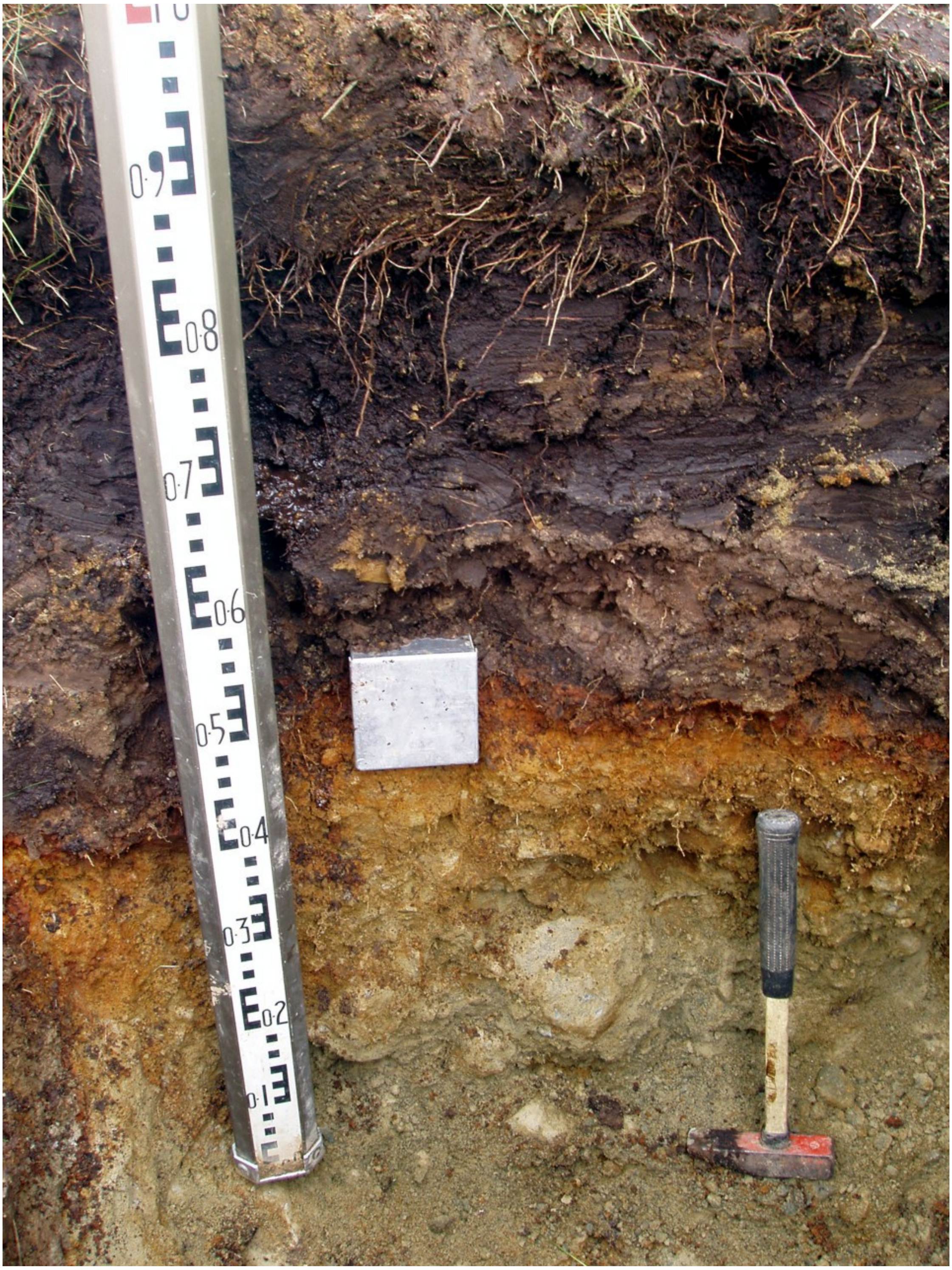


Figure 8 Photograph of trial pit AFIN96 showing the Kubiena tin used for undisturbed sampling of an iron pan formed at 0.44 – 0.54 m below ground level in HMGD.

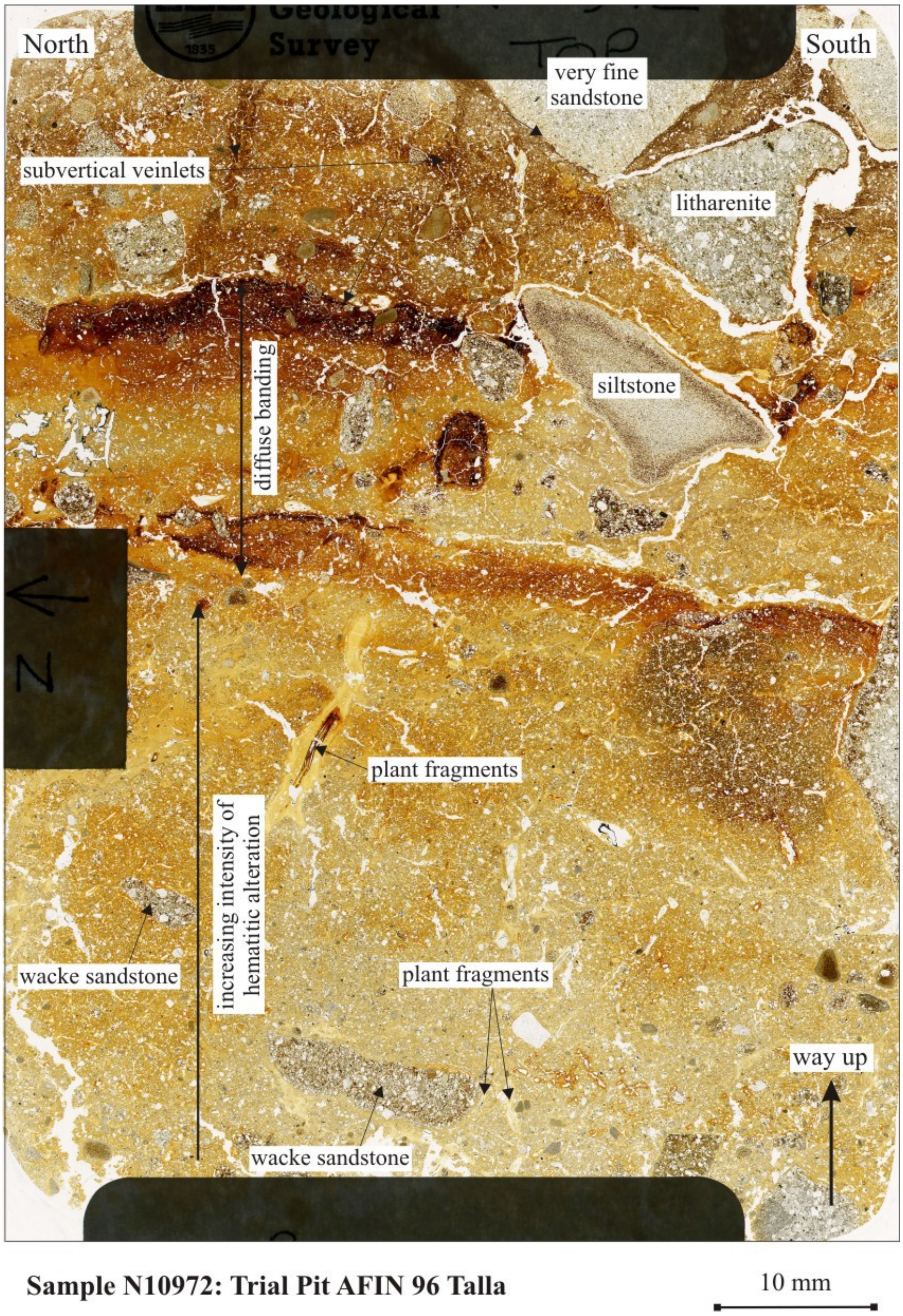


Figure 9 Annotated scan of thin section N10972 taken from 0.45 m depth in trial pit AFIN96.

5 Discussion and conclusions

The Langholm Till Formation deposits that occur at Talla Moss are classified as coarse-grained (non-cohesive) soils for ground engineering purposes (following BS5930:1999 terminology). The till is generally well-graded and comprised of silt, sand and subangular gravel with cobbles and boulders. The till is composed of between 25 - 40 % sand with a fine fraction of 18% or less; the clay component of the till is typically very low (<5%). Some of the clay size fraction may well represent ground-down silt particles (or rock flour) (Head, 1980).

Clasts are composed of a variety of lithologies, mostly locally-derived sedimentary/low grade meta-sedimentary rock fragments including quartzose litharenite, wacke sandstone, very fine-grained sandstone, siltstone and occasionally meta-mudstone. The quartzose nature of the sandstone rock fragments is consistent with their derivation from the underlying Silurian Greywacke of the Gala Group (storing to extremely strong, hard rock).

The relative density of the transported till soil is 'dense' to 'very dense' or 'hard' (using BS5930:2015 terminology), with a stiff to hard (when dry) silty or very dense sand matrix. The till can be excavated with a light mechanical excavator (easy- dig), although large 1-2 tonne extremely-strong boulders may present problems for smaller excavators and breakers. Pit walls in till are generally stable at steep angles above the water table, although excavations in blanket peat bogs can quickly become unstable and slump, particularly after rainfall; this ground behaviour was observed in trial pit AFIN91 which had to be abandoned at 0.8 m due to pit wall instability (it was not propped).

Large boulders are present in the till and these are estimated to be typically 'very strong' rock (UCS 100-200 MPa). Discoloured 'rotten' cobbles with a 10 to 20 mm weak outer crust are more common in the tills in the valley floor under peat deposits, due to enhanced chemical weathering, acidity, and water flow. Rotton cobbles typically have a 10 to 20 mm thick outer zone of weak 'crumbly' red and brown colour lower density rock which would be expected to add to bulk fines content after mechanical reworking (abrasion).

The clay minerals in the till are likely to be of 'low' plasticity (mostly illite) and overall would be expected to have 'low' shrink-swell soil hazard potential. The peat has very high shrink potential on drying. The low fines content of the till is likely to make the horizontal permeability of the till 'moderate', however, the vertical permeability may in places be more variable and will be influenced by secondary soil forming processes such as hard pan development.

On the south facing slopes till deposits have been reworked by solifluction processes into Head deposits, such as those in the micromorphology analysis of sample N10972. These deposits proved to be typically 0.5 m thick and have a similar composition to the till parent material.

The results of this study are particularly relevant to validation of assumptions made about sediment properties, particularly modelling of shallow groundwater storage potential in drift-filled montane catchments in southern Scotland for flood management. The work also provides a background for anticipating geotechnical properties and ground engineering behaviour for infrastructure planning and construction projects/groundworks/fill selection, and for geohazard related studies.

6 References

ANON 1990. Methods of test for soils for civil engineering purposes, BS1377 - Part 2: Classification tests. British Standards Institution, London.

ANON 1999. Code of Practice for Ground Investigations, BS5930. British Standards Institution, London

EVANS. D.J.A., PHILLIPS.E.R., HIEMSTRA.J.F., AUTON. C.A. 2006. Subglacial till: Formation, sedimentary characteristics and classification. Earth-Science Reviews 78, 115- 176.

HEAD, K.H. 1980. Manual of Soil Laboratory Testing volume 1: Soil classification and compaction tests, 3rd edition. Whittles Publishing Ltd. pp416.

MCMILLAN, A.A , MERRITT, J.W. 2012. A new Quaternary and Neogene Lithostratigraphical Framework for Great Britain and the Isle of Man. Proceedings of the Geologists' Association 123, 679-691

SCHEIB, A.J., ARKLEY, S., AUTON, C., BOON, D., EVEREST, J., KURAS, O., PEARSON, S., RAINES, M., WILLIAMS, J., 2008. Multidisciplinary characterisation and modelling of a small upland catchment in Scotland. Quaestiones Geographicae 27A/2, Adam Mickiewicz University Press, Poznań 2008, 45–62. http://nora.nerc.ac.uk/id/eprint/6816/

Appendix 1 Bulk sample details

Table 4 List of bulk (disturbed) samples.

BGS Lab Job No	Trial pit ID	Sample Depth (cm)	Fresh (field) sample mass (kg)	Comment	X (Easting)	Y (Northing)
115/1	CAA3	0.41- 1.10	27.1	1 bag	314386.8	619946.0
115/2	CAA4	0.76-1.66	32.35	1 bag	314719.3	620120.3
115/3	CAA5	0.75-1.60	25.5	1 bag	315009.9	620275.4
115/4	AFIN88	0.50-1.20	31.3	1 bag	314795.9	619755.9
115/5	AFIN89	0.29-1.30	27.25	1 bag	314678.8	619798.5
115/6	AFIN90	0.35-1.00	16.15	1 bag	314522.7	619892.9
115/7	AFIN90	1.35-1.57	27.55	1 bag	314522.7	619892.9
115/8	AFIN91	0.44-0.76	18.9	1 bag	314425.7	619817.1
115/9	AFIN92	0.32-1.50	23.95 & 20.2	2 bags	314938.9	619573.8
115/10	AFIN93	0.25-0.45	24.5	1 bag	314718.8	620206.1
115/11	AFIN93	0.45-1.25	27.15	1 bag	314718.8	620206.1
115/12	AFIN93	1.25-1.70	22.6	1 bag	314718.8	620206.1
115/13	AFIN94	0.40-0.75	21.55	1 bag	314472.6	620117.6
115/14	AFIN94	0.75-1.30	28.05	1 bag	314472.6	620117.6
115/15	AFIN95	0.59-0.95	18.65	1 bag	314331.6	620017.4
115/16	AFIN95	1.06-1.29	28.05	1 bag	314331.6	620017.4

Appendix 2 Trial pit logs and photos

British Geological Survey

Site	Trial Pit Number
Talla Linnfoots, Southern Uplands, Scotland, UK	AFIN88

Excavation Method	Dimensions	Ground Level (mOD)	Client	Job Number
Excavator backhoe	Pit orientated 200 on 20 degree slope.	453.57	BGS	TALLA
	Location	**Dates**	**Engineer**	**Sheet**
	314799 E 619754 N	01/01/2007		1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
					(0.30)	Firm plastic amorphous PEAT.		
				453.27	0.30 (0.10)	Soft plastic amorphous PEAT. Slow water seepage from 0.3m.		
0.50-1.20	B PSD			453.17	0.40 (0.25)	Greyish brown slightly silty very well graded SAND and GRAVEL with common cobbles of fine grained very strong Silurian greywacke. Sand and gravel is fine to coarse sub angular subrounded low spherosity.		
				452.92	0.65 (0.10)	Lens of thinly to very thinly bedded poorly cross-stratified mottled light brown and dark brown fine to medium SAND with deep red hard pan at base. [Fluvially transported]		
				452.82	0.75 (0.45)	Yellow silty sandy GRAVEL with occasional cobbles. Second hard pan 40mm thick at 1.15m.		
				452.37	1.20			
						Complete at 1.30m		

Plan

Remarks

Scale (approx)	Logged By	Figure No.
1:20	DBOON	TALLA.AFIN88

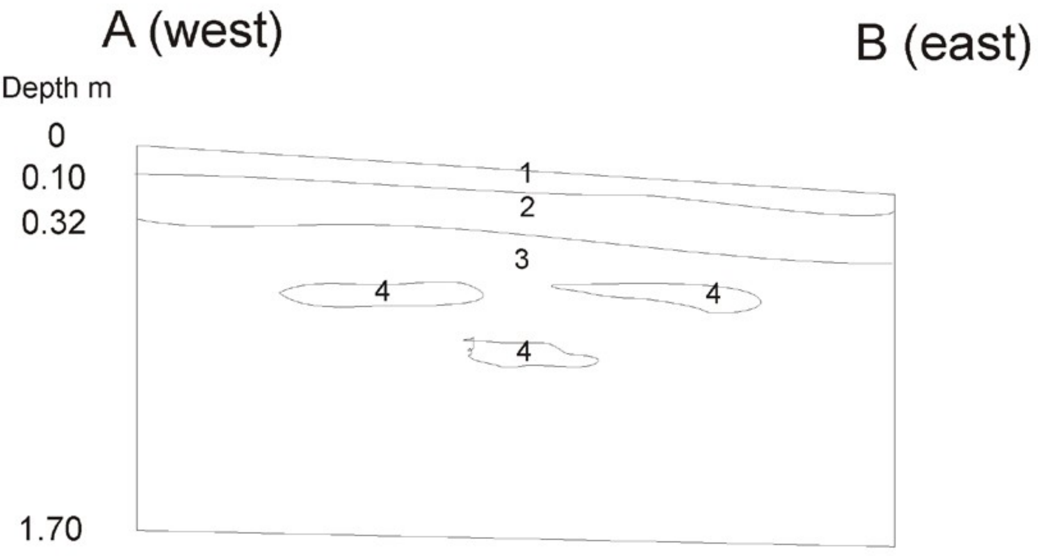
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

SITE: Talla, 3D soils

TRIAL PIT LOG

GRID REF: 314938,619580
480.02 mOD

PIT ID: AFIN 92

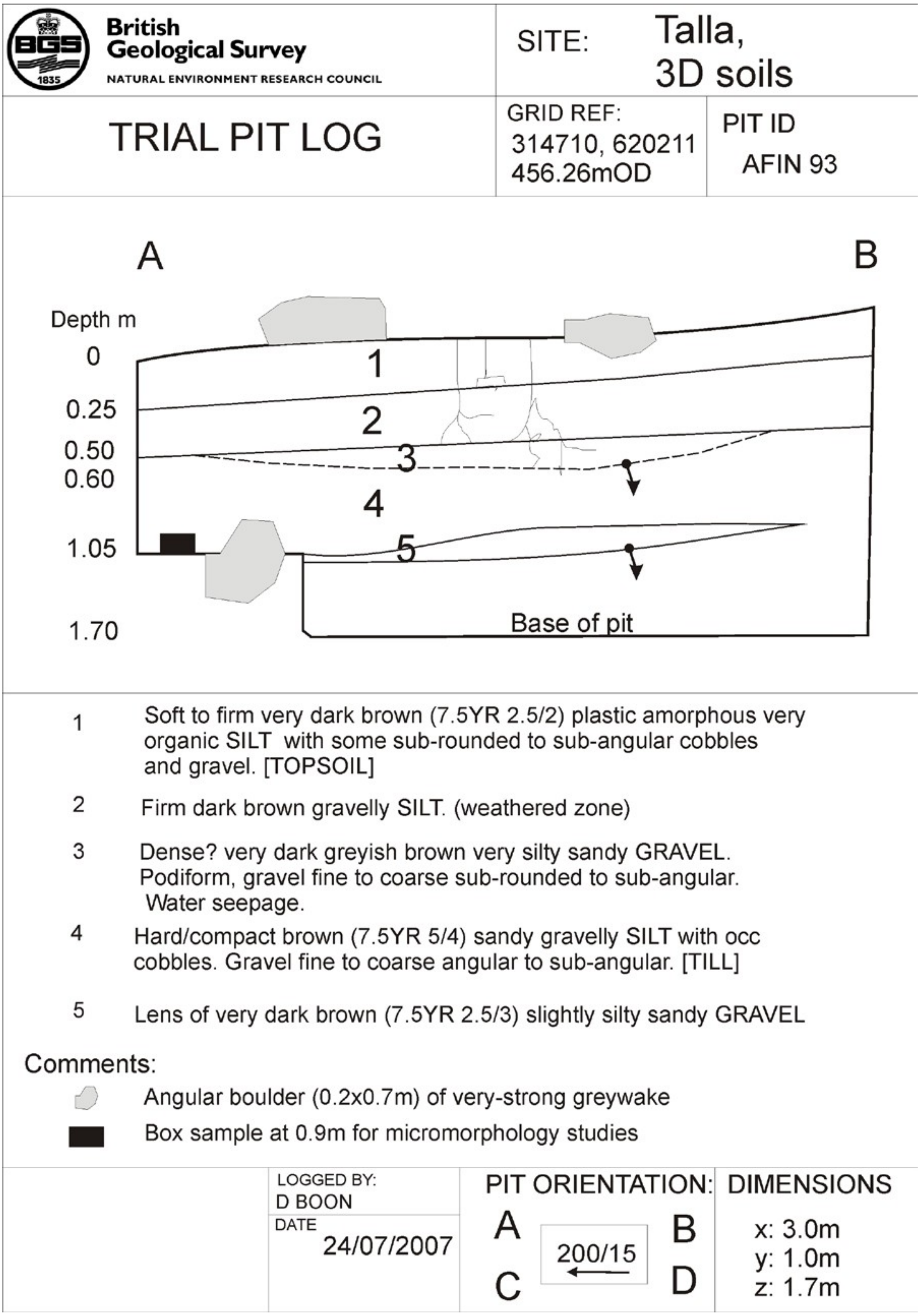


1	Dark greyish brown slightly sandy SILT matrix with occasional subrounded cobbles of greywacke.
2	Soft light brownish grey gravelly SILT with some cobbles. Gravel is fine to coarse sub-angular to sub-rounded. [Weathered GLACIAL TILL]
3	Matrix of hard light yellowish brown gravelly SILT with cobbles. Gravel is medium to coarse sub-angular strong greywacke. [GLACIAL TILL]
4	Persistent lenses of brown very silty fine to coarse subrounded SAND and GRAVEL with occasional tabular cobbles of very strong greywacke. [GLACIAL TILL]

Comments: Excavated with mechanical digger, moderate digging.
Pit backfilled with material.
Slow seepage at 1.7m.
Bulk Sample (40kg) taken from 0.32 to 1.50 m

Project	Logged by / Date	Pit orientation	Dimensions
BGS, Talla Earth Observatory	LOGGED BY: D BOON DATE: 24/07/2007	A 130/05 → B	x: 2.5m y: 1.0m z: 1.7m

Figure 10 Photograph of Trial Pit AFIN 92. Taken facing upslope looking towards the northwest. Note slight water seepage encountered at 1.7 m in base of pit.



British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

SITE: Talla, 3D soils

TRIAL PIT LOG

GRID REF: 314710, 620211 456.26mOD

PIT ID AFIN 93

1	Soft to firm very dark brown (7.5YR 2.5/2) plastic amorphous very organic SILT with some sub-rounded to sub-angular cobbles and gravel. [TOPSOIL]
2	Firm dark brown gravelly SILT. (weathered zone)
3	Dense? very dark greyish brown very silty sandy GRAVEL. Podiform, gravel fine to coarse sub-rounded to sub-angular. Water seepage.
4	Hard/compact brown (7.5YR 5/4) sandy gravelly SILT with occ cobbles. Gravel fine to coarse angular to sub-angular. [TILL]
5	Lens of very dark brown (7.5YR 2.5/3) slightly silty sandy GRAVEL

Comments:

Angular boulder (0.2x0.7m) of very-strong greywake

Box sample at 0.9m for micromorphology studies

LOGGED BY: D BOON

DATE 24/07/2007

PIT ORIENTATION: A B C D 200/15

DIMENSIONS x: 3.0m y: 1.0m z: 1.7m

Figure 11 Trial pit log (AFIN 93) located on moranic deposits. Steep south facing slope strewn with boulder tongs/lobes.

Figure 12 Photograph of 1.7 m deep trial pit walls and base (AFIN 93) exposing till overlain by solifluction Head deposits.

British Geological Survey

Site	Trial Pit Number
Talla Linnfoots, Southern Uplands, Scotland, UK	AFIN89

Excavation Method	Dimensions	Ground Level (mOD)	Client	Job Number
backhoe excavator		446.61	BGS	TALLA
	Location	**Dates**	**Engineer**	**Sheet**
	314680 E 619799 N	01/07/2007		1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
					(0.30)	Firm heterogeneous dark reddish grey slightly gravelly, slightly clayey, sandy SILT. Moderately sorted. with common angular to sub-rounded cobbles and boulders.		
				446.31	0.30			
					(0.45)	Firm reddish grey and subrounded very strong COBBLES in sandy silt matrix. Clast supported, heterogeneous, un-bedded.		
				445.86	0.75			
					(0.55)	Clast supported BOULDERS with matrix of compact very stiff to hard light yellowish brown fine sand to coarse silt. Irregular upper contact. Rare roots.		
				445.31	1.30			
						Complete at 1.30m		

Plan

Remarks

Pit halfway up valley side. Orientated 020 on 14 degree slope, dimensions 0.45m X 3.10m.

Scale (approx)	Logged By	Figure No.
1:25	DBOON	TALLA.AFIN89

British Geological Survey

Site	Trial Pit Number
Talla Linnfoots, Southern Uplands, Scotland, UK	AFIN94

Excavation Method	Dimensions	Ground Level (mOD)	Client	Job Number
backhoe excavator	Pit orientated 090 on 3 degree slope.	430.78	BGS	TALLA
	Location	**Dates**	**Engineer**	**Sheet**
	314470 E 620116 N	01/01/2007		1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
					(0.20)	Plastic amorphous dark brown organic SILT with some fine to medium sub-angular to angular gravel and sun-rounded cobbles of greywacke.		
				430.58	0.20			
					(0.30)	Dark brown slightly sandy very silty fine to coarse subrounded to sub-angular GRAVEL with occasional subrounded cobbles of greywacke.		
				430.28	0.50			
					(0.40)	Dense light brown silty medium to coarse SAND with some fine to coarse sub-angular gravel. Irregular basal and upper contact. Isolated pods of water bearing (seeping) dark brown sand and gravel.		
				429.88	0.90			
					(0.70)	Compact /hard strong-brown (7.5YR 5/6) SILT with some gravel. [TILL]		
				429.18	1.60			
						Complete at 1.60m		

Plan

Remarks

Scale (approx)	Logged By	Figure No.
1:20	DBOON	TALLA.AFIN94

British Geological Survey	Site: Talla Linnfoots, Southern Uplands, Scotland, UK	Trial Pit Number: **AFIN91**

Excavation Method	Dimensions	Ground Level (mOD)	Client	Job Number
backhoe excavator		440.26	BGS	TALLA
	Location	**Dates**	**Engineer**	**Sheet**
	314423 E 619820 N	01/07/2007		1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
					(0.20)	Spongy fibrous very organic silt and PEAT. [TOPSOIL]		
				440.06	0.20			
					(0.25)	Very soft to soft greyish brown organic SILT with occasional medium grained angular sand. Uneven basal contact.		
				439.81	0.45			
					(0.35)	COBBLES (60%), set in sandy silty matrix with pockets of dense sand and boulders of greywacke.		
				439.46	0.80			
						Complete at 0.80m		

Plan

Remarks

Till slope, very vet, water ingress unstable pit slopes. Pit orientated 310 down 20 degree slope. Standing water at 0.38m just after rainfall.

Scale (approx)	Logged By	Figure No.
1:25	DBOON	TALLA.AFIN91

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

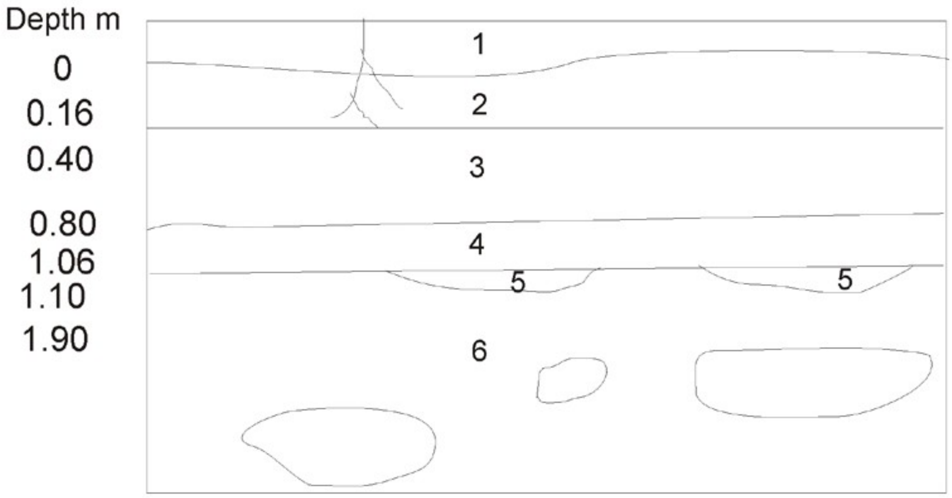
SITE: Talla, 3D soils

TRIAL PIT LOG

GRID REF:	PIT ID
314324,620022 410.88 mOD	AFIN 95

Moranic feature near river

A B



1 Firm Fibrous PEAT

2 Soft plastic pseudo fibrous PEAT. Extent of root growth.

3 COBBLES (60%), up to 200mm diameter, set in soft to firm brown (7.5YR 4/4) slightly sandy very gravelly SILT matrix. Very closely spaced pseudo fibrous roots. Gravel is fine to coarse sub angular to subrounded often tabular. [MORANIC COVER] Gravel and cobbles often weak with duricrust (10mm) greenish grey (GLEY 1 6/1). Matrix multicoloured with dark brown, reddish brown, reddish grey. Clast supported with pockets of light Greeny grey sand and organic brown silt.

4 Thin to medium (200mm) bed of greyish brown sandy GRAVEL. Sand is greenish grey angular. Cobbles more frequent from 0.9m.

5 Thin beds or lenses (100mm) of very dark brown fine to coarse well graded angular gravel. Water Seepage.

6 Strong-brown very silty and sandy GRAVEL with many sub-angular cobbles and boulders. Gravel is fine to coarse sub-angular to angular grading to silty coarse sub-angular grave with some cobbles and boulders from 1.4m. Some iron staining. ICE FRONT MATERIAL]

Comments:	LOGGED BY:	PIT ORIENTATION:	DIMENSIONS
Pit backfilled with material. Standing water at 1.3m after 20 mins.	D BOON DATE 24/07/2007	A 290/02 ← B	x: 3.0m y: 1.0m z: 1.9m

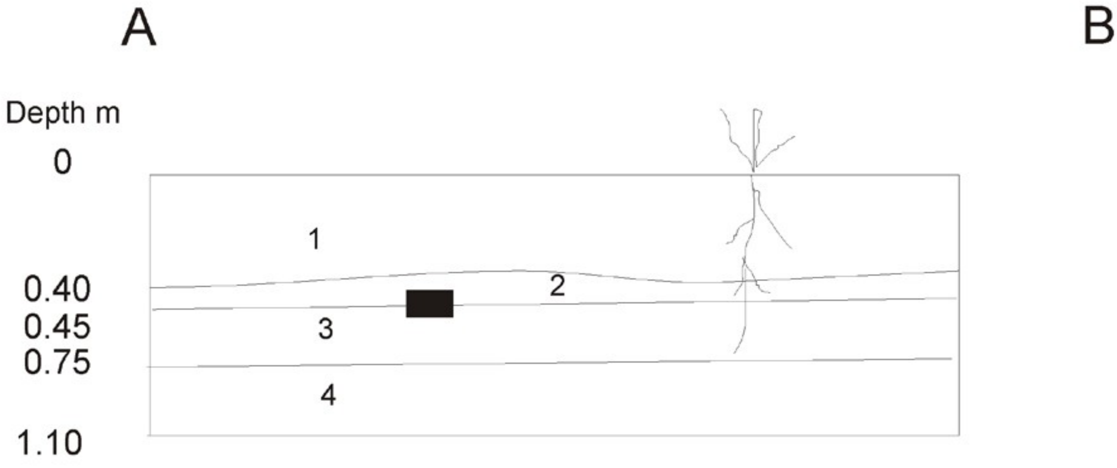
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

SITE: Talla, 3D soils

TRIAL PIT LOG

GRID REF: 314425,619968 421.47 mOD

PIT ID AFIN 96



1 Very soft plastic fibrous PEAT.

2 Greenish grey fine to medium sand with common tabular subangular cobbles of greywacke.

3 Red (2.5YR 4/8) slightly sandy gravelly SILT with some subrounded and bullet shaped greywacke cobbles . Roots stop at base.

4 Brown fine to coarse angular to sub-angular SAND and GRAVEL with sub-angular cobbles and occasional boulders (<400mm).

Comments:

Pit backfilled with material. Dry at base.

■ Box sample at 0.45m for micromorphology studies

LOGGED BY: D BOON

DATE 24/07/2007

PIT ORIENTATION: A 290/00 ← B

DIMENSIONS
x: 2.5m
y: 1.0m
z: 1.1m

Appendix 3 Ternary plots of PSD