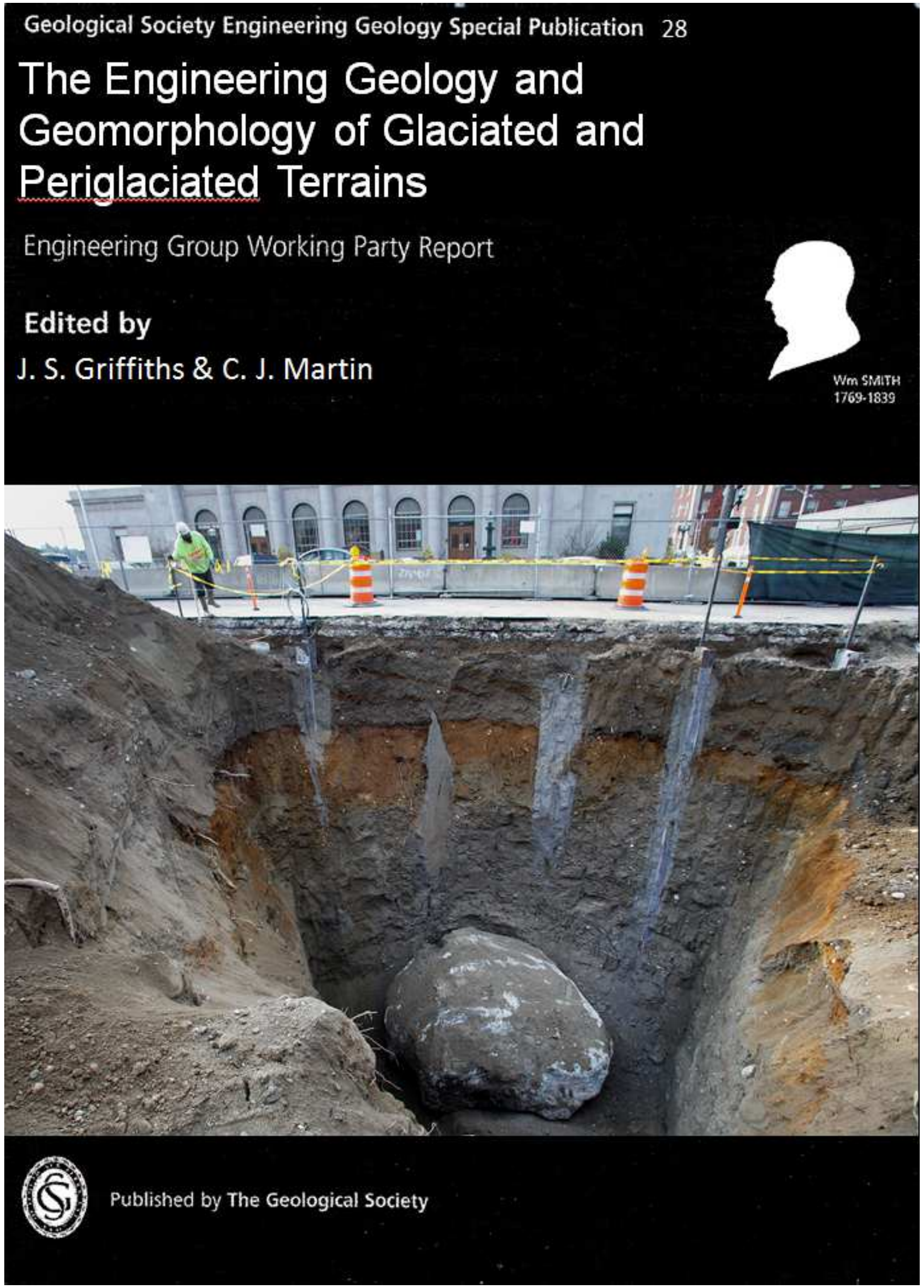


West Midlands Regional Group of the Geological Society

10 April 2018

The Engineering Geology and Geomorphology of Glaciated and Periglaciated Terrains – *Engineering Group Working Party Report*

Prepared by Chris Martin, David Giles, Martin Culshaw and other members of the EGGS Working Group

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

"When the work of the geologist is finished and his final comprehensive report written, the most important chapter will be upon the latest and shortest of the geologic periods"

(Gilbert 1890, Lake Bonneville. USGS Monograph 1)

"There is no such thing as simple geology"

(Gemma Sherwood – Glossop Award Lecture, November 2017)

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

Background

- Quaternary Engineering Geology EGSP no. 7 (Forster *et al.* 1991).
- Trenter, N.A. 1999. Engineering in glacial tills. CIRIA Report C504.
- Clarke, B. 2012. Glacial Soils. Chapter 33. ICE Manual of Geotechnical Engineering, Institution of Civil Engineers, London.
- Clarke, B. 2017. Engineering of glacial deposits. CRC Press, Boca Raton, Florida.

- New Working Party recommended by Hot Deserts WP, to complement Hot Deserts and Tropical Residual Soils themes.
- EGGS Forum, November 2011.

The Engineering Group of the Geological Society

Terms of Reference

- State-of-the-art review on the ground conditions associated with former Quaternary periglacial and glacial environments and their materials, from an engineering geological viewpoint.
- Appropriate coverage of the modern processes and environments that formed these materials.
- Not intended to define the geographic extent of former periglacial and glacial environments around the world, but to concentrate on ground models that would be applicable to support the engineering geological practitioner.
- Illustrated with numerous high quality and original case studies, figures, and photographs.
- Act as an essential reference handbook for professionals as well as a valuable textbook for students and others.
- Working Party members will be collectively responsible for the whole book.

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

The Engineering Group of the Geological Society

Working Party Members

- Prof. James Griffiths (Editor)
- Christopher Martin (Chair)
- Anna Morley (Secretary)
- Prof. Martin Culshaw
- Dr Michael de Freitas
- Prof. David Evans
- Dr David Giles
- Dr Sven Lukas
- Prof. Julian Murton
- Prof. David Norbury
- Prof. Mike Winter

THE GROUND FORUM GF

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

The Engineering Group of the Geological Society

WORKING PARTY FIELD TRIPS

Scope of the Report

- British Isles focus, but global application and examples.
- Relict materials and landforms, but cognisant of formative processes.
- Cold ‘stadials’, not warm ‘interstadials’. Quaternary only.
- Link between modern geomorphological terminologies and long-standing engineering geological nomenclature (Eurocode 7 and BS 5930). Extensive visual glossary (Chapter 3).
- Landsystems approach with ground models advocated.

Structure of the Book

1. Introduction to Engineering Geology and Geomorphology of Glaciated and Periglaciated Terrains **(Martin *et al.*)**
2. The Quaternary **(Lukas *et al.*)**
3. Geomorphological Framework - Glacial and Periglacial Sediments, Structures and Landforms **(Giles *et al.*)**
4. Conceptual Glacial Ground Models: British and Irish Case Studies **(Evans)**
5. Periglacial and Permafrost Ground Models for Great Britain **(Murton & Ballantyne)**
6. Material Properties and Geohazards **(Culshaw *et al.*)**
7. Engineering Investigation and Assessment **(De Freitas *et al.*)**
8. Design and Construction Considerations **(Winter *et al.*)**
9. Conclusions and Illustrative Case Studies **(Griffiths & Giles)**

The Engineering Group of the Geological Society

Chapter 1

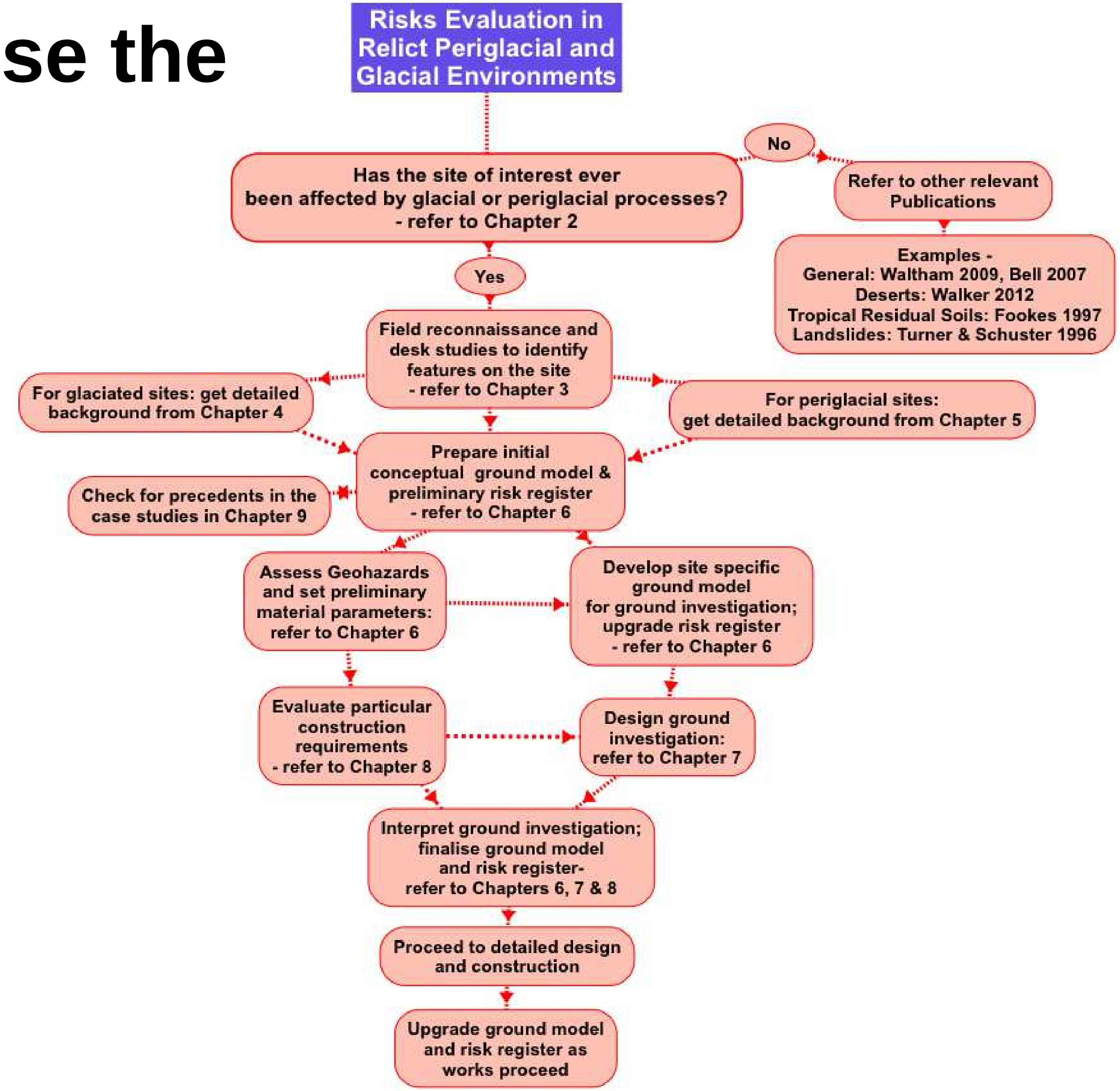
Introduction to Engineering Geology and Geomorphology of Glaciated and Periglaciated Terrains

C. J. Martin, A. L. Morley and J.S. Griffiths

THE GROUND FORUM GF

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

How to use the Book



The Engineering Group of the Geological Society

Chapter 2

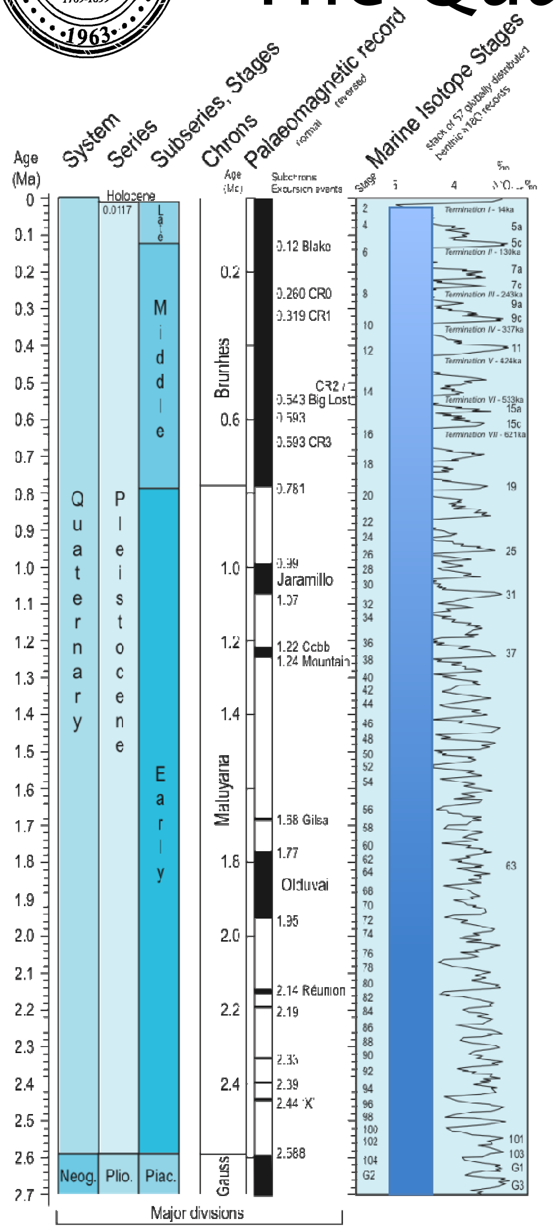
The Quaternary

S. Lucas, F. Preusser, D.J.A. Evans, C.M. Boston, and H. Lovell

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

The Engineering Group of the Geological Society

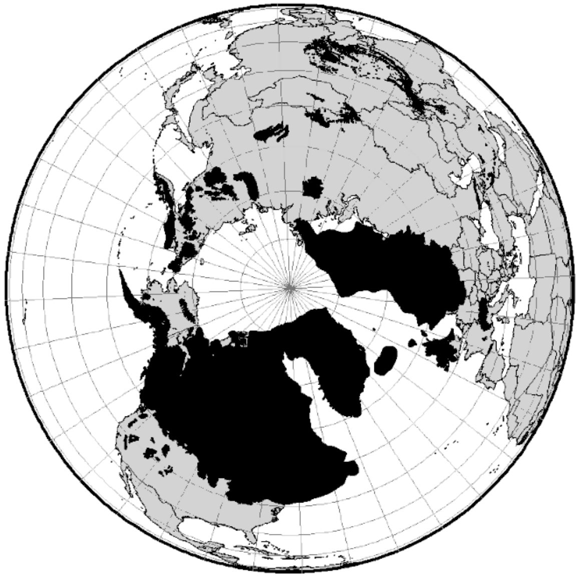
The Quaternary: the last 2.6 Ma

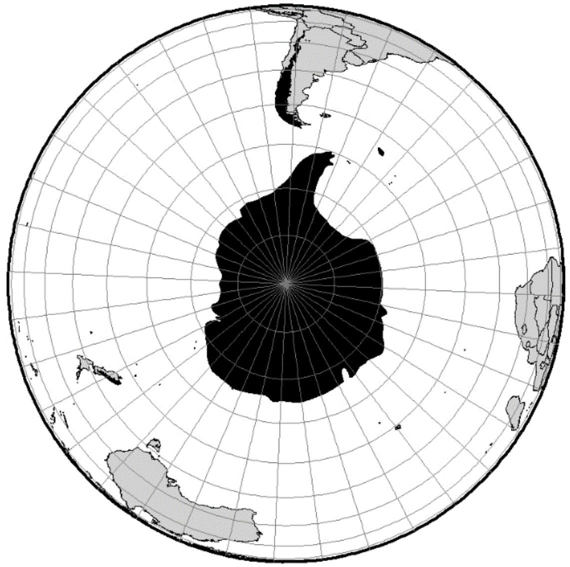


- The Quaternary is very different to previous periods in the Cainozoic Earth's history (plate tectonics ➔ mountain uplift, configuration of continents, atmospheric and ocean circulation)
- Complex picture of temperature fluctuations through last 2.6 Ma
- Most pronounced after 780 ka (Mid-Pleistocene Revolution), most likely due to changes in orbital parameters
- Alternating cold periods (Glacials) and warm periods (Interglacials) resulted in complex sequences of sediments characteristic of different process regimes

The Engineering Group of the Geological Society

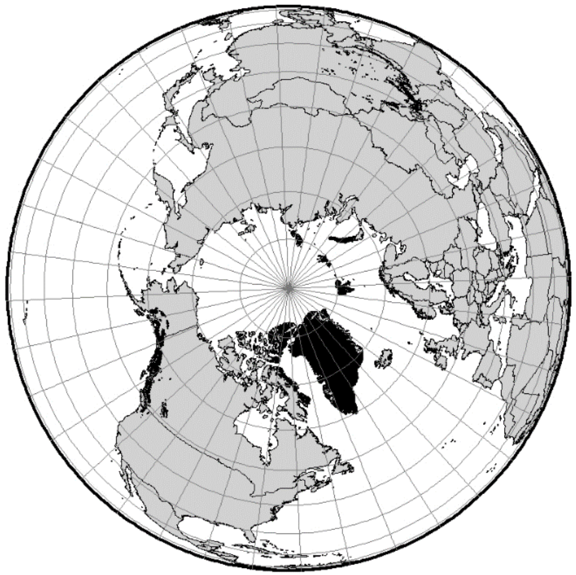
Ice mass distribution LGM(NH)

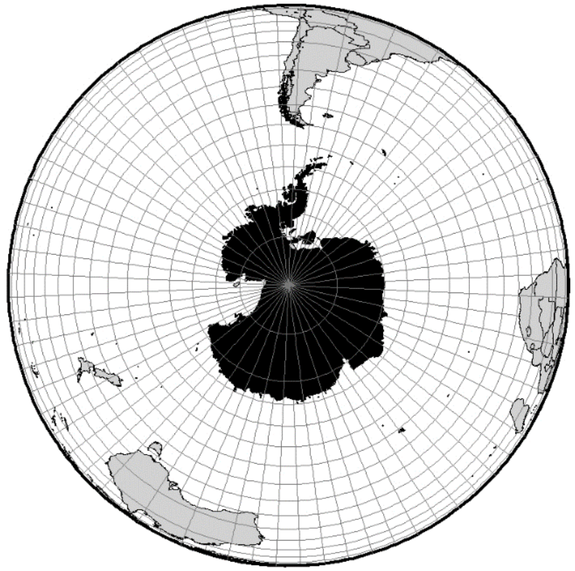




Ice mass distribution LGM(SH)

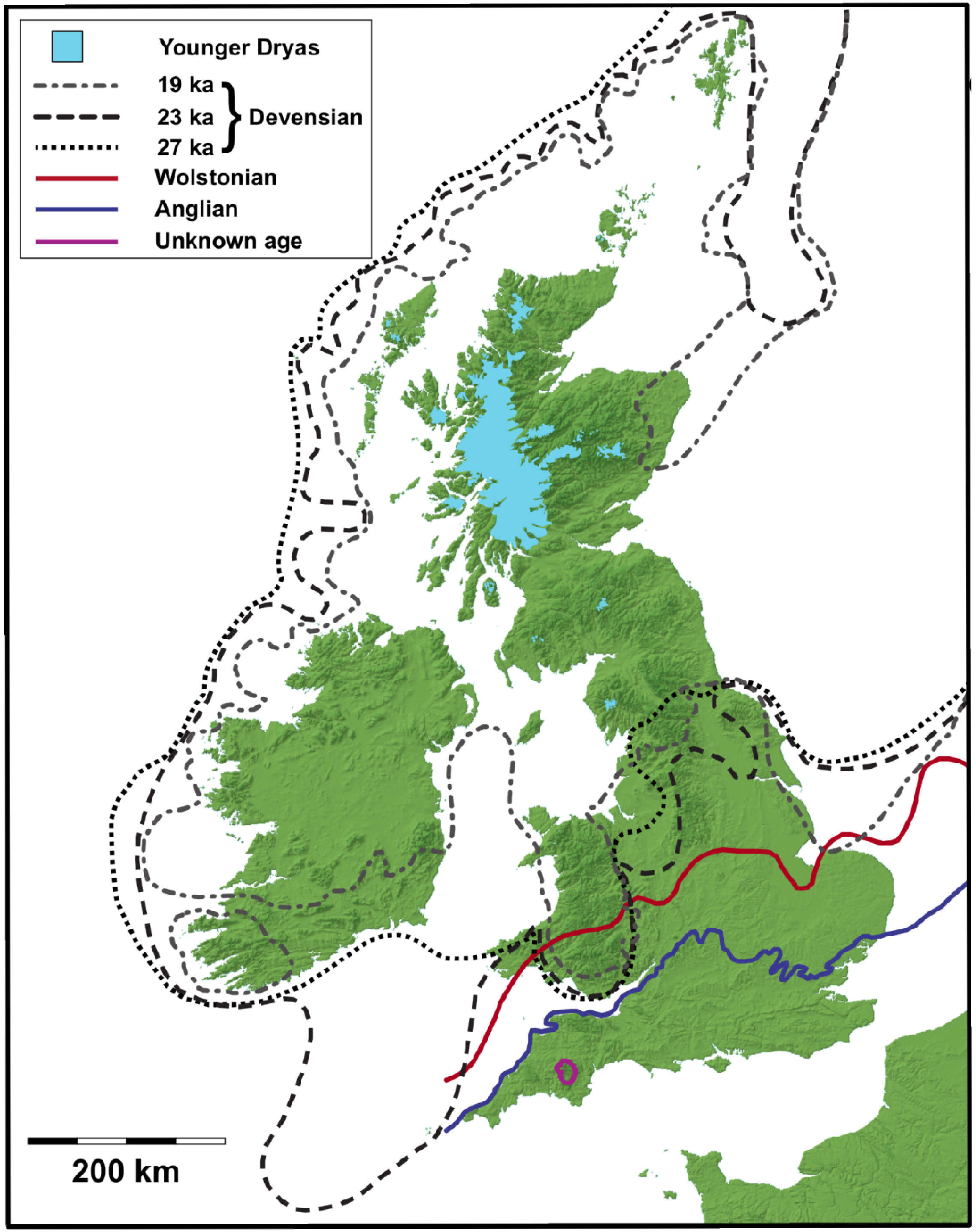
Ice mass distribution today (NH)





Ice mass distribution today (SH)

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering



Glaciation

- Different glaciations have different planetary and atmospheric boundary conditions (duration, sea level, sea ice conditions and a host of other factors... thus p, t,) and thus reach different extents
- Centres of ice accumulation in similar locations (watershed!), hence central areas experienced more significant glaciation than marginal parts
- Concept of ‘average glaciation‘
- Overprinting, erosion and re-entrainment of earlier sediments

➔ ***complexity of Quaternary sediment successions!***

And outside the glaciated areas?

- Periglacial processes, sea-level change and fluvial processes are just three examples
- Quaternary landform-sediment associations and sequences are characterised by overprinting and complex arrangement of very different process-response regimes in space and time
- This results in geomorphological and stratigraphical complexity both vertically and horizontally
- Therefore, standard stratigraphic (‘layer-cake‘) models are most often not applicable to Quaternary sediment successions (at all!)

Synthesis

- The Quaternary is characterised by climatic fluctuations of different frequency and magnitude that result from complex boundary conditions
- These fluctuations have resulted in repeated glacial-interglacial and stadial-interstadial cycles
- Repeated glaciation and periglaciation have resulted in a complex arrangement of sediments with vastly differing geotechnical properties
- Spatial and temporal variability of these processes also lead to ‘sudden‘ horinzontal and vertical changes in stratigraphic successions, making the standard ‘layer-cake‘ model inapplicable to terrestrial Quaternary successions
- Understanding of this complexity, and the application of genetic models based on modern analogues (see Chapters 3-5) is key to success and to avoiding costly misinterpretations (Chapters 6-9)

The Engineering Group of the Geological Society

Chapter 3

Geomorphological Framework - Glacial and Periglacial Sediments, Structures and Landforms

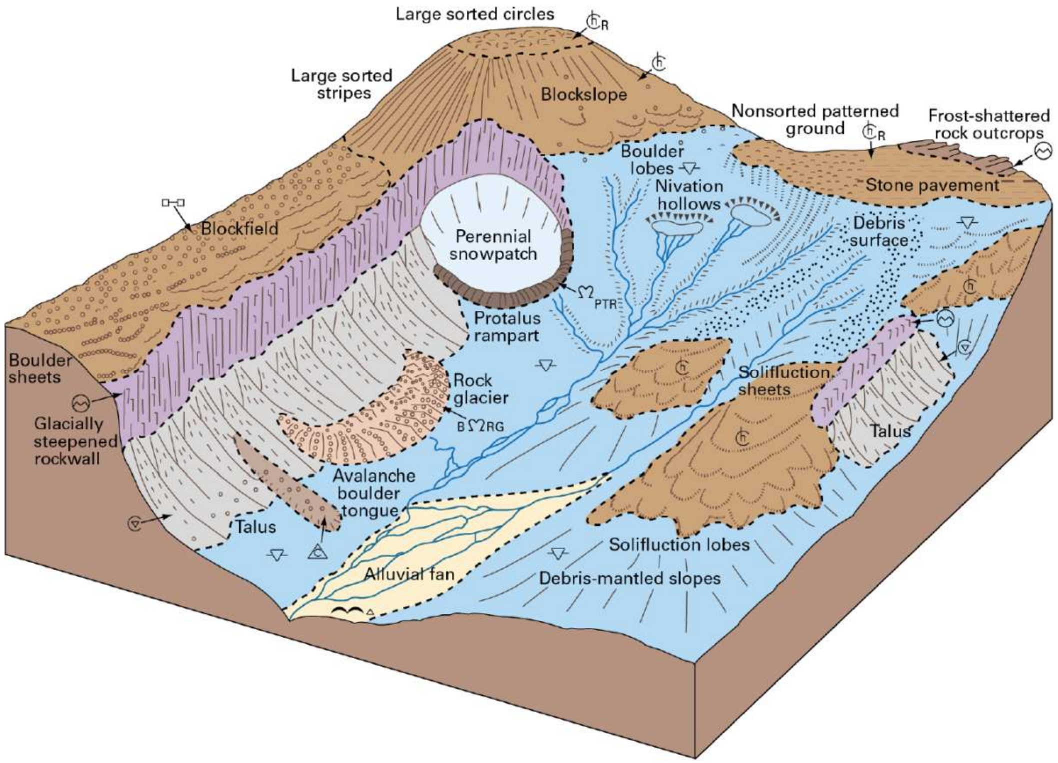
D.P. Giles, J.S. Griffiths, D.J.A. Evans & J.B. Murton

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

The Engineering Group of the Geological Society

Informing the Ground Model

- Building blocks required to develop ground models for glaciated & periglaciated terrains
- Catalogue of
  - Sediments
  - Structures
    - Macro
    - Micro
  - Landforms



Schematic representation of the Late Devensian periglacial features of the Scottish Highlands that were probably active during the Loch Lomond Stadial (Ballantyne, 1984)

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

The Engineering Group of the Geological Society

Glacial Landforms

Terrain Unit	3.10.1.6 Whaleback
Image	 Fig 3.8.1.6a Whalebacks, Coire Lagan, Skye, Scotland (D.J.A Evans)
Form / Topography	A streamlined smoothed or scratched bedrock knoll with symmetrical longitudinal profiles, several metres to a few hundred metres high, resembling a whale in profile.
Landsystem	Upland glacial landsystem (hard rock terrain): Subglacial footprint
Process of Formation	Formed by abrasion of both stoss and lee sidesof a rock knoll. Small whalebacks can form under only a few hundred metres of ice, larger ones under deep ice streams.
Modern Analogue	 Fig 3.8.1.6b Striated whaleback, Konowbreen, Svalbard (D.J.A Evans)
Associated Features	Rock drumlins
Principal Engineering Significance	Sheared bedrock
Principal References	Rea (2013a), Glasser & Bennett (2004), Evans, I.S. (1996)

Associated features

Principal engineering significance

Principal references

Engineering geology case studies

THE GROUND FORUM

The Engineering Group of the Geological Society

Periglacial Landforms

Terrain Unit	3.11.2.1 Solifluction Sheets and Aprons
Image	 Fig 3.11.2.1a Relict solifluction sheets, Broadway, Cotswolds, Worcestershire, England. (D. Giles)
Form / Topography	Solifluction landforms are expanses of mobile or formerly mobile sediments on gentle to moderate slopes that have moved downslope by solifluction and which often terminate downslope at a step or riser. Solifluction sheets generally have little or no surface expression. Morphologically they are smooth convexo-concave slopes that can extend from several hundred metres to 3 or 4km downslope. Shear surfaces can be found typically at 2-3m deep in clay-rich deposits.
Landsystem	Lowland Periglacial Terrain: Upland Periglacial Terrain: Sediment-Mantled Hillslope Landsystem
Process of Formation	Predominant form of periglacial mass movement in active periglacial environments and solifluction deposits and landforms are widespread and are common in relict form. Result from the slow downslope movement of soil due to recurrent freezing and thawing of the ground. Solifluction is due to one or more of three related processes: needle-ice creep, frost creep and gelifluction. Emplaced on slopes with inclinations as low as 1-2° due to excessive pore water pressures generated in thaw.
Modern Analogue	 Fig 3.11.5.2.1b2 Active solifluction sheet Beinn Bheoil, N Highlands, Scotland. (C.K. Ballantyne)
Associated Features	Solifluction lobes, benches and terraces.
Principal Engineering Significance	Ground movement, Shear surfaces, Anisotropic strength, Low shear strength
Principal References	Ballantyne & Harris (1994), Harris (1987, 2013) Hutchinson (1991, 1992), Spink (1991), Skempton & Weeks (1976), Chandler (1970, 1972), Harris (1977), Skempton et al. (1991), Croot & Griffiths (2001), Whitworth et al. (2005)

Image of relict form

Form / Topography

Landsystem

Process of formation

Image of modern form

The Engineering Group of the Geological Society

Sediments

Previous terms

Diagnostic characteristics

Environment of formation

Common Structures present

Principal Engineering significance

Typical images

Proposed sediment name

Sediment Name 3.5.1.3	**Supraglacial mass flow diamicton/glaciogenic debris flow deposit**
Previous Terms	Supraglacial morainic till, flow till, melt-out till, ablation till
Diagnostic Characteristics	Predominantly clast-supported, massive to crudely stratified or graded diamictons but the sedimentology of supraglacial depo-centres is complex due to multiple cycles of redeposition during formation. Typical facies associations comprise interbedded diamictons and discontinuous bodies of laminated lacustrine sediments, and glaciofluvial sands and gravels. Internal disturbance is common and characterized by normal faulting, flow folding and soft sediment deformation.
Environment of Formation	Glacier surfaces or on ice-cored moraines
Common Structures Present	Although they appear largely massive, individual debris flows can form tabular or lens-shaped units, often with erosional, channelized bases and flat tops. Successive flows can therefore be distinguished by their upper and/or lower boundaries, which are commonly marked by basal concentrations of clasts, upper washed horizons/ interbeds of silt, sand or gravel, or very subtle partings. Each of these characteristics, as well as any internal structures, reflect the nature of the mass flow type, specifically related to the moisture content and coherence of the matrix. Supraglacial mass flow deposits are most confidently identified when juxtaposed with typical supraglacial facies associations. At microscale, structures are particularly well developed at the basal boundaries of individual flows. Here the substrate can be characterized small folds, thrusts and shears, associated with rotated to slightly attenuated diamicton pebbles derived from the overlying debris flow. The debris flow-substrate interface can be marked by elongate 'flames' of the substrate material separating lobate or pendant structures of the debris flow diamicton, which are progressively tilted downflow. The base of the debris flow can contain detached 'flames' or ribbons of the substrate material as well as indicators of rotational deformation, such as circular, arcuate and galaxy-like grain arrangements. Importantly, none of these features is singularly diagnostic of debris flow deposits and can be found in subglacial tills also.
Principal Engineering Significance	Variable particle sizes, Anisotropic permeability, Anisotropic strength, Anisotropic stiffness, Perched water tables, Coarse horizons, Shear surfaces, Sheared bedrock

Typical Images

Fig 3.5.1.3a Crudely stratified gravelly mass flow deposits comprising a stacked sequence of discontinuous layers of predominantly clast-supported but locally matrix-supported diamictons separated in places by gravelly lags. Kvíárjökull, Iceland. (D.J.A. Evans)

Sedimentological description

Engineering description

Fig 3.5.1.3c Very crudely stratified boulder-rich and predominantly clast-supported diamictons with contorted bedding structures and localized pockets of stratified sand and gravel. Gillespie's Beach, New Zealand. (D.J.A. Evans)

Sedimentological Description	Engineering Description
Crudely stratified diamictons with a range of clast contents and matrix properties. Often interbedded with or separated by discontinuous layers of silt, sand and gravel. Can display crude grading, often with basal concentrations of clasts. Flow structures or soft sediment deformation features are visible wherever the deposits possess any stratification.	Often indistinctly bedded gravelly sandy CLAYS with low to medium cobble and low boulder content. Occasionally fine upwards. Bedding affected by flow and soft structure deformation features.

Principal References

Lawson (1979), Eyles (1979), Johnson & Rodine (1984), Owen (1994), Johnson & Gillam (1995), Phillips (2006), Evans et al. (2010)

Engineering Geology Case Studies

Bell (2000), Culshaw et al. (1991), McMillan et al. (2000), Reeves et al. (2006a, 2006b)

Principal references

Engineering geology case studies

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

The Engineering Group of the Geological Society

Macro Structures

Structure Name 3.7.14	Relict periglacial shears
Diagnostic Characteristics	Underlie gently sloping ground underlain by weathered clay bedrocks. Shear surfaces may be polished and striated. Shallow, low-angle basal shears are the most extensive form, at depths of *c.* 1.5–3.0m, at or near the base of the reworked clay or the top of destructured clay, and subparallel to the ground surface. Deeper, subhorizontal continuous shears occur near the base of weathered clay at depths of *c.* 4–8m. Smaller, discontinuous shears produced by internal deformation during mass movement are commonly associated with both the shallow and the deeper shears. High-angle shears sometimes present in reworked and destructured clay, and occur to depths of *c.* 3m beneath hillslopes of 5° or less. Shears are often difficult to see in freshly dug sections when the soil is at its natural water content, and time is needed for drying to cause shrinkage so that the clays pull apart along the shear surfaces.
Principal Engineering Significance	Ground movement, Shear surfaces, Low shear strength, Anisotropic permeability

Typical Image

Fig 3.7.14 Basal shear surface with striations and polish in clay-rich head deposits, Sevenoaks, Kent, England. Scale in inches. (J.N. Hutchinson)

Principal References

Harris (2013);
Hutchinson (1991), Spink (1991), Skempton & Weeks (1976), Chandler (1970, 1972), Harris (1977), Skempton et al. (1991)

Diagnostic characteristics

Principal Engineering significance

Typical images

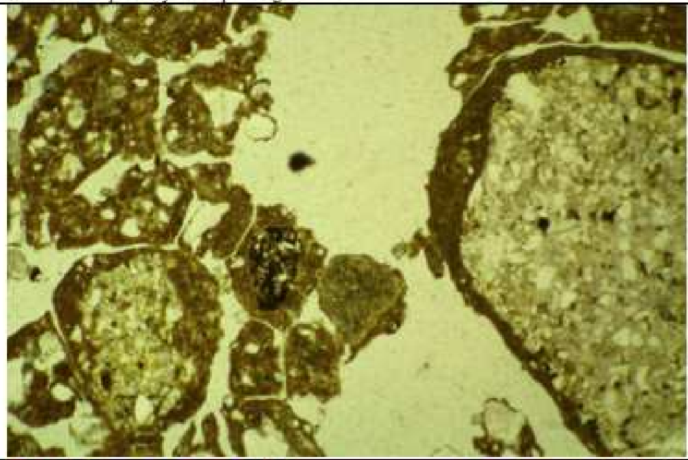
Principal references

Engineering geology case studies

Micro Structures

3.8.2.4 Calcitans Microstructures

Calcitans are discontinuous coatings of secondary calcium carbonate that form by precipitation beneath particles. In this example, they are not found on the same side of the aggregates but in different orientations, which indicates that the aggregates have rotated after the calcitans started to form. Rotation probably accompanied gelifluction.



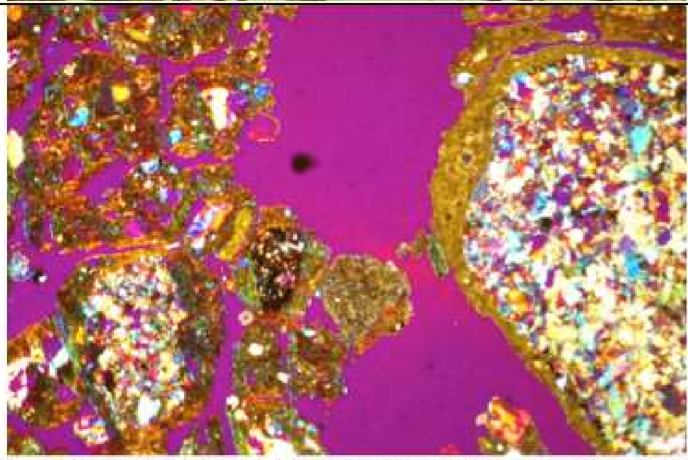


Fig 3.6.7.4a PPL Fig 3.6.7.4b XPL with gypsum wedge. Calcitans (dark brown in upper image) surrounding sediment aggregates ('pebble structure'; multi coloured in lower image) in silty-clay diamicton (till), Mount Provender, Shackleton Range, Antarctica. Field of view = 6.4 mm wide. (J. van der Meer)

Principal References

van der Meer et al. (1993)

The Engineering Group of the Geological Society

Chapter 4

Conceptual Glacial Ground Models: British And Irish Case Studies

D.J.A. Evans

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

Reconciling landsystems and domains in Britain & Ireland

- **Ice sheet related landsystems**

  Sediment-landform associations

  = subglacial footprint; ice-marginal complexes;

  supraglacial debris complexes

*[**Example**: Ice sheet marginal setting of Holderness]*

- **Upland glacial landsystems (hard bedrock terrain)**

  Sediment-landform associations

  = subglacial footprint; ice-marginal complexes;

  supraglacial debris complexes

*[**Example:** Mountain icefield of south Loch Lomond]*

- **Glaciofluvial sediment-landform associations**

  Sediment-landform associations

  = ice-contact settings; proglacial settings

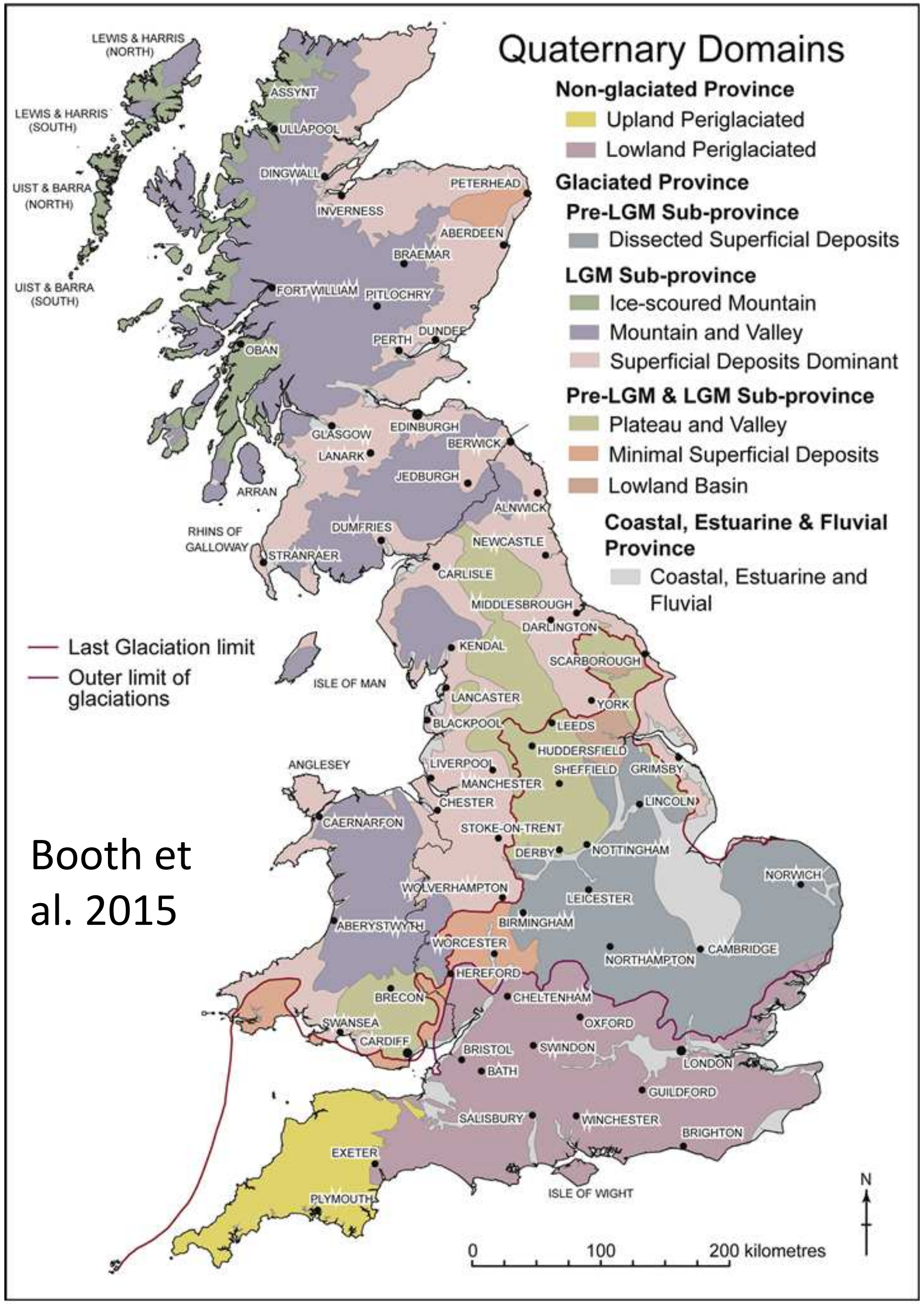
*[**Example:** The Brampton kame belt]*

- **Subaqueous glacial depositional sequences**

  Sediment-landform associations

  = ice-proximal depo-centres; distal sediment piles

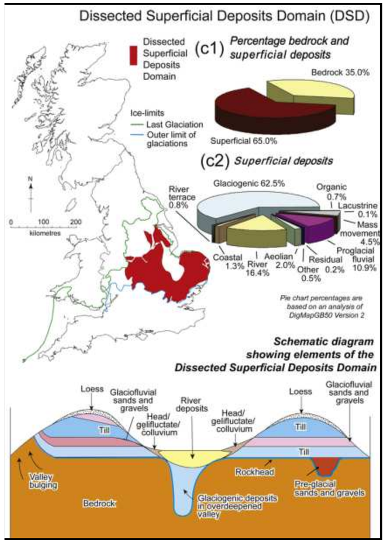
*[**Example**: Waterville, Ireland]*

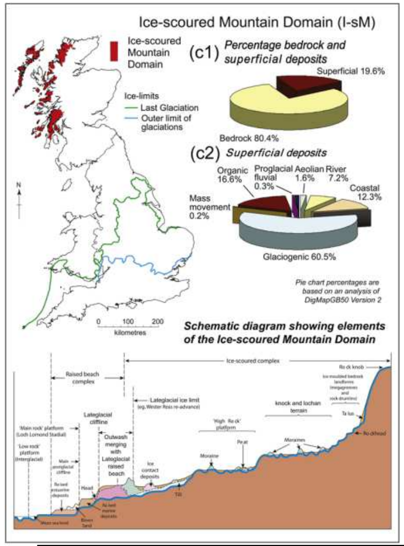


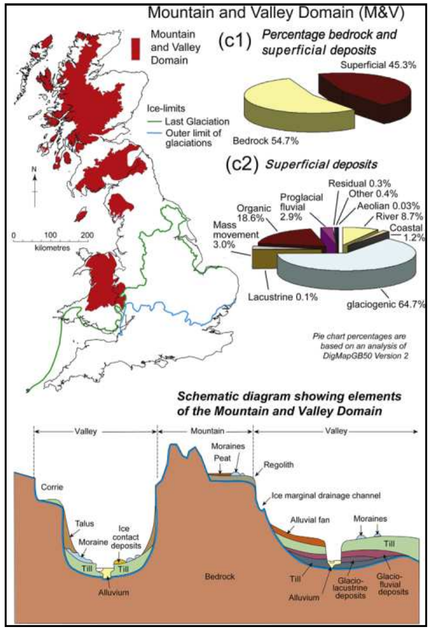
Booth et al. 2015

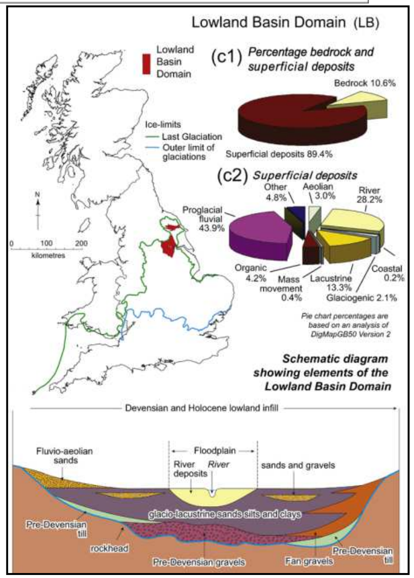
Ground models to Quaternary Domains

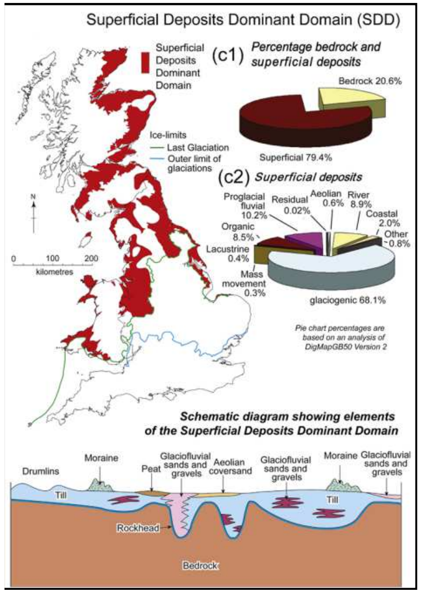
(Booth et al. 2015)

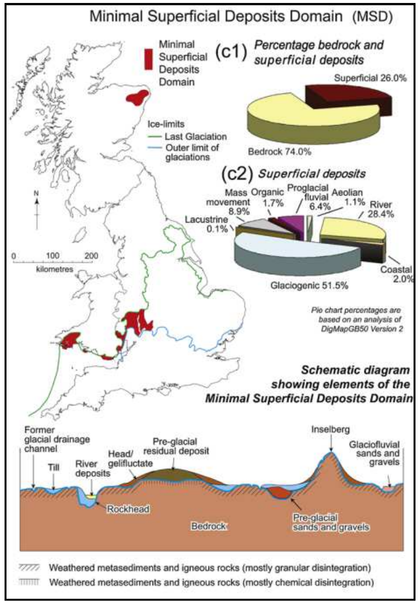


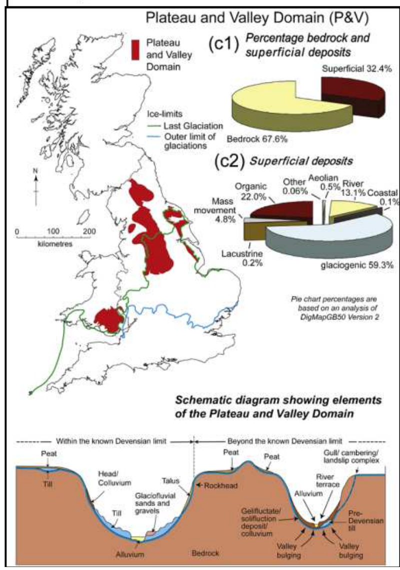


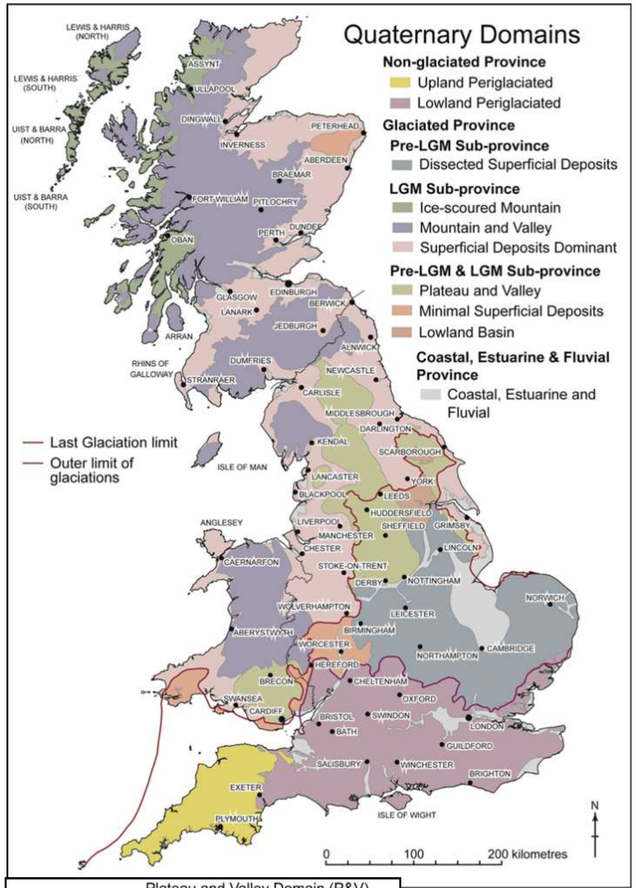












Chapter 5

Periglacial and Permafrost Ground Models for Great Britain

J.B. Murton and C.K. Ballantyne

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

The Engineering Group of the Geological Society

Periglacial landsystems

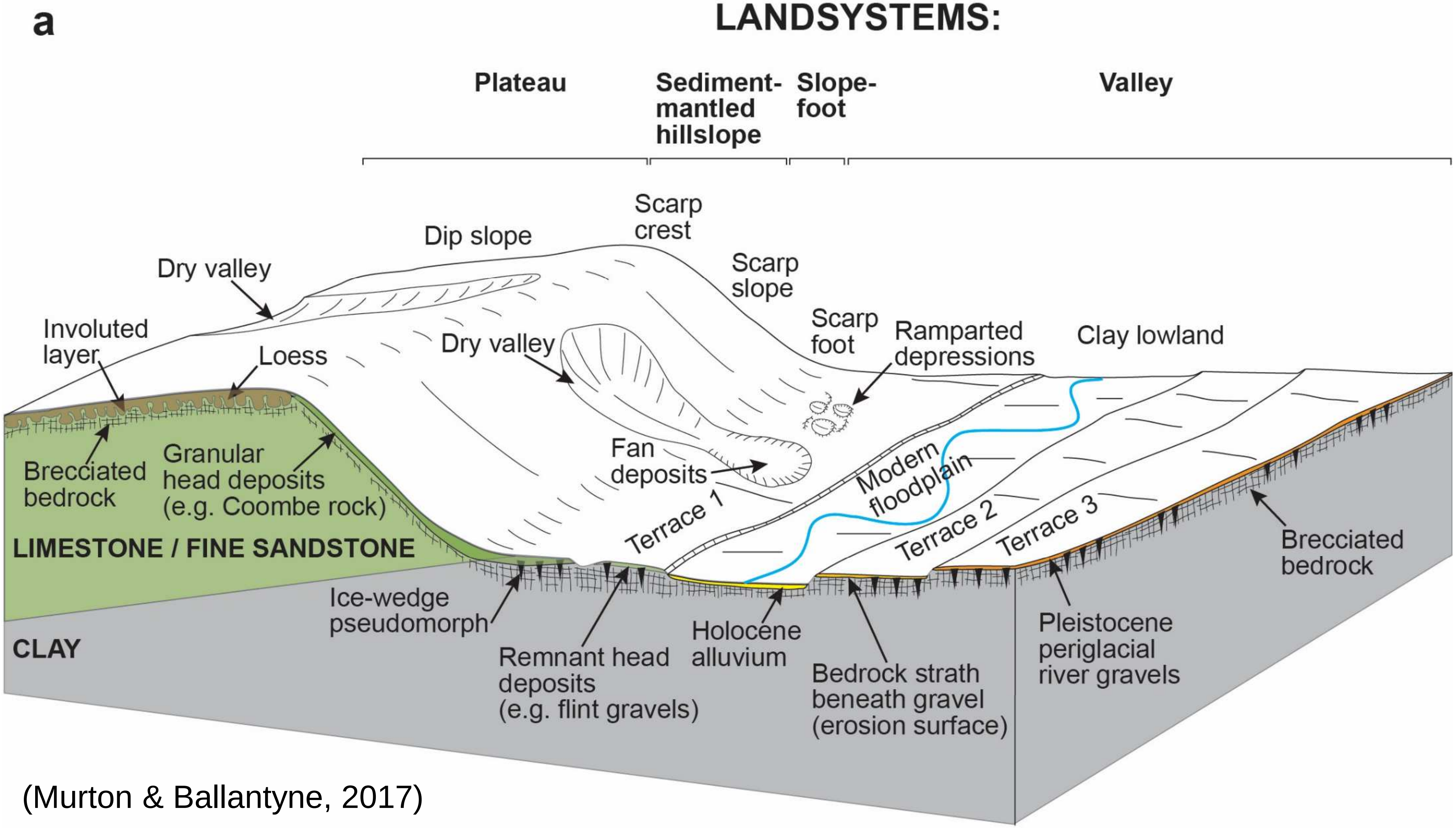
Assemblages of periglacial landforms, regolith cover, sediments & subsurface structures characteristic of particular locations defined by altitude, topography & presence or absence of regolith or sediment cover

- Plateaux
- Sediment-mantled hillslopes
- Rock slopes
- Slope feet
- Valleys
- Buried
- Submerged

The Engineering Group of the Geological Society

Ground models

Limestone plateau-clay vale



(Murton & Ballantyne, 2017)

The Engineering Group of the Geological Society

Chapter 6

Material properties and geohazards

M.G. Culshaw, D.C. Entwisle, D.P. Giles, T. Berry, A. Collings, V.J. Banks, L.J. Donnelly

THE GROUND FORUM

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

Tills

Previous classifications have identified tills based on:

- Formative processes (comminution till; *deformation till*)
- Transportation processes (superglacial till; englacial till; basal till)
- Depositional processes (ablation till; *melt-out till; lodgement till*; *flow till*; water-lain till)

Trenter (CIRIA C504 1999) & Clarke (ICE Manual of Geotech Eng 2012) recognised only:

- Lodgement till
- Melt-out till
- Flow till
- Deformation till

In this new book, the following 'tills' are recognised:

- ***Subglacial Traction Till*** (includes lodgement till, deformation till, comminution till and subglacial melt-out till)
- ***Glaciotectonite*** (can include any material that has been deformed by ice movement)
- ***Supraglacial mass flow diamicton/glaciogenic debris flow deposits*** (can also include supraglacial morainic till, flow till and melt-out till)

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

Midland Valley Glacigenic Subgroup (MVG)
Wilderness Till Formation (WITI)

Description: Firm to extremely weak, sometimes jointed, reddish brown (if composed of Devonian and Upper Coal Measures), brownish grey or dark grey (if composed of other Carboniferous rocks), or greenish grey (if composed of Highland metamorphic rocks), gravelly, sandy CLAY or SILT or MUDSTONE with cobbles and boulders. May contain beds of medium sand or laminated clay up to 100 mm thick. It may be locally graded, either coarsening upwards or downwards with occasional gravel to boulder size. Very occasional firm to stiff, laminated CLAY beds up to 10 m thick and several 10's of metres in extent near the base of the formation.

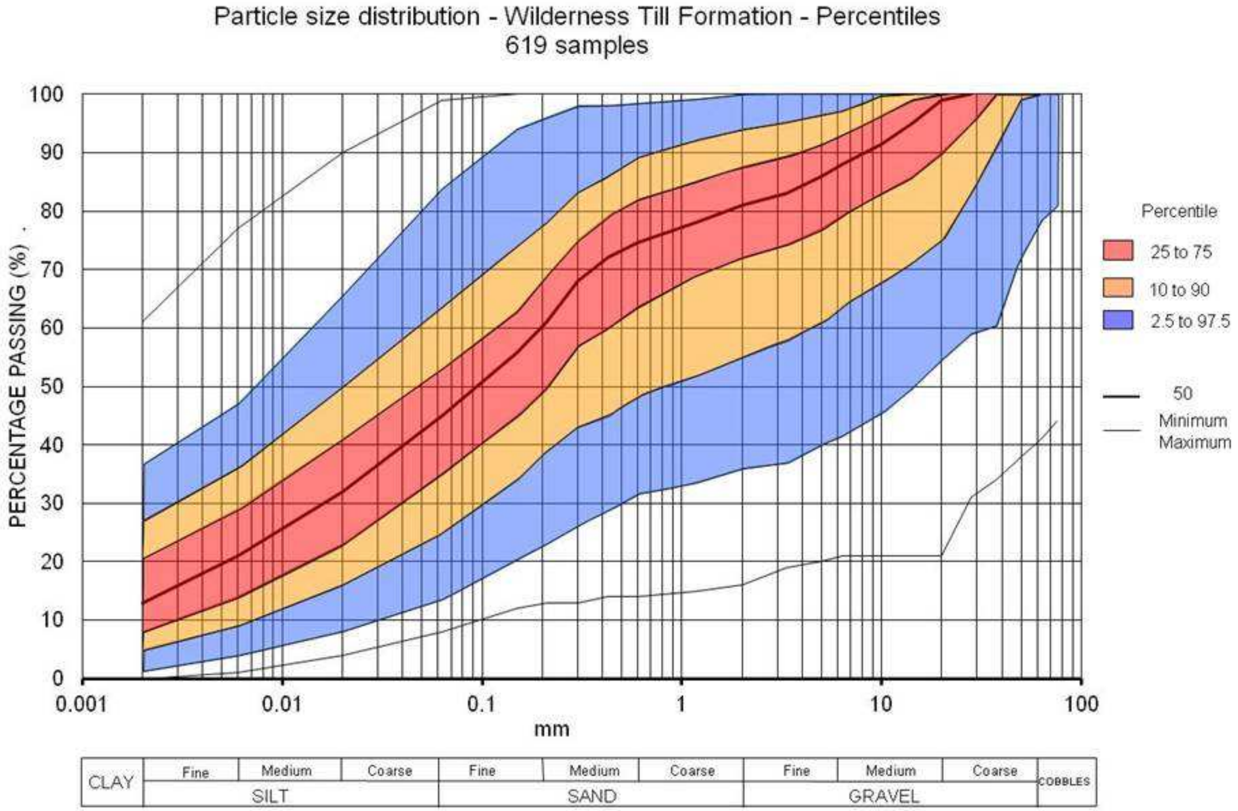
Reference section: BGS Belshill Borehole. BGS borehole NS 76SW 451 [NS 7304 6161].

Thickness: 30 m or more, particularly in drumlins.

Distribution and extent: Midland Valley of Scotland, north Ayrshire to Stirling, Tayside, the Lothians and Fife.

The Engineering Group of the Geological Society

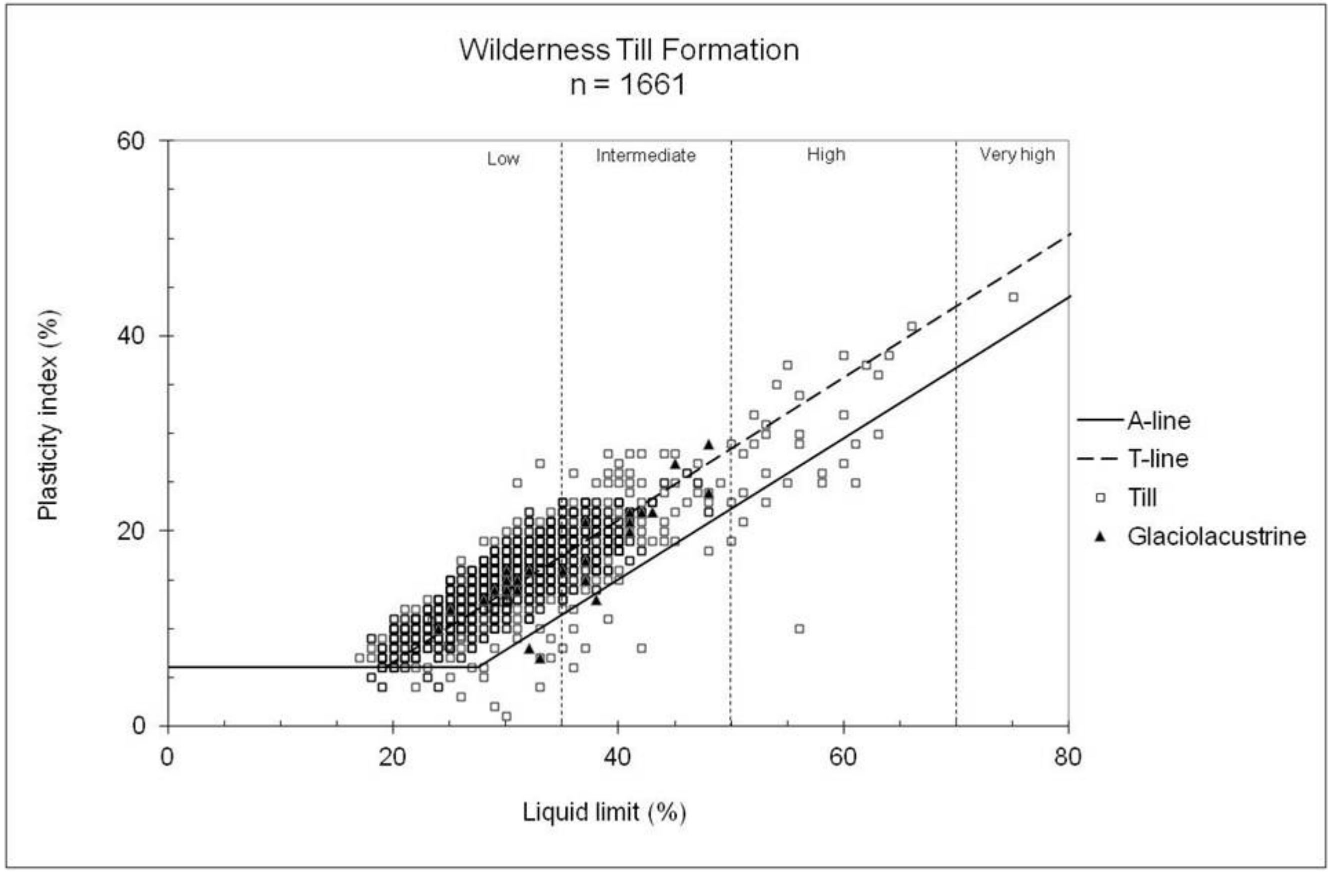
Wilderness Till Formation – psd (619 samples)



E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

The Engineering Group of the Geological Society

Wilderness Till Formation – plasticity (1661 samples)



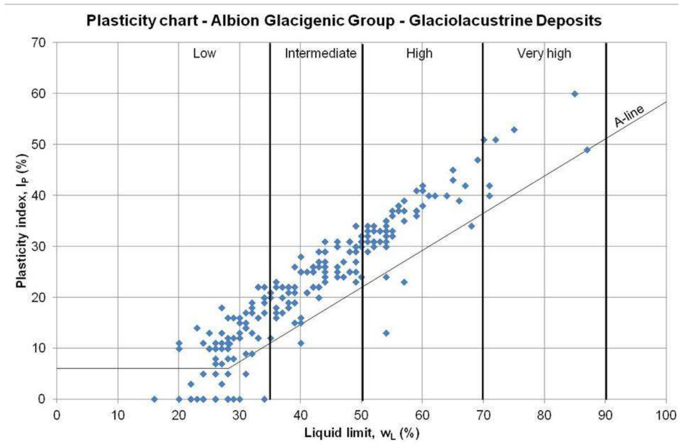
E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

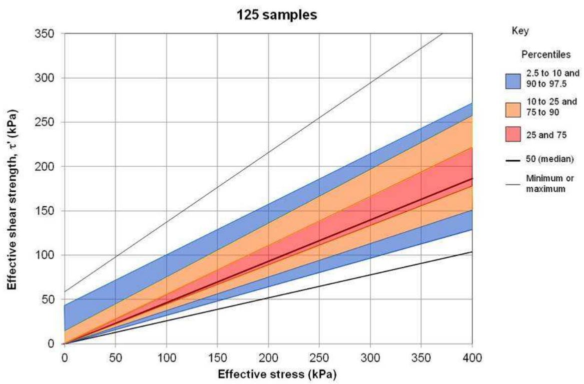
The Engineering Group of the Geological Society

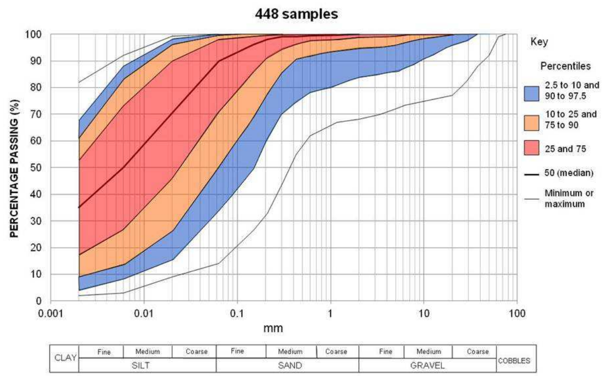
Glaciolacustrine deposits

Series of silt/clay couplets with the silt-rich layer indicative of summer depositional conditions and the clay-rich layer indicating winter conditions.

Because of the compound nature of these laminated deposits, some standard geotechnical tests may give misleading results with regard to their engineering behaviour.







Loess

On geological maps:

- Brickearth
- River Brickearth
- Head Brickearth
- Head Brickearth, Older
- Head Brickearth, Younger

However, not all mapped brickearths are loessic (eg, ‘Norwich Brickearth’)

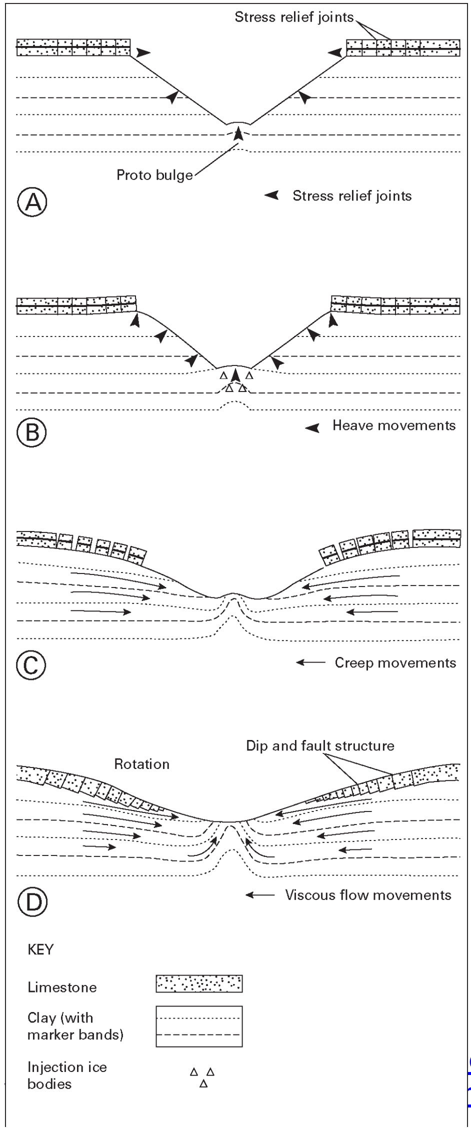
Proposal: to avoid confusion and remain consistent with the long historical usage of the term ‘brickearth’ on geological maps, the term ‘loessic brickearth’ should be used for those deposits in the UK that are clearly of aeolian/loessic origin.

THE GROUND FORUM

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

The Engineering Group of the Geological Society

Local & Regional Geohazards

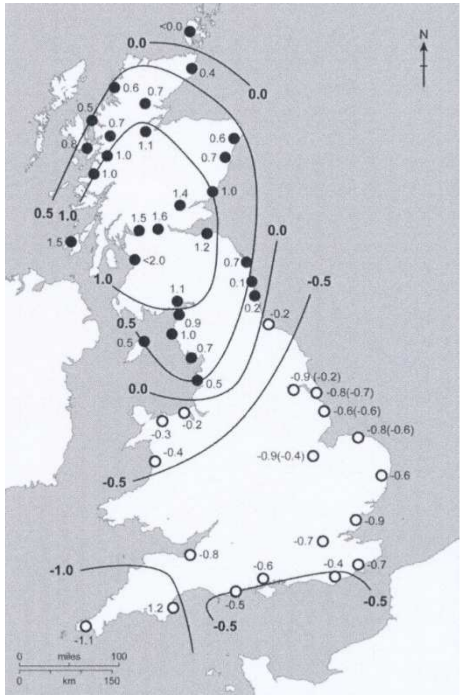


Local geohazards

Landslides (except related to solifluction) and highly compressible *peat* not included as not specifically related to glacial/periglacial processes

Superficial valley disturbances

- *Cambering*
- *Gulls*
- *Valley bulging*
- Surprisingly little researched in the UK
- Sometimes appear on geological maps as 'Foundered strata'



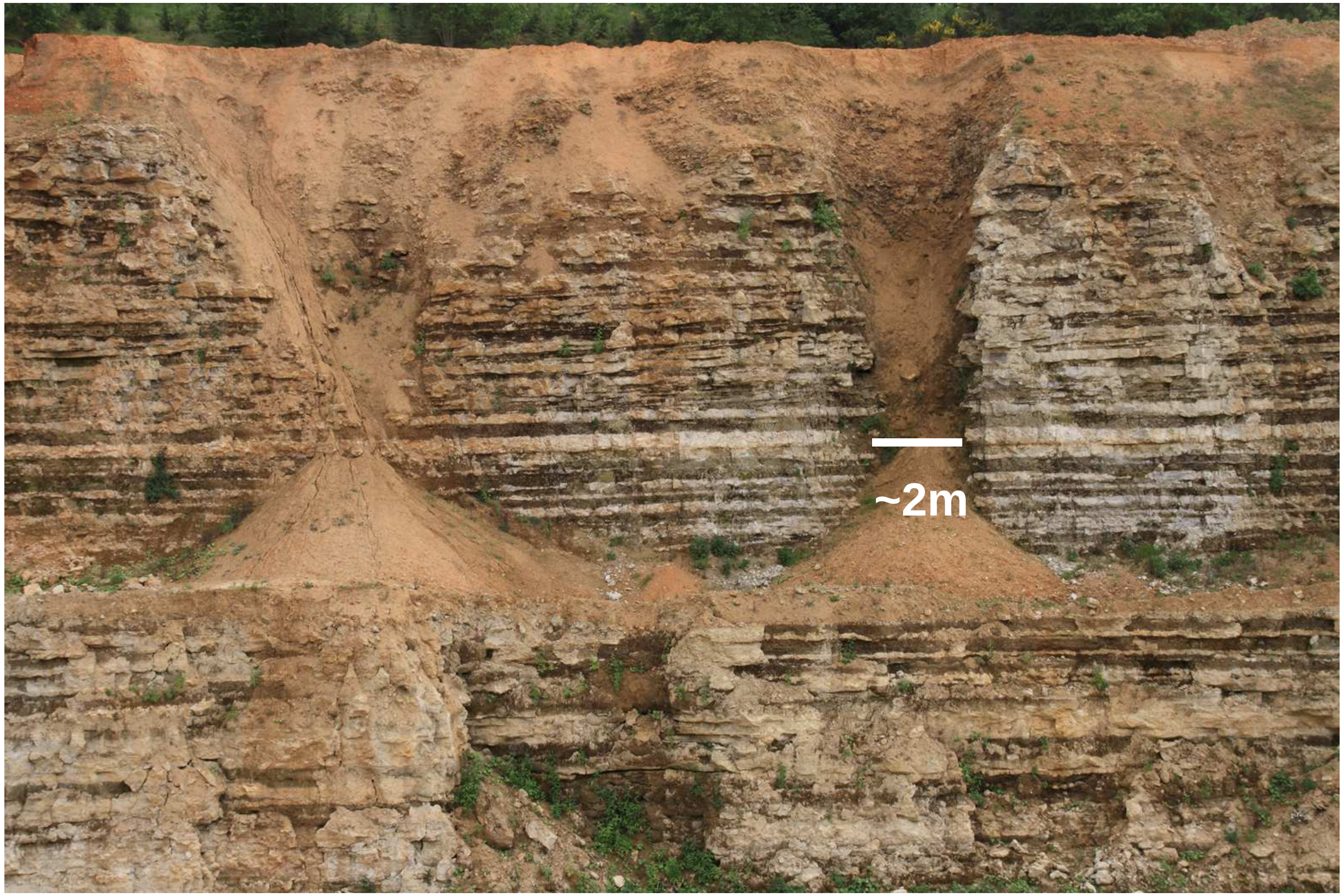
Regional geohazards

- Neotectonics and the consequent changes in sea level
- Quaternary palaeoseismicity, including possible fault reactivation

c.org.uk
ng

The Engineering Group of the Geological Society

Cambering? Solution pipe? What else?



Hermitage Quarry, near Maidstone, Kent. The infill features in the Kentish Ragstone have been previously described as sand-filled gulls resulting from valley cambering. However, during the field visit considerable doubt was cast upon this interpretation and a number of alternative hypotheses were postulated (e.g. solution pipes). The neck of each of the infills is around 2m wide at the narrowest point

THE GROUND FORUM GF

The Engineering Group of the Geological Society

Chapter 7

Engineering Investigation And Assessment

M.H. de Freitas, J.S. Griffiths, N. Press, J. Russell, A.A. Parkes, I.G. Stimpson, D.N. Norbury, C. Coleman, J. Black, G. Towler, & K. Thatcher

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

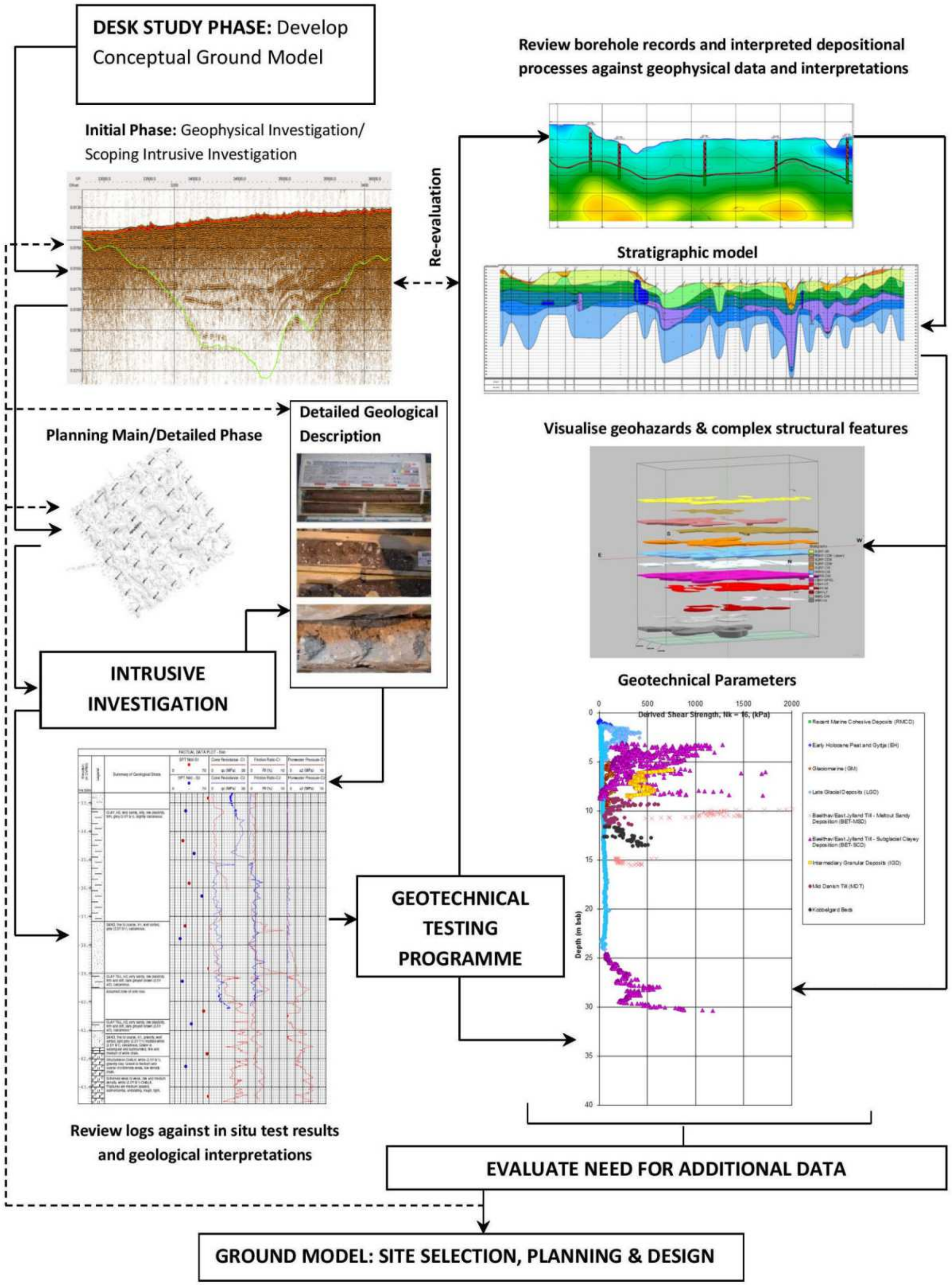
The Engineering Group of the Geological Society

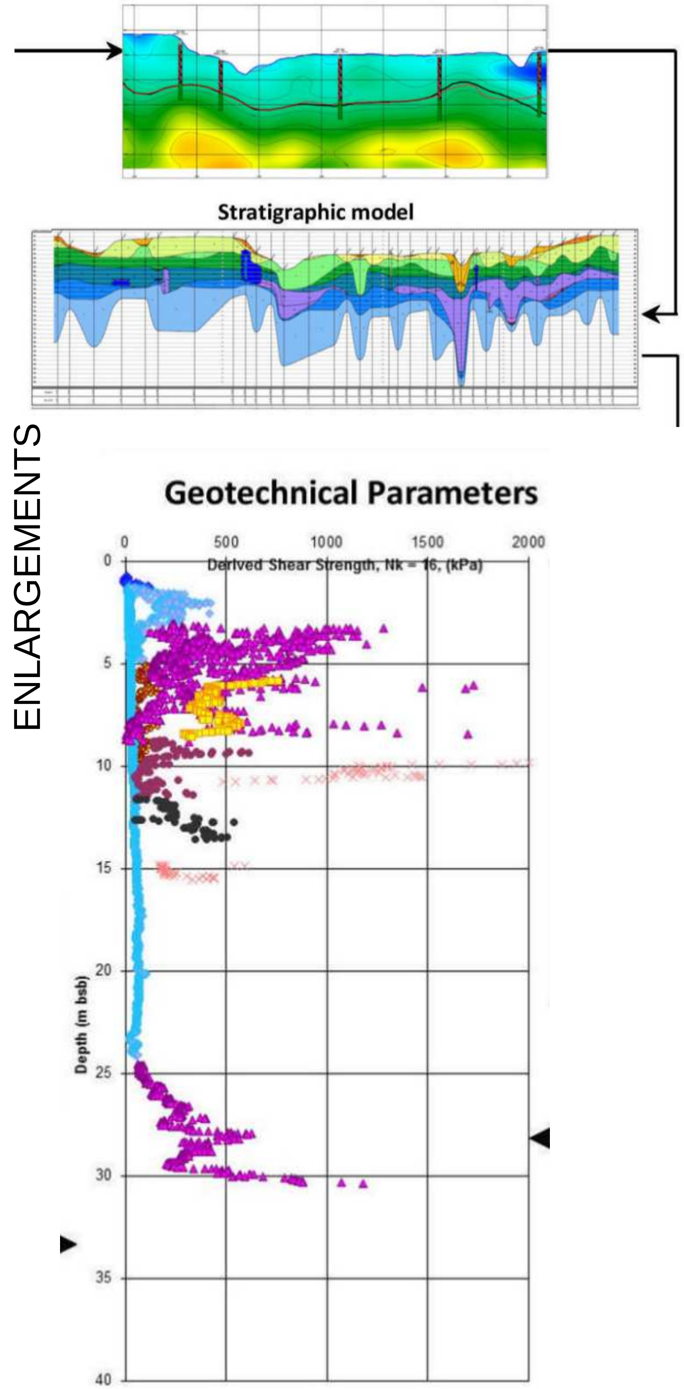
Differences between sedimentological and geotechnical classification

	Sedimentological terms	Engineering geological terms	
Very thick beds	>1000	>2000	Very thick beds
		600 – 2000	Thick beds
Thick beds	30 – 1000	200 – 600	Medium beds
		60 – 200	Thin beds
Medium beds	10 – 30	20 – 60	Very thin beds
		6 – 20	Thick laminae
Thin beds	3 – 10	<6	Thin laminae
Very thin beds	1 – 3		
Thick laminae	0.6 – 1		
Medium laminae	0.3 – 0.6		
Thin laminae	0.1 – 0.3		
Very thin laminae	<0.1		

	Sedimentological terms (eg Stow 2006)				BS5930 terms used in engineering practice	
	boulder					boulder
		256		200		
	cobble					cobble
		64		63		
	pebble				coarse	
gravel				20		
					medium	gravel
		4		6.3		
	granule				fine	
		2		2		
	very coarse				coarse	
		1				
	coarse					
		0.5		0.63		
sand	medium				medium	sand
		0.25		0.2		
	fine				fine	
		0.125				
	very fine					
		0.063		0.063		
	coarse				coarse	
		0.032				
	medium					
silt		0.016		0.02		
	fine				medium	silt
		0.008				
	very fine			0.0063		
		0.004			fine	
	coarse					
		0.002		0.002		
	medium					
		0.001				
clay	fine					
		0.0005				clay
	very fine					
		0.00025				
	colloid					

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering


DESK STUDY PHASE: Develop Conceptual Ground Model
Initial Phase: Geophysical Investigation/ Scoping Intrusive Investigation
Re-evaluation
Review borehole records and interpreted depositional processes against geophysical data and interpretations
Stratigraphic model
Planning Main/Detailed Phase
Detailed Geological Description
Visualise geohazards & complex structural features
INTRUSIVE INVESTIGATION
Geotechnical Parameters
Derived Shear Strength, Nk = 16, (kPa)
Depth (m bsb)
GEOTECHNICAL TESTING PROGRAMME
Review logs against in situ test results and geological interpretations
EVALUATE NEED FOR ADDITIONAL DATA
GROUND MODEL: SITE SELECTION, PLANNING & DESIGN


ENLARGEMENTS
Stratigraphic model
Geotechnical Parameters
Derived Shear Strength, Nk = 16, (kPa)
0
500
1000
1500
2000
Depth (m bsb)
0
5
10
15
20
25
30
35
40

The Engineering Group of the Geological Society

Chapter 8

Design And Construction Considerations

M.G. Winter, V. Troughton, R. Bayliss, C. Golightly, L. Spasic-Gril, P. R. N. Hobbs and K. D. Privett

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

The Engineering Group of the Geological Society

Engineering Challenges

- The spatial variability of the nature of the deposits (e.g. fabric, macro-structure, fissures, laminations, sand pockets and lenses)
- The wide range of particle sizes often included within a given soil
- The potential inclusion of significant proportions of particle sizes larger than those that can be normally accommodated in standard soils tests (the maximum particle size for compaction tests, for example, is typically either 20mm or 37.5mm)
- The potential for properties and behaviour to be dominated by either the fines or the granular component of the soil
- The wide range of clay content, which in glacial materials may comprise, in whole or part, clay-sized particles comprising rock flour rather than true clay materials
- Spatial variation in soil type and properties including, but by no means limited to, stiffness and shear wave velocity
- Variation in depth to rock head and variable degrees of weathering and, particularly, chemical alteration
- Presence of groundwater as perched, sub-artesian and artesian conditions
- Presence of solution features and fissures, partly or completely infilled with soft or loose material
- Presence of (often shallow) shear surfaces at residual strength

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

Examples

Earthworking in glaciolacustrine deposits. The subsoil was exposed during the wettest part of the year and trafficked with very little protection. The ‘Moxy’ type plant were bogged down for a period that lasted several months

The Engineering Group of the Geological Society

Key Design And Construction Considerations

- The influences of
  - Variability
  - Complexity
  - Uncertainty
- Pervade activities in relict periglaciated and glaciated areas
- Multiple landforms will be encountered
- Frequently more than one land system will be encountered
- Always important
  - Gaining a clear understanding of the geomorphology
  - To better understand the geology
  - To provide clear insights into the local geotechnical characteristics
- Nowhere else is this logical sequence of such clear benefit
- Chapter 8 provides guidance on the types of issues that may be encountered
  - It does not provide information or numbers for design

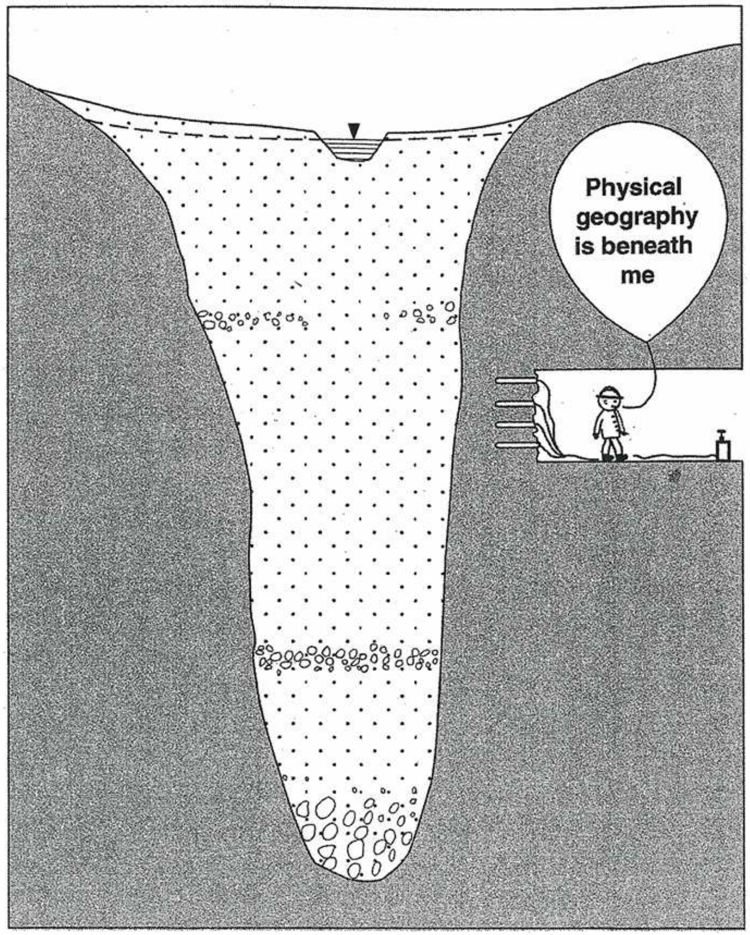


Image "The Folly of Prejudice"
John Hutchinson (2001)

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

The Engineering Group of the Geological Society

Chapter 9

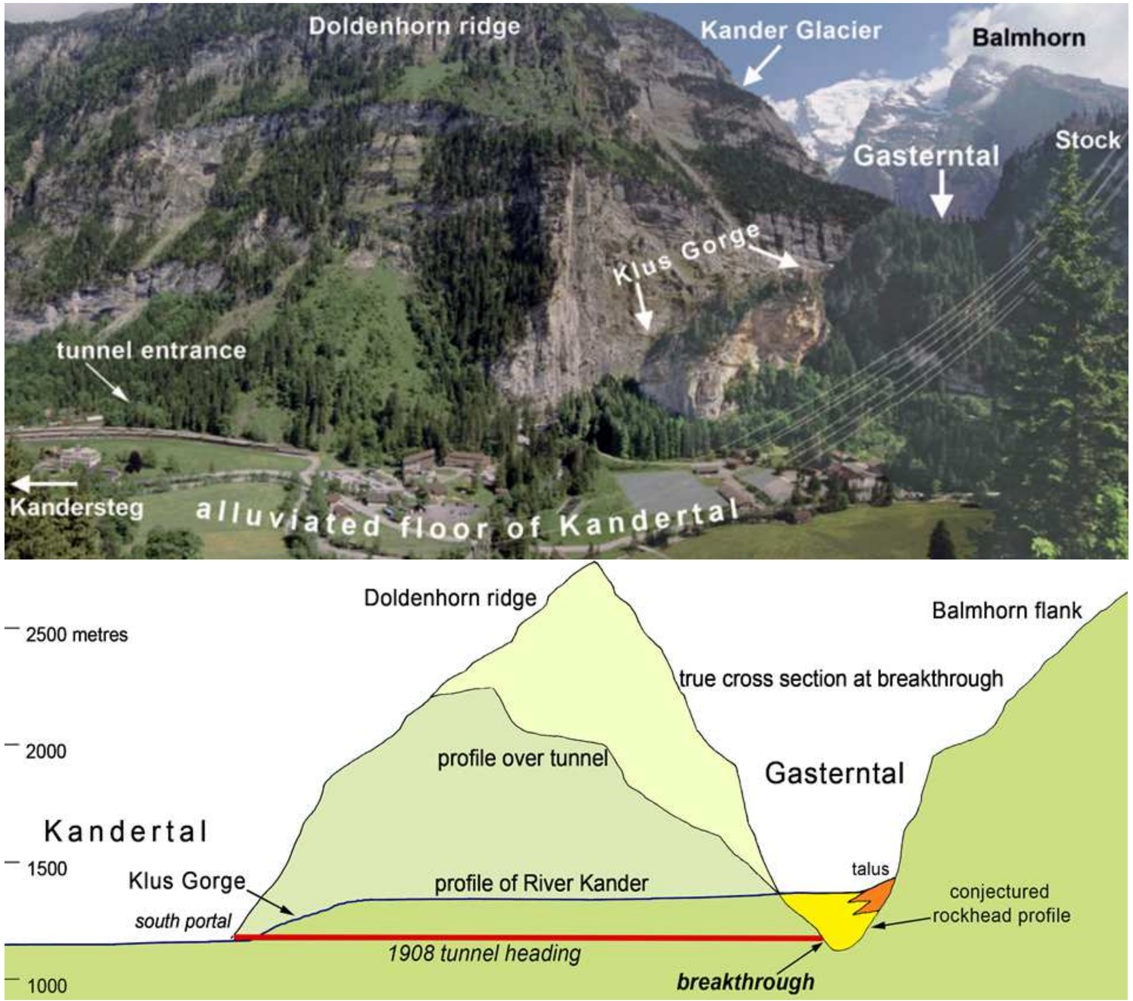
Conclusions and Illustrative Case Studies

J.S. Griffiths and D.P. Giles

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

The Engineering Group of the Geological Society

Lotschberg Tunnel Disaster, 1908, Tony Waltham (Waltham, 2008)



Waltham, 2008

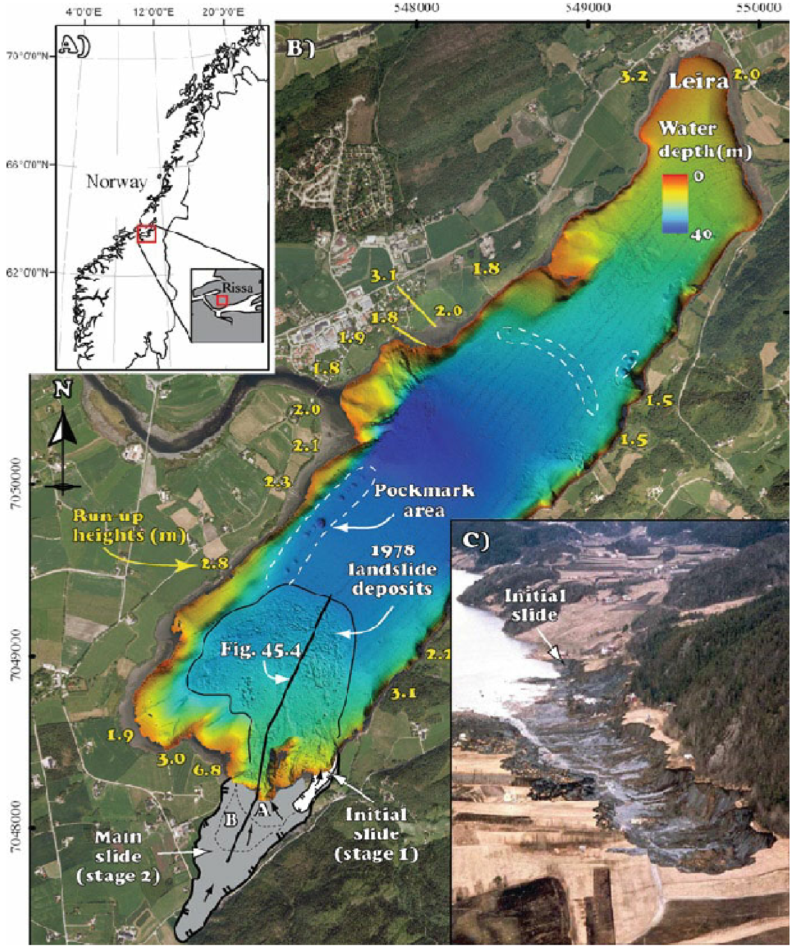
The Engineering Group of the Geological Society

Solifluction shear surfaces at low slope angles, 1967, Sevenoaks Bypass, Kent. Keith Gabriel (Weeks, 1969)

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

The Engineering Group of the Geological Society

Quick clay landslide in Rissa, Norway, 1978. Jim Griffiths (Gregersen, 1981)



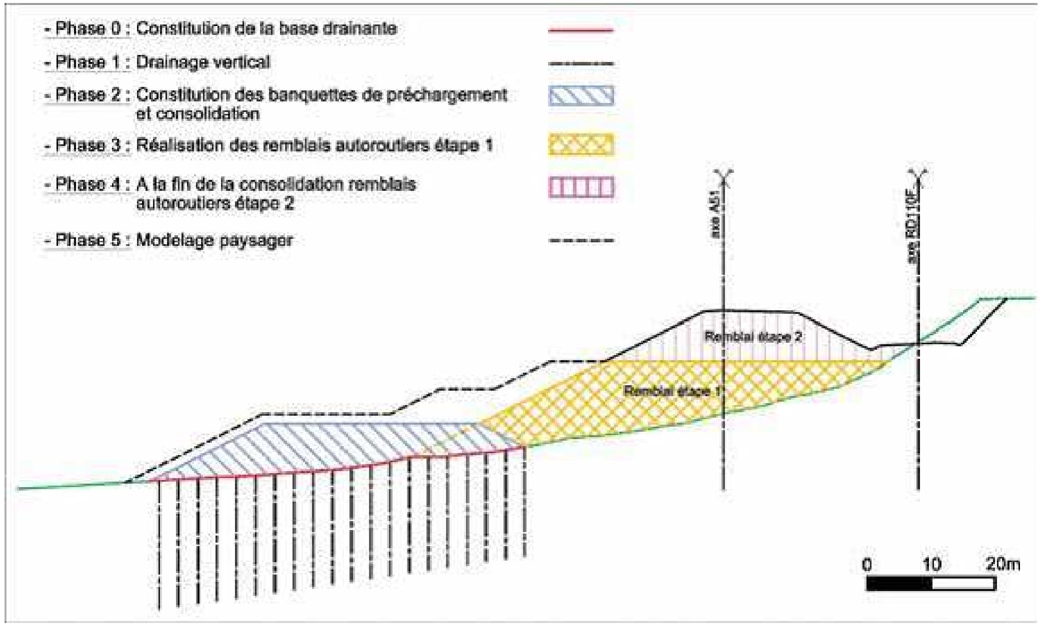
L'Heureux et al 2012

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

The Engineering Group of the Geological Society

A51 Grenoble to Sisteron Autoroute through Former Glacial Lac de Trièves, 2005, Dave Giles (Martin et al, 2005)

Glaciolacustrine sediments of the former Lac du Trieves.



After Martin et al,. 2005

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

The Engineering Group of the Geological Society

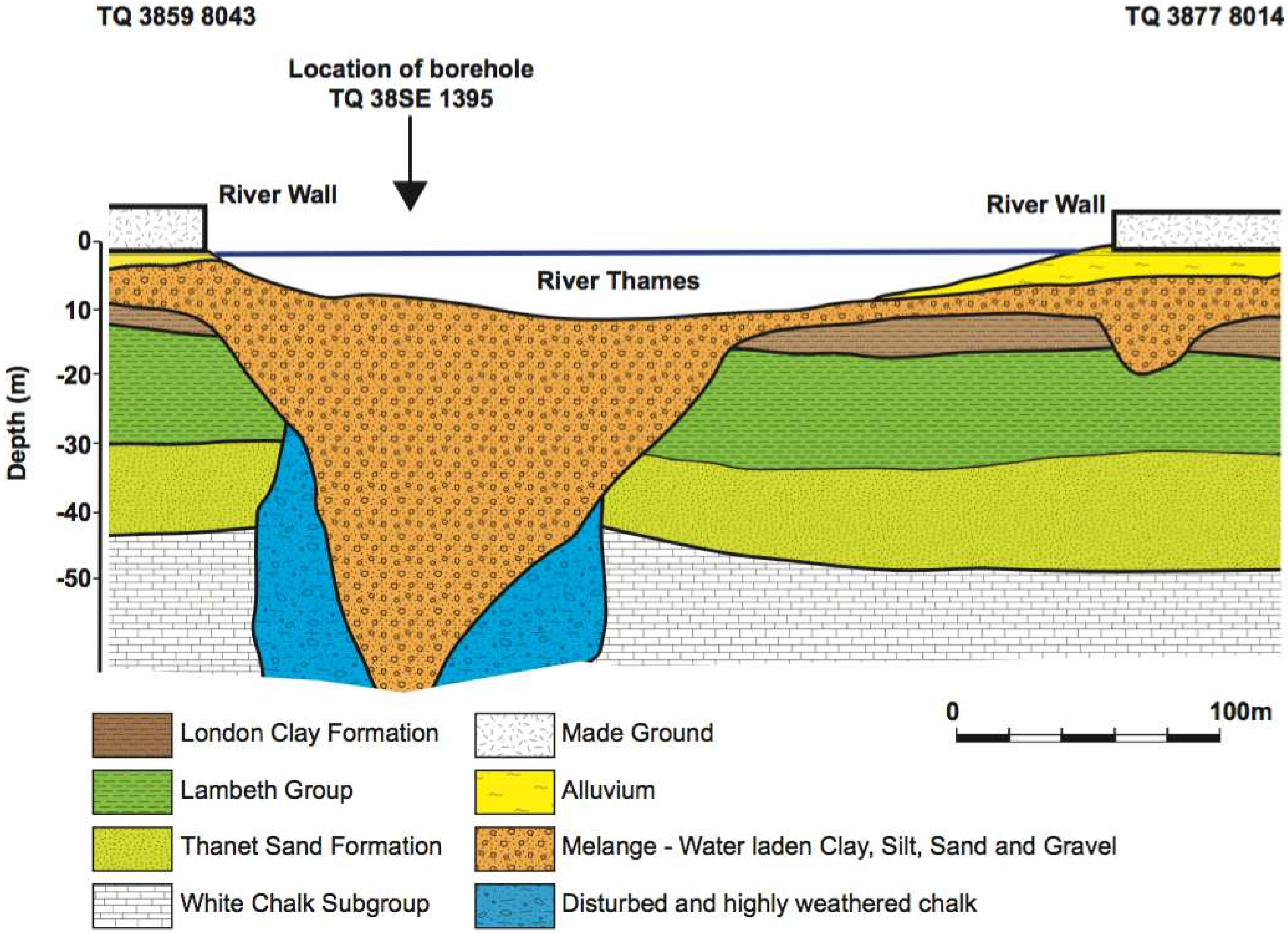
Glaciotectonic raft of Chalk interpreted during an offshore ground investigation, 2010, Christopher Kilsby

Photograph from The Northfolk Project, 2015

Depth below sea bed (m)		Formation	Geotechnical Description
Depth from	Depth to		
0	32	Various	Various
32	39	Swarte Bank Formation	Hard grey sandy gravelly CLAY. Gravel is fine to medium, mainly of chalk
39	46	Chalk	Very weak to weak low density white CHALK (Grade B2) (interpreted as raft of chalk)
46	55	Swarte Bank Formation	Very stiff grey slightly silty CLAY
55	73 (end of borehole)	Chalk	Very weak low density white to light grey CHALK (Grade Dm) (interpreted as in situ chalk)

E-mail: engineering.group@geolsoc.org.uk
Web: www.geolsoc.org.uk/engineering

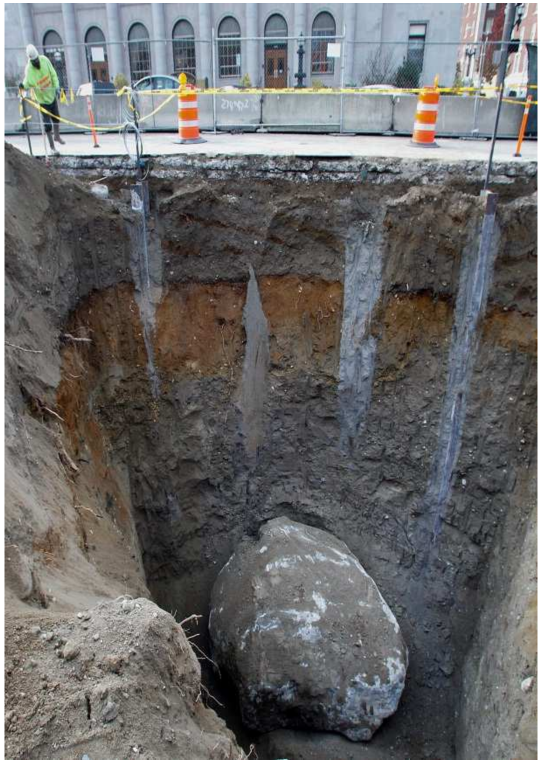
London Ring Main – Dave Giles (after Newman 2009)



The Engineering Group of the Geological Society

Key conclusions

- **Inherent complexity in glaciated and periglaciated terrains**
  - Superposition of processes
  - Lateral and vertical variability of ground and groundwater conditions
- **Lends itself to landsystems approach**
  - Ground model and risk register updated as project understanding develops
- **Multi-disciplinary approach advocated**
  - Quaternary science, geography, geomorphology, geology, hydrogeology, geophysics, archaeology, geotechnical engineering
  - Breadth of available information and resources
  - Caution when interpreting differing references and case studies
- **Latest scientific approaches incorporated into engineering practice**
  - Eurocode 7 / BS5930 description of materials combined with new classification for materials and landforms
  - Reclassification of ‘Glacial Till’
  - Importance of segregated ice during periglacial conditions



Any questions?

THE GROUND FORUM GF