Notes

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Project title	Geological Society Periglacial and Glacial Engineering Geology Working Party
Meeting name and number	02/2012
Location	Arup, 13 Fitzroy Street, London
Time and date	10:30 for 11:00 22nd May 2012
Purpose of meeting	Second meeting of Periglacial and Glacial Engineering Geology Working Party

Attendance

Jim Griffiths (Editor)
Chris Martin (Chair)
Anna Morley (Secretary)
Sven Lukas (Author Ch 2 Quaternary Setting)
Dave Giles (Author Ch 3 Geomorphological Framework)
Dave Evans (Author Ch 4 Glacial Conceptual Ground Model)
Julian Murton (Author Ch 5 Periglacial Conceptual Ground Model)
Martin Culshaw & Laurance Donnelly (Author Ch 6 Engineering Materials and Hazards)
Mike de Freitas (Author Ch 7 Engineering Investigation & Assessment)
Mike Winter (Author Ch 8 Design & Construction Considerations)

Apologies None

Circulation

Those attending.
EGGS committee.

	Action	By
1. Chairman's introduction and review agenda		
• The Chair thanked everyone for attending the second working party meeting and thanked Arup for hosting the meeting.		
• Meeting priorities: • Ratify Terms of Reference; • Chapter-by-Chapter Review - develop and agree ToC; Confirm co-authors; Agree page count, figures, etc.		
• MW noted that Kevin Privett has expressed an interest in maintaining his involvement following his participation on the Steering Group. Chair noted.		
• ***Action 2.1 - CJM to follow up on KP future WP involvement.***	**CJM**	**Jun-12**
• The need for maintaining a list of external reviewers was discussed.		
• ***Action 2.2 - ALM to start and maintain list of external reviewers*** (combine with Action 1.10).	**ALM**	**Jun-12**

Prepared by Anna Morley

Date of circulation 31st May 2012

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		Action	By
2.	**Ratify minutes and review actions from previous meeting**		
	The previous minutes were ratified by all members as a true and accurate record. The following actions were reviewed from the previous meeting:		
	• *Action 1.1 - JG to produce a guidance document for figure preparation, based on e.g. USGS, GSPH, QJEGH guidance.* Documentation circulated. See AOB for discussion with respect to figure preparation.	Closed	
	• *Action 1.2 - Comments are invited on the revised ToR, which will be ratified at the start of the next WP meeting.* No comments received. See Item 3 below.	Closed	
	• *Action 1.3 - All Lead Authors requested to produce a revised and augmented contents list for each chapter by Monday 23rd April.* Compiled revised chapters circulated prior to meeting.	Closed	
	Action 1.4 - DG to discuss about ground model vs. land systems approach with DE. DG commented that a good balance has been achieved.	Closed	
	• *Action 1.5 - The new proposed ToC structure is attached for comment by all WP members.* ToC developed by the lead authors for each chapter.	Closed	
	• *Action 1.6 - CJM to brief JM and DE on Chapter 4 and 5 discussions.* CJM discussed with JM and followed up with DE at this meeting.	Closed	
	• *Action 1.7 - CJM to discuss Chapter 8 suggestions with MW.* Done.	Closed	
	• *Action 1.8 - ALM to find 'Earth Manual' reference and circulate to WP.* Done.	Closed	
	• *Action 1.9 - CJM to discuss Chapter 9 approach with LD.* Done. LD to contribute to Chapter 6. Chapter to be developed by WP.	Closed	
	• *Action 1.10 - ALM to develop and maintain a register of possible contributors / interested parties and possible case studies.*	**ALM**	**1/06**
	In progress. To combine with Action 2.2.		
	• *Action 1.11 - MdF to develop ideas on collaboration with Institute of Archaeology.*	**MdF**	**Ongoing**
	MdF reported that he has written to Dr. M. Pope twice and followed up with a phone call but has yet to get hold of him. ***MdF to follow up.*** LD noted he could follow up with an alternative contact if necessary.		

		Action	By
	• *Action 1.12 - SL and DE were requested to maintain links with QRA.*	**SL/DE**	**Ongoing**
	DE reported that QRA are keen to maintain link by holding a joint meeting or workshop. It was agreed that a joint field meeting should be held in 2-3 years time to fit in with QRA schedule. QRA requirement that a comprehensive field guide is published.		
	Action 2.3 - DE to develop a proposal for a joint EGGS/QRA field meeting.	**DE**	**03/10**
	• *Action 1.13 - All expense claim forms and receipts to be sent to ALM for collation and forwarding to Ursula Lawrence of EGGS. Done.*		Closed
	• *Action 1.14 - JG/CJM to confirm acceptance of GSPH Letter of Support.* Done.		Closed
	• *Action 1.15 - All WP members requested to review web-content and propose recommendations.* Ongoing.		Closed
	• *Action 1.16 - All WP members to book travel arrangements and ALP to confirm venue.* Done.		Closed
3.	**Ratify Terms of Reference**		
	• Draft 4 of the Terms of Reference were reviewed by the Working Party.		
	• Noted that Hot Deserts Working Party Report had now been published. Otherwise the ToR were approved by the WP.		
	• ***Action 2.4 - Revise point 3 wrt HDWP status and update the ToR to Final revision (attached).***	**CJM**	**01/06**
4.	**Chapter – by – Chapter Review**		
	The content of the compiled chapters was reviewed in detail. Refer to attached marked up chapter compilation.		
	Action 2.5 – All authors to develop further detail in individual chapters. Aim to develop chapters to at least 5 to 10 pages of text.	**All**	**03/09**
	• ***Action 2.6 – Authors to forward pdf of key references (e.g. CIRIA 514, ICE MOGE Chapter 31) to ALM for circulation.***	**All** **ALM**	**01/06** **01/06**
5.	**Expense claims**		
	• Individual payments for 27/02/12 meeting had been received.		
	• The expense claim form was circulated.		
	• ***Action 2.7 - All expense claim forms and receipts to be sent to ALM asap for collation and forwarding to Ursula Lawrence of EGGS.***	**All / ALM**	**01/06**

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	Action	By
6. AOB		
6.1 Figure Preparation		
• The guidance for figure preparation prepared by JG was circulated.		
• CJM noted all authors should start to capture suggested figures in draft, screen dumps etc. but drafting and editing could be undertaken in year 2.		
• ***Action 2.8 – All lead authors and co-authors to start developing figure ideas and include in next chapter revision.***	**Authors**	**03/09**
• GSPH advice on text preparation and WP advice on figure preparation to be followed from the onset where possible (circulated with meeting agenda).		
• Authors need to a keep track of provenence / citation for all figures.		
• It was agreed that EPS is the best graphics format to use and that, where possible, figures should be developed as TIFs and images as JPGs. This is not mandatory.		
• DG noted that photos can be collated in the WP website. http://www.ukgeohazards.info/pages/Glacial_Periglacial_Working_Party/pgeg_wp.htm		
• ***Action 2.9 – Authors to forward any images for uploading to WP website to ALM.***	**All / ALM**	**Ongoing**
6.2 Major References		
• It was agreed that the aim of the WP report would be to make reference to and précis key references (e.g. CIRIA C514), but not replicate the content wholesale. The WP report should aim to be a standalone document.		
• Where appropriate, the WP report should also aim to provide updates on such key references.		
6.3 Common Nomenclature		
• Following discussion it was agreed that common nomenclature together with former synonyms should be developed in a table. This is most appropriate for the classifaction of glacial deposits, where geographers and engineering geologist adopted significantly different terminology.		
• ***Action 2.10 – DE/JM to develop table of common terms to be used through the book and circulate for comment.***	**DE/JM**	**01/06**
• ***Action 2.11 - CJM to forward EG description table from David Norbury book to DE/JM.***	**CJM**	**01/06**
• Glossary of terms would be developed in 2013 as part of internal WP review.		

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Periglacial and Glacial Engineering Geology Working Party (PGEG WP)

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	Action	By
• ***Action 2.12 - ALM to check if term diamicton is used in EG in USA.***	**ALM**	**03/10**
• JM suggested that case study of Filey Bay could be used to demonstrate QRA vs EG approaches to soil logging (David Norbury has developed material for Sussex University MSc).		

6.4 Geographical Extent

• It was agreed to focus on relict conditions in the British Isles including Republic of Ireland, but would include modern analogues from examples world-wide.		
• ***Action 2.13 - DE to provide proposed definition of upland and lowland.***	**DE**	**01/07**
• It was agreed that the report should include offshore regions.		
• Reference should be made to quick-clays, including possible Scottish examples		
• It was agreed that peat would be described in terms of a synopsis and the reader would be referred to other references for further advice.		

7. Date of Next Meeting(s):

• 11am to 5pm Wednesday 3rd October at Geological Society.		
• ***Action 2.14 - All WP members to book travel arrangements for 03/10/12 meeting.***	**All / ALP**	**01/08**
• It was noted that the Hot Deserts symposium will be held on 4th October at Geological Society.		
• 11am to 5pm Wednesday 12th December.		
• Two meetings are budgeted for 2013: Wednesday 6th March and Friday 31st May are proposed.		
• The possibility of following the meeting on 31st May with a field trip in the Durham or North Yorkshire area was discussed.		
• ***Action 2.15 - DG to look into possible venues and programme for a combined field trip.*** This would be open to all following a WP meeting on the Friday.	**DG**	**03/10**
• A further meeting could be held in September 2013 or January 2014 depending on progress of report and availability.		

Attachments:

- ToR – Final revision
- Updated Chapter by Chapter review
- Pdf of key references (sent via link)
- Draft 1 of Tables of Nomenclature

PERIGLACIAL AND GLACIAL ENGINEERING GEOLOGY

A Geological Society Engineering Group Working Party

TERMS OF REFERENCE

1. These Terms of Reference are as agreed by the Periglacial and Glacial Engineering Geology Working Party (PGEGWP).

2. The PGEGWP has been established by the Engineering Group of the Geological Society and comprises officers and specialist participating members who will act as lead authors. The participating members may be assisted by any number of co-authors and corresponding members.

3. The PGEGWP will produce a report, in book format, to complement the earlier report on Tropical Residual Soils produced by an earlier Working Party of the Engineering Group, first published in 1990 and republished in book format in 1997. A similar format was adopted by the Hot Deserts Working Party, who published their final report in 2012. It is intended that the report will be a 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. There necessarily will be appropriate coverage of the modern processes and environments that formed these materials.

4. It is 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.

5. The aim of the PGEGWP is to produce a report that will act as an essential reference handbook for professionals as well as a valuable textbook for students and others. The style will be concise and digestible by the non-specialist, yet be authoritative, up-to-date and extensively supported by data and collations of technical information. The use of jargon will be minimised and necessary specialist terms will be defined in an extensive glossary. There will be copious illustrations, many of which will be original, and many good quality photographs.

6. The content of the report will embrace a full range of topics, from the latest research findings to practical applications of existing information. Likely directions of research and predictions of future developments will be highlighted where appropriate. The report will be based on world-wide experience in periglacial and glacial terrain and will draw upon the experience of its members and publications on periglacial and glacial conditions.

7. The Working Party members will be collectively responsible for the whole report. Although each participating member will be the named author or co-author of one or more chapters, all members will be expected to review and contribute to the chapters drafted by other members and would be acknowledged as such. Individual book chapters will be included in the Thomson Book Citation Index.

8. It is intended that the report will be completed within three years.

** Nomenclature subject to review over the duration of the Working Party.*

WP members & acknowledgements
Contents
Forward
Preface

Griffiths, J.S. (ed.) *Periglacial and Glacial Engineering Geology – Engineering Group Working Party Report.* Geological Society, London, Engineering Group Special Publication, xx, xx - xx

Chapter 1 Introduction

C. J. Martin* & Engineering Group Working Party
Upstream Engineering Centre, BP Exploration Operating Company Ltd, Chertsey Road, Sunbury on Thames, TW16 7LN, UK.
**Corresponding author (e-mail: christopher.martin@uk.bp.com)*

1. Introduction

1.1. Periglacial and Glacial Environments

1.1.1. Definitions

1.1.2. Scope of this report

- Relict
- Not aim to define extent (reference others), but focus on ground models approach.

1.1.3. Engineering significance

- Illustrate with important case studies, e.g. Sevenoaks Bypass, Carsington Dam, Waltons Wood, South Wales, TRL Scotland? Others?

1.2. The Working Party

1.2.1. Background

- Previous Geological Society Engineering Geology Special Publication 7 on Quaternary Engineering Geology (Forster *et al*, 1991). Proceedings of the 25th Annual Conference of the Engineering Group of the Geological Society, Heriot-Watt University, Edinburgh, 10-14 September 1989.
- Following recommendation by the Hot Deserts Working Party, which was endorsed by the Engineering Group of the Geological Society, a Steering Group was established in November 2010 to explore the options for a new Working Party on Periglacial and Glacial Engineering Geology.
- Complement (or part of trilogy..?) previous Working Parties on Tropical Residual Soils (Fookes, 1990 and Fookes, 1997) and Hot Deserts: Engineering, Geology and Geomorphology (Walker, 2012).
- The Steering Group comprised John Charman (Chair), Chris Martin (Secretary), Dave Giles, Prof Jim Griffiths, Julian Murton, Kevin Privett and Mike Winter.
- Developed Publication Proposal.
- The outline of the Publication Proposal was presented and ratified at the Engineering Group Forum on Quaternary Engineering Geology on 24th November 2011, where it received extremely positive support from the wider Geography, Engineering Geology and Geotechnical Engineering communities.
- Publication Proposal subsequently approved by Geological Society Executive Secretary and Publishing House.

1.2.2. Membership

- The first meeting of the Working Party, chaired by Mr Chris Martin, was held on 27th February 2012.
- Members of the Working Party were drawn from persons with known periglacial and glacial engineering geology experience, from academics, researchers, consultants and *contractors*, including geomorphologists, engineering geologists and *civil engineers*.

Comment [a1]: Introduce idea that based on 'new' classification. Make point that moving forward. Acknowledge international significance of till then focus on British Isles. See Fookes keynote in SP7

Comment [a2]: Touch upon land systems to domains approach

Comment [a3]: Case study Filey Bay to give example of differences between quat and EG

Comment [a4]: Use term but make reference to former – see glossary

Comment [a5]: Signpost to Chapter 2

Comment [a6]: Ref material variability and complexity as key

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1.2.3. Objectives

- Terms of Reference

Text box 1.1 Terms of Reference of the Working Party

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3. The PGEGWP will produce a report, in book format, to complement the earlier report on Tropical Residual Soils produced by an earlier Working Party of the Engineering Group, first published in 1990 and republished in book format in 1997. A similar format was adopted by the Hot Deserts Working Party, which is due to publish their final report in 2012. It is intended that the report will be a state-of-the-art review on the ground conditions associated with former Quaternary1 periglacial and glacial environments and their materials, from an engineering geological viewpoint. There necessarily will be appropriate coverage of the modern processes and environments that formed these materials.
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6. The content of the report will embrace a full range of topics, from the latest research findings to practical applications of existing information. Likely directions of research and predictions of future developments will be highlighted where appropriate. The report will be based on world-wide experience in periglacial and glacial terrain and will draw upon the experience of its members and publications on periglacial and glacial conditions.
7. The Working Party members will be collectively responsible for the whole report. Although each participating member will be the named author or co-author of one or more chapters, all members will be expected to review and contribute to the chapters drafted by other members and would be acknowledged as such. Individual book chapters will be included in the Thomson Book Citation Index.
8. ~~It is intended that the report will be completed within three years.~~

1.3. Structure of the report: contents

References

Comment [a7]: Link to CIRIA and Eyles

Fookes, P. G. (ed.) 1990. Tropical Residual Soils Geological Society Engineering Group Working Party Report. *Quarterly Journal of Engineering Geology*, **23**, 4-101, doi: 10.1144/GSL.QJEG.1990.023.001.01.

Fookes, P. G. (ed.) 1997. *Tropical Residual Soils: A Geological Society Engineering Group Working Party Revised Report.* Geological Society, London, Professional Handbooks.

Forster, A., Culshaw, M. G., Cripps., J. C., Little, J. A. and Moon., C. F. (eds.) 1991. Quaternary Engineering Geology. Geological Society, London, Engineering Geology Special Publication, 7.

Walker, M. J. (ed.) 2012. Hot Deserts: Engineering, Geology and Geomorphology - Engineering Group Working Party Report. Geological Society, London, Engineering Geology Special Publication, 25.

Chapter 2 The Quaternary

Authors (alphabetical order at present)

Comment [a8]: Looking for author on sea level and neotectonics - Phil Gibbard, Dave Bridgland and Phil Westerway are option. SL to review and contact.

Sven Lukas, School of Geography, Queen Mary University of London, UK (lead author)
Clare M. Boston, School of Geography, Queen Mary University of London, UK
David J.A. Evans, Department of Geography, University of Durham, UK
Frank Preusser, Department of Quaternary Geology and Physical Geography, University of Stockholm, Sweden
NN (sea-level, neotectonics)

Comment [a9]: Quaternary geology and dating expert

2. The Quaternary

2.1. Introduction

Comment [a10]: Make clear that other 'things' going on at same time as glaciations and periglacial processes: tectonics, volcanics, sea-level variations

- Definitions, duration, terminology
- Brief overview of recent debate on status of Quaternary and current standing within Geological Timescale
- Outline of chapter structure and focus/purpose
- Definition and understanding of Quaternary for the purpose of WP (from initial discussion at first meeting: exclude Holocene; regional focus on Britain, with reference to appropriate case studies from both modern and palaeoenvironments, usually in the Northern Hemisphere; focus on relict processes, but specify that active periglacial processes do occur in upland areas in UK, e.g. Scottish Highlands)

2.2. Quaternary events and stratigraphy

2.2.1. The role of the Quaternary in the longer geological history (brief)

2.2.2. Palaeoclimatic archives and climatic fluctuations in the Quaternary

- Marine sediment cores and ice cores; oxygen isotope stages
- Cold and warm periods, introduction of technical terminology (glacials/interglacials, stadials/interstadials etc.)
- Global and regional terminology (e.g. Weichselian etc.)
- Summary diagram showing broad climatic fluctuations (variations in $\partial^{18}O$) and how different phases relate to British/European/US stratigraphy (list of countries beyond Europe to be discussed; envisaged as being in a similar format to the diagram found here: http://www.quaternary.stratigraphy.org.uk/correlation/chart.html)
- Drivers of climate change (Milankovitch cycles etc) (brief)
- Methods of dating and correlation (brief)
- Dave Bridgeland and Rob Westaway to contribute?

Comment [a11]: Guidance as to how stratigraphy is developing in UK. SL – notes link back to oxygen isotope table. Add additional column on time into oxygen isotope table. Phil Gibbard to contribute?

Comment [a12]: E.g. ice core standards

2.2.3. Sedimentary response to climatic fluctuations

2.2.3.1. Terrestrial response

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- Processes of sedimentation in cold and warm stages: glacial, periglacial, fluvial, lacustrine; minerogenic versus organic
- Different timescales of response (annual, decadal, centennial, millennial, whole-Quaternary timescales, e.g. glacier response, average glaciation concept)
- Highlight complexity of responses, varying response rates and implications for sedimentary processes and products

2.2.3.2. Marine response

- Relative sea-level change in the past (eustatic, isostatic)
- Relative sea-level change at present
- The role of neotectonic activity; reactivation of old tectonic structures

2.3. **Global and regional distribution of Quaternary sediments**

- Brief overview of geographical distribution of glacial and periglacial sediments in different countries (Northern Hemisphere)
- Maps showing modern and former glacial and periglacial zones (e.g. permafrost limits and periglacial processes)

2.4. Implications for Engineering Geology

- Focus on complexity of Quaternary stratigraphic sequences, e.g. sedimentary units of varying thicknesses and depths; relevance of lateral and vertical variations for drilling and foundation work
- Loading and unloading?
- Hiati/stratigraphic gaps and lateral variations make application of straightforward layer-cake model problematic
- Challenges presented by irregular contacts of units where they intersect the earth surface; highlight potential misinterpretations of assuming a uniform thickness and distribution of one sedimentary unit over an area

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Chapter 3 Geomorphological Framework

D. P Giles[1] & J.S. Griffiths[2]

[1]School of Earth & Environmental Sciences, University of Portsmouth, Portsmouth, PO1 3QL

[2]School of Geography, Earth & Environmental Sciences, University of Plymouth, Plymouth, PL4 8AA

3. Geomorphological Framework

3.1. Abstract

3.2. Introduction

3.3. Terrain Systems Approach

Terrain Systems Mapping
Ground Models
Land Systems
Earth Systems Models
PUCE System
Nomenclature adopted for this report

3.4. Terrestrial Glacial Environment

3.4.1. Definition

3.4.2. Key Landforms

Aerial Scouring
Glaciated Valleys
Hanging Valley
Watershed Breach
Whaleback
Groove
P Forms
Striations
Polished Surfaces
Trough Head
Rock Step
Cirque
Col
Roche Moutonnee
Riegel
Lunate Fracture
Crescentric Gouge
Crecsentric Fracture
Chattermark
Arêtes
Horn
Nunatak

Comment [a13]: Link to Chapter 4

Comment [a14]: DE: Wider definition e.g. physiography?

Comment [a15]: Focus on global modern analogues. Relict UK follows in Ch 4&5

Comment [a16]: Try to combine as many as possible into each text-box

Comment [a17]: Link to glossary and definition tables

Comment [a18]: Quaternary team to input which terms should not be included

Comment [CM19]: Ref Canadian study / block diagram showing all microscale forms (DE)

Comment [a20]: Blue text = USGS ref

Comment [a21]: Plastically moulded. Relevance?

Formatted: French (France)

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Lateral Moraine
Medial Moraine
Shear / Thrust Moraine
Recessional Moraine
Annual Push Moraine
Fluted Moraine
Hummocky Ground Moraine
Cover Moraine
Terminal Moraine
Moraine Dump
Rockfall
Dirt Cone
Erratic
Crevasse Filing
Drumlin
Drumlinoid Ridge
Crag and Tail Ridge
De Geer (Washboard) Moraine
Rogen (Ribbed) Moraine
Ground Moraine
Hummocky or Dead Ice Moraine
Till Plain
Gentle Hill
Debris Flow
Trimlines

Glacial tectonic landforms – e.g. rafts, ref to Dave Hughes Geotechnical Journal. Refer to 3D diagram of micro erosional structures (DE to provide)

3.4.3. Key Deposits (Brief overview – depth and detail in later chapters)

Comment [a22]: Remove this – covered in a Ch 6

Tills
Glaciolacustrine Sediments
Glaciofluvial Sediments
Moraine

3.5. Fluvial Glacial Environment

3.5.1. Definition

3.5.2. Key Landforms

Tunnel Valley
Subglacial Gorge
Nye Channel
Esker
Kame
Kame Field
Kame Plateau
Kame Terrace
Kame Delta
Outwash Plain (Sandur)
Valley Train
Outwash Fan
Pitted Plain

Outwash Delta Complex
Kettle Hole / Pond

3.5.3. Key Deposits (Brief overview – depth and detail in later chapters)
Proximal
Medial
Distal

Comment [a23]: Cover in later chapter

3.6. Lacustrine Glacial Environment

3.6.1. Definition

3.6.2. Key Landforms

Deltas
Delta Moraines
De Geer Moraines
Shorelines or Strandlines

3.6.3. Key Deposits (Brief overview – depth and detail in later chapters)
Deltaic Sediments
Lake Bottom Sediments
Meltout Sediments

Comment [a24]: Cover in later chapter

3.7. Marine Glacial Environment

3.7.1. Definition

3.7.2. Key Landforms

Fjord
Flutes
Moraine Banks
Grounding Line Fans
Ice Contact Deltas
Fluviodeltaic Complexes
Till Delta
Submarine Troughs
Tunnel Valleys
Ice Berg and Sea Ice Scours
Slope Valleys
Boulder Pavements
Flutes
Transverse Ridges
Shelf Moraines

3.8. Key Deposits (Brief overview – depth and detail in later chapters)
Proglacial Laminites
Fjord Bottom Sediment Complexes
Beach and Tidal Flat Features
Iceberg Turbate Deposits
Quick Clays

Comment [a25]: Cover in later chapter

3.9. Periglacial Environment

3.9.1. Definition

3.9.2. Key Landforms

Comment [a26]: Focud on landforms, not processes (ref Ch 4 & 5)

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Frost Creep
Frost stirring & sorting
Sorted Stone Circles
Thermokarst
Periglacial landslides & rockfalls
Solifluction
- Lobes
- Benches
- Sheets

Pingos
- Open system
- Closed system

Superficial valley disturbances
Anomalies beneath river terraces
Glacio-eustatic / isostatic effects
- Buried valleys
- Sub seal level caves
- Reactivation of coastal landslides
- Leaching of former marine sediments
- Intra plate faulting & earthquakes

Glacial overflow & marginal channels
Ice Wedges
Ice Wedge Polygons
Protalus rampart
Cryoplanation terrace
Blockfields/felsenmeer
Nivation hollow
Tors

Deleted: Frost cracking¶

Comment [a27]: MW to provide example

3.9.3. Key Deposits (Brief overview – depth and detail in later chapters)

Comment [a28]: Cover in later chapter

Periglacial solifluction
- Granular materials
- Clayey materials

Aeolian deposits

3.10. Acknowledgements

References

Terrain Element / Facet Descriptors (for each element / facet as detailed above)

Terrain Element / Terrain *Unit*	**NB Heading dependent on nomenclature adopted for report.**
Image	
Diagram	
Form / Topography	
Principal Environment of Formation	

Comment [a29]: To be defined

Process of Formation	
Engineering Significance / Constraint	
Principal References	

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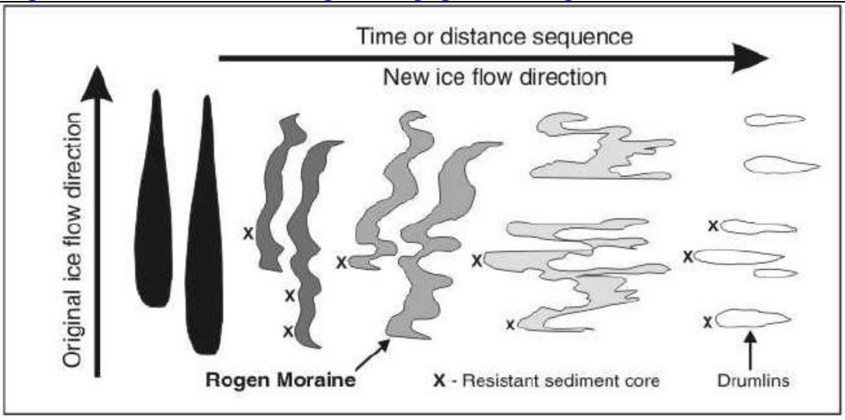
Terrain Element Descriptor Example

Terrain Element / Terrain Unit	Rogen (Ribbed) Moraine
Image	 Rogen Moraines on the Bruce Peninsula, Ontario. (Canadian Landform Inventory Project) http://libwiki.mcmaster.ca/clip/index.php/Main/RogenMoraines
Diagram	 Figure 1: Bed-Deformation Model as explained by Marich et al. 2005.

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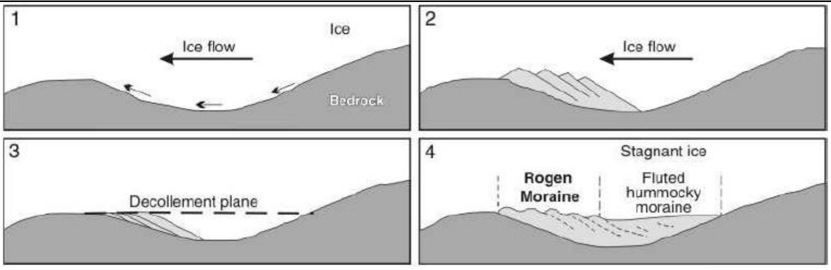
<table>
<tr><td></td><td>


Figure 2: Shear Stack Model as explained by Marich et al. 2005.

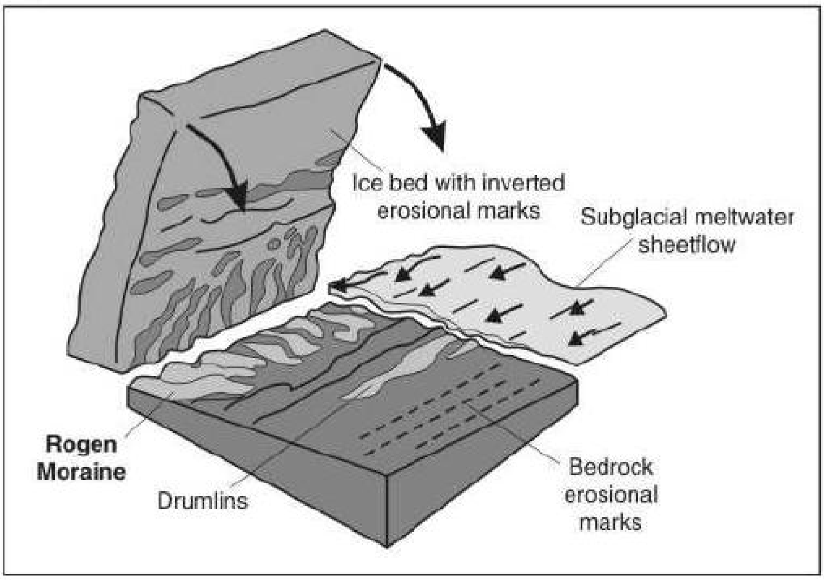


Figure 3: Subglacial Meltwater Flood Model as explained by Marich et al. 2005.

http://libwiki.mcmaster.ca/clip/index.php/Main/RogenMoraines
</td></tr>
<tr><td>Form / Topography</td><td>Streamlined ridges of glacial sediment orientated transverse to the direction of ice flow. The ridge may have a lunate form and be drumlinised.</td></tr>
<tr><td>Principal Environment of Formation</td><td>Indicative of subglacial deformation and warm-based ice. May provide a record of changing ice flow patterns.</td></tr>
<tr><td>Process of Formation</td><td>The formation of Rogen moraines is a topic that is subject to much debate in recent literature. Marich et al. (2005) examined ribbed moraines on the Avalon Peninsula in Newfoundland. Within this paper, three theories of ribbed moraine formation are discussed. Firstly a bed-deformation model (Figure 1), secondly (Figure 2) how rogen moraines are formed relying on the underlying bedrock terrain and ice stagnation and thirdly (Figure 3) formation involving radically different methods and parameters than the previous two. In the previous two methods, sediment was deformed in some way by the movement of the ice itself, whereas in this theory, the creation of Rogen moraines relies on subglacial meltwater in catastrophic magnitudes.</td></tr>
</table>

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Engineering Significance / Constraint	
Principal References	Bennett & Glasser, (2009) Marich, A., Batterson, M., & Bell, T. (2005)

Chapter 4 Glacial Conceptual Ground Model

David J. A. Evans, Durham University

4. Glacial Conceptual Ground Model

4.1. Introduction and rationale

4.1.1. The glacial debris cascade and till sedimentology

4.1.2. The glacial landsystems approach

4.1.3. British palaeoglaciology

Comment [a30]: Needs classification scheme / translator. QRA, vs EG vs historic/regional terms

Comment [a31]: What did ice cover look like in UK. Ice sheet vs mountain ice. Complexities. Chris Clarke reconstructions.

4.2. Ice sheet related landsystems

4.2.1. Sediment-landform associations

4.2.1.1. Subglacial footprint

4.2.1.2. Ice-marginal complexes

4.2.1.3. Supraglacial debris complexes

4.2.2. Typical UK ground models

4.2.2.1. Ice sheet marginal settings (Eastern England; East Anglia; Irish Sea Basin; Chalk downlands; Thames basin)

4.2.2.2. Ice sheet beds (Eden Valley/Solway Lowlands; Moray Firth; Vale of York; Tweed lowlands)

Comment [CM32]: = BGS Selby

4.3. Upland glacial landsystems (hard bedrock terrain)

4.3.1. Sediment-landform associations

4.3.1.1. Subglacial footprint

4.3.1.2. Ice-marginal complexes

4.3.1.3. Supraglacial debris complexes

4.3.2. Typical UK ground models

4.3.2.1. Ice sheet recessional settings/topographically-constrained ice flow (west Scotland; Pennines)

4.3.2.2. Mountain icefields (South Loch Lomond; Skye; NW Highlands; SW Lake District)

4.3.2.3. Smaller mountain glaciers (Brecon Beacons; Applecross; Skye; Snowdonia)

4.4. Glacifluvial landform-sediment associations

4.4.1. Sediment-landform associations

4.4.1.1. Ice-contact settings

4.4.1.2. Proglacial settings

4.4.2. Typical UK ground models

4.4.2.1. The Brampton kame belt

4.4.2.2. Lleyn Peninsula

4.4.2.3. Strathallan

4.4.2.4. Carstairs

4.5. Subaqueous glacial depositional sequences

4.5.1. Sediment-landform associations

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4.5.1.1. Ice-proximal depo-centres
4.5.1.2. Distal sediment piles
4.5.1.3.Add Offshore e.g. buried valleys in north sea

4.5.2. **Typical UK ground models**

4.5.2.1. Rhosesmor and Wrexham deltas
4.5.2.2. Achnasheen

4.6. Conclusions - from landsystems to domains (BGS)

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- **Include Ireland**
- **Example areas, Selby, Vale of York, Sellafield, Glasgow (BGS developed), North Norfolk, Devensian margin around Stoke**
- **Include Offshore - NW UK Margin and North Sea. Trough mouth fans, buried valleys.**
- **Link till sedimentation to overconsolidation (covered in Ch 6)**
- **Link to Doug Nichols Urban Geology of South Wales.**

Chapter 5 Periglacial and Permafrost Conceptual Ground Model

Comment [a33]: Add Loess and Brickearth?

Comment [a34]: Include lmst dissolution?

J.B. Murton and ANO [for uplands]
Permafrost Laboratory, Department of Geography, University of Sussex, Brighton BN1 9QJ, UK.
Corresponding author (e-mail: j.b.murton@sussex.ac.uk)

5. Periglacial Conceptual Ground Model

5.1. Periglacial and permafrost environments

5.1.1. Ground thermal regime

5.1.2. Periglacial processes (frost weathering, frost heave, thaw consolidation, thermal contraction cracking, gelifluction, active-layer detachments, cambering, valley bulging)

5.1.3. Ground ice (pore, segregated, wedge, intrusive, massive)

5.1.4. British periglacial studies + main periglacial episodes

5.2. Upland periglacial terrains

Comment [a35]: Collin Ballantyne? – co author

5.2.1. Sediment-landform associations

- Permafrost
- Seasonally frozen ground
- Periglacially modified glaciated terrains

Comment [a36]: Touches on paraglacial.

5.2.2. Typical UK ground models

- Scottish mountains
- Pennine hills
- Granitic landscapes of SW England

5.3. Lowland periglacial terrains

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5.3.1. Sediment-landform associations

- Permafrost
- Seasonally frozen ground
- Periglacially modified glaciated terrains

5.3.2. Typical UK ground models

Comment [a37]: Karst development acceleration during glacial and periglacial environments. Baker study

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- Chalk downlands and plateaus in SE England
- Terrace staircases of the Thames basin
- Slate lowlands of Devon and Cornwall
- Till sheets of central and Eastern England
- Slope deposits of W Wales
- Coversands of central England
- Hythe Beds escarpments
- Clay slopes of southern England - Sevenoaks - Weeks & Skempton
- Anomolous depressions - Hutchinson, Berry, Vanessa Banks. Pingos / scour hollows / ice marginal / artesian overpressure?

Comment [a38]: Periglacial modifications on Till Sheets, involutions

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5.4. Conclusions

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Chapter 6 Engineering Materials and Hazards

(to be developed by Martin Culshaw)

- Focus on difficult areas.
- More details of the main g/h from Ch 3 & 4. Sub-headings for each g/h described.
- Start with lists from Ch 3 & 4.
- Same sub-headings in Ch 3 & 4 as Ch 5. Expand to para-pages as required.
- Matrix based on higher level of classification eg cambering.
- Link to SI in Ch 6.
- PRELIMINARY STRUCTURE, depending on outcome of Ch 4 & 5.
- Engineering behaviour of rock and soil materials.
  a) Deformed/shattered bedrock, frost heave and thaw settlement deposits, ice-rich soil/rocks, till, sand & gravel, laminated silts & clays, quick clay, loess & brickearth, solifluction deposits, ice rafts, boulder fields, patterned ground, peat (associated with periglacial/glacial terrain - acknowledge / cross-ref, or just mention in Ch3-5?).
  b) Example for tills – engineering classification, PSD, Atterbergs, moisture content, liquidity, post-depositional modification, shear strength, influence of discontinuities, compressibility, in-situ stress.

Consider structuring as:

6. Engineering Materials and Geohazard

6.1. Hazards related to particular soil types or associations of soil types
6.2. Ice-related terrains: sub-glacial, supra-glacial & glaciated valley
6.3. Water-related terrains: glaciofluvial, glaciolacustrine & glaciomarine
6.4. Ice-front-related terrains: glaciotectonic & ice marginal
6.5. Upland region periglacial terrains
6.6. Lowland region periglacial terrains

Different deposits to be included under each heading

- **Loess (collapsible and non) Kevin Northmore or Ian Jefferson**
- **Upland deposits – BGS Scottish geologists**

Associations at site level

- **E.g. two tills or one till that's weathered. Show materials at a site scale to show variability.**

Hazards at a regional scale

- **Table to show risk checklist e.g. deposit, geohazards, how might investigate it**

MC to circulate ICE MOGE Glacial Tills Chapter

Norbury soil/rock description - should it be in Ch 6 or 7? Cross-ref required

Comment [a39]: Brief summary of the material properties and consequences of behaviour. Variability is key factor. Mass behaviour. Use 'deposits' taken out of DG chapter. Regional hazards (fault reactivation)

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Chapter 7 Engineering Investigation & Assessment

Lead author: MH de Freitas

7. Engineering Investigation & Assessment

7.1. Preliminaries

(Peter Phipps: Mott MacDonald)

Guidance on what to expect in such terrain – desk study including case histories – remote sensing – walkover – surface water - eng. geomorph mapping – **first conceptual model**.

7.2. Surface Geophysics

(Mike Sainsbury or A.N. Other: Zetica)

Materials and their contrasts – boundaries – lithological properties - mechanical properties – **integration with first conceptual model.**

7.3. Soil & Rock descriptions

(David Norbury)

Particular difficulties with describing such materials so that their implications are meaningful - very coarse assemblages – widely graded soils – laminations - weathering profiles - fabric including shear surfaces – the soil rock boundary and rockhead identification - attributing core loss at "rock-head" – **expectations from first conceptual model**

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7.4. Ground investigation

(Chris Coleman & Others: Fugro)

Peculiarities of pitting, trenching & drilling in these materials & measurement of pore pressure – vertical profile integrated with first conceptual model – BH geophysics (probably done by Zetica) – **second conceptual model** – insitu testing (strength, stiffness & permeability) in coarse, fine & laminated materials– sampling & sample quality - sampling coarse, fine, laminated & fabric (for ground water see later) – laboratory testing (for classification, strength, stiffness & permeability). **Third conceptual model (geomechanical).**

Consider other techniques e.g. Till fabric analysis, thin section analysis

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Monitoring and observations during construction and operation to develop ground model

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7.5. Hydrogeological investigations

(Dr Victor Bense: Univ East Anglia)

Design based on second & third conceptual models – methods of investigation (recession analyses of rivers and water levels - single hole & multiple hole methods – materials & their boundaries – hydraulic & thermal conductivity – storage – water quality – water supply. **Fourth conceptual model (Hydrogeological)**

7.6. Engineering Ground Model

(MHdeF with above authors)

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Pulling all this together – getting a model out of a team e.g. what inputs needed to get model - resources required (time, money, skills & personnel) to get to this point – the identification of assumptions and unknowns – their link to risk when using the model. The early establishment of (i) base line values & (ii) observation points for monitoring.

Deleted: Construction and operation info?¶

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Chapter 8 Design and Construction Considerations

Authors are those specifically named below and additional parties that contribute, led by MGW. Kevin Privett to contribute on periglacial at second stage

~~**Consider 'Earth Manual'** type **approach**~~.

Focus on issues relevant/specific to periglacial and glacial materials.

Focus on case studies, where things have gone right and wrong.

Further combine sections where possible.

Needs a general statement that intra and inter-deposit spatial material variability is a always major consideration. It may well be (and I favour this) that the main issues related to linear infrastructure (particularly road and rail) and that are not dealt with in subsequent generic sections are dealt with here.

This Chapter will inevitably heavily draw on parts of CIRIA 504, with which I was closely involved, but will need to be sharper, flagging key issues without lengthy text explanations. It is, of course, important that we ensure that we cover periglacial (e.g. loess, weathered chalk, etc) and not just glacial materials (lodgement, moraine, etc).

8. Design and Construction Considerations

8.1. Foundations

(Viv Troughton being contacted, Dave Toll, John Brown as alternatives)

Shallow foundations

- Variations in soil type and effect son bearing capacity and settlement.
- Construction difficulties.
- Retaining wall foundations.
- Infrastructure foundations design of investigation – route selection

Deep foundations

Pile foundations

- Pile selection and design considerations.
- Design depth
- Mixed successions (subglacial, supraglacial, buried valleys, end bearing in mioxed successions)
- Shaft resistance in clay tills (shaft adhesion, shear strength).
- Shaft resistance characteristics in granular tills
- Construction considerations

8.1.1 Common Problems

Bearing capacity and settlement, rockhead, shallow foundations, piles, wind farms.

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8.2 SLOPES AND EARTHWORKS (Mike Winter)

8.2.1 Earthworks

Excavation, acceptability of fill, placement, compaction.

Acceptability of glacial materials as general fill – Matheson & Winter, Winter, Lindh & Winter cover most bases. Also worth alluding to Irish work in European Earthworks.

Excavation, refer back to variability, use of face excavation rather than scraper to ensure that materials are excavated as single materials rather than a mixes that can have relatively unpredictable behaviours.

See also Perry in #8.2 re service life, etc.

(Tempted to combine with #8.2.)

8.2.2 Cuttings

Drainage, fabric and cutting orientation (ref McGown), stability analysis

See Perry (TRL Report, etc) and issues related to service life, also McGown work on fissuring in drumlins and cut slope stability.

Need also to mention issues with respect to highly stable steep slopes in lodgement tills that can become unstable if they get wet soon after cutting (e.g. M8 cuttings and bridge foundation excavations).

Sand lenses in fluvioglacial materials as hazard in cut slopes (e.g. Nairn).

Excavations for retaining walls.

8.2.3 Embankments

Stability analysis (including effective stress analysis), failure surfaces.

8.2.4 Natural slopes

This should not be overemphasised other than that design and construction need to take account of instability. The key issue that sets periglacial and glacial materials apart is the availability of moraine materials (for example) for debris flow and the SRNLS study provides a reasonable reference point.

Distribution of landslide types in Trenter, otherwise apart from glaciolacustrine section relatively trivial treatment therein.

Possible case study on periglacial Sevenoaks Bypass.

8.3 AGGREGATES AND OTHER MATERIALS (Mike Smith or Ian Jefferson)

Having difficulty tracking Mike down as he left IoQ for University of Derby, from which he now seems to have departed. Any ideas would be appreciated; I have tried a few approaches.

Ian Simms?

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E.g. Brickearth, glass sands, Fuller's earth?, boulderfields as armourstone, placer deposits).

Include mineral resources (placer deposits) or ref elsewhere? Focus on Engineering Geology, rather than Economic Geology

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I am included to think that the tills (etc) are well covered in EGSP 9 (Aggregates, p 7, 19-24). Brickearth (p24), placer deposits (p127) and glass sand (p129) are also covered. There ought to be sufficient for our purposes in EGSP 16 on armourstone – I suspect that the reference to boulderfields comes from a particular experience that usefully could be shared.

8.4 DAMS AND RESERVOIRS (Ljiljana Spasic-Gril being contacted) – AM to chase

8.4.1 Common Problems

Valley profiles, rockhead, rock conditions, groundwater, construction materials, buried valleys, superficial deposits.

8.4.2 Foundations, Slopes and Earthworks

Refer back to #8.1, #8.2 and #8.3, and focus on issues strictly related to dams such as the need to impound water and the potential over-topping wave risk from landslides (including debris flow).

8.5 TUNNELS AND UNDERGROUND STRUCTURES (Russell Bayliss)

8.5.1 Groundwater lowering

- Sump pumping
- Wellpoints
- Pumping wells
- Ejector systems

Applicable to other areas but perhaps best dealt with here.

Nuclear repository – Tom Berry?

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8.5.2 Common Problems

Water, variability of ground conditions.
More than one soil type in face (sand lenses, etc for example)
Varying soil thicknesses and rockhead depths
Nest of cobbles and boulders

Varying groundwater conditions

Tyne tunnel, cut-and-cover approaches (bottom-up and top-down diaphragm walling) to immersed tube, contiguous piled wall, open cut box. TBM to be sourced elsewhere. Void form in bottom for heave. Laminated and stony clays, into bedrock. Significant rockhead level variation even across cross-section.

8.6 LINEAR INFRASTRUCTURE

Comment [a40]: Remove and cover elsewhere? Should should be on extrapolation of results. Route selection. Geohazard avoidance.

Many of the issues related to roads and railways (and possibly pipelines) are likely to be addressed in the opening statement, and the sections relating to Slopes, Slope Stability and Earthworks.

8.6.1 Roads (Input from all)

Paved roads (embankments, cuts, see notes on M74 for possible inclusion wrt variability). Refer back to earthworks and slopes.

Unpaved roads often in areas part-way up slope and thus more vulnerable to debris flow (higher velocity). Local sources of materials (refer back to Aggregates).

8.6.2 Railways (Input from all)

How do the issues wrt to Railways differ to those for roads (maybe some loading issues).

8.6.3 Pipelines and Buried Cables (Pete Hobbs)

How do the issues wrt to Pipelines and Buried Cables differ to those for roads (maybe some foundation settlement issues for pipelines).

Slope stability issues are clearly critical.

8.6.4 Transmission Lines (possibly combine with above)

Are these really linear infrastructure in the sense of roads, railways, etc which are continuous whilst these are discontinuous? My feeling is that the key issues will be dealt with under foundations, some of which are related to wind turbines and others not. Certainly in the sense of installation to installation there is significant tolerance of differential settlement.

8.7 OFFSHORE (John Oliphant and others)

Main North Sea issue is trenching for pipelines and it can prove quite problematic – stiffer materials, boulders (removal), etc. Needs to be extended

BP staff could contribute at the next stage

8.7 LANDFILL

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e.g. Leachate migration on till

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Chapter 9 Risk Assessment and Mitigation – change to risk management of periglacial and glacial engineering geology?

Comment [a41]: Should this be Chapter 6?

- Approach and content to be developed by WP as main publication progresses?
- Consider input from insurance underwriters.
- Links with Managing Geotechnical Risk (Barry Clarke and Paul Maliphant)? – talking to insurers
- How hazards have been converted into risk e.g. case studies?
- Address that chapters after chapter 6 deal with managing risk
- Summary? Process Flowchart? 10 major lessons?
- Mott MacDonald / TRL - earthwork cost overruns associated with glacial till.
- Matthew Free volunteered to help if required
- known unknowns – reminders of what is missing
- Editorial intro to climate change impact on landslides in QJEGH – MW to circulate
- 10 case studies of where people have got it wrong and lessons learnt
- How to avoid the problem
- Summary of take-home messages / Conclusions

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References and Bibliography **-** at end of each chapter.
Include 'key references' in Introduction, each chapter or separate appendix?
Appendices.
Glossary.
Index.

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Table 1: Glacial, periglacial and permafrost sediment nomenclature

Depositional process	Genetic terms adopted in this volume	Previous terms where applicable*
Glacial	Subglacial traction till (Evans et al. 2006; Benn & Evans 2010)	Boulder clay; Lodgement till; Deformation till; Comminution till; Subglacial melt-out till; Lee-side cavity fills/ice-bed separation deposits; Endiamict glaciotectonite; Clast/boulder pavements; Tectomict
	Glacitectonite (Benn & Evans 1996): Type A Type B	Exodiamict glaciotectonite; Tectomict
	Supraglacial mass flow diamicton/glacigenic debris flow deposit (Lawson 1979)	Supraglacial morainic till; Flow till; Melt-out till
Glacifluvial	Hyperconcentrated flow deposits (jökulhlaup-type flood deposits)	
	Gravel rhythmites (flood facies)	
	Plane bed deposits	
	Cross-bedded facies (dunes & antidunes)	
	Gravel sheets	
	Ripple cross-laminations (inc. climbing ripple drift)	
	Facies associations/architectural elements (Miall 1985, 1992): - channel fills (CH) - downstream accretion macroforms (DA) - lateral accretion macroforms (LA) - gravel bars & bedforms (GB) - sediment gravity flow (SG) - sandy bedforms (SB) - laminated sand sheets (LS) - overbank fines (OF)	
Glacilacustrine and glacimarine	Rhythmites (non-genetic)	
	Varves (seasonal rhythmites)	
	Cyclopels & cyclopsams (tidally influenced rhythmites)	
	Turbidites	
	Dropstone mud & plumites / silt & mud drapes (inc. Ice-rafted debris – IRD)	
	Dropstone diamicton & glacimarine varves (inc. Ice-rafted debris – IRD)	Iceberg dump till
	Undermelt diamicton	Waterlain till; Undermelt till; Subaquatic melt-out till; Subaqueous basal till; Grounding line till; Dropped para-till
	Iceberg contact deposits (ice keel turbate, iceberg dump structures & mounds)	Iceberg till
	Debris flow (debrites) / subaqueous slide &	Sediment gravity flow/mass flow/density

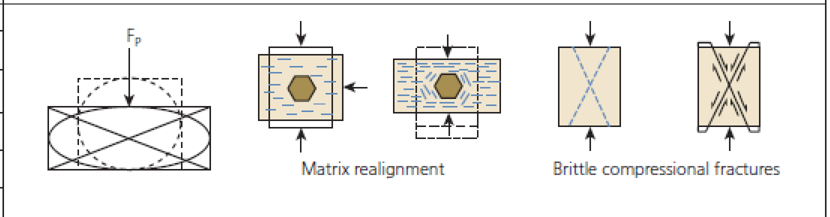
	slump deposits (inc. cohesive & cohesionless)	flow; Subaquatic flow till; Submarine flow till
	Subaqueous debris fall deposits (inc. olistostromes)	Grain fall
	Palimpsest lags	
Slopes	Debris flow deposits/debrites (subaerial Types I-IV; Lawson 1979)	Sediment gravity flow/mass flow/density flow
	Debris fall deposits (scree/talus)	Colluvium
	Slide & slump deposits	
Permafrost		
Periglacial		
Pressurized groundwater escape	Clastic dykes & hydrofrature fills (inc. burst-out structures; Rijsdijk et al. 1999, Le Heron & Etienne 2005)	

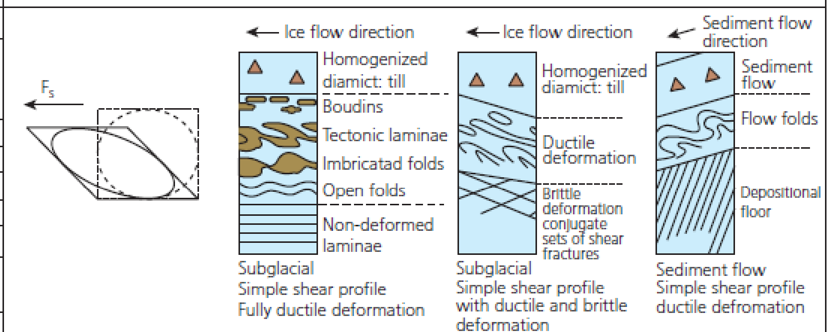
* These include some alternative terms and groups of terms now covered by single classifications

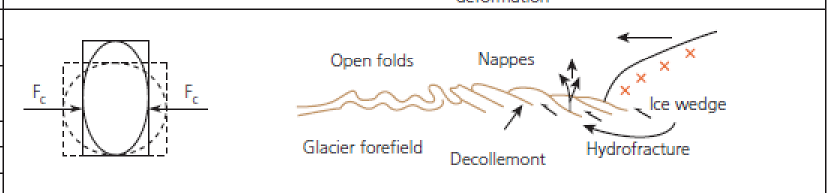
Table 2: Deformation styles, structures and nomenclature

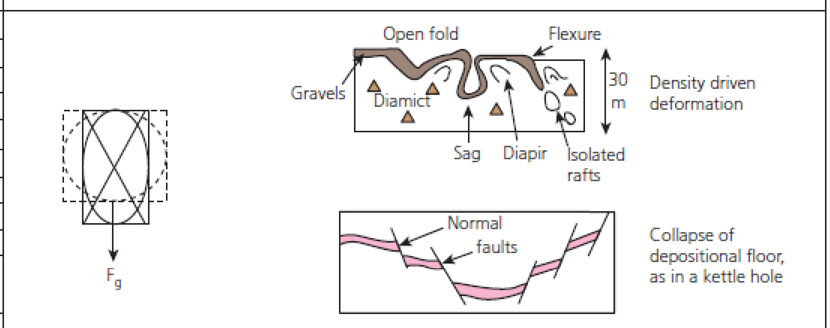
Code	Description
P	**Pure shear**
PDH	Horizontal dilation (psa vertical)
PDI	Inclined dilation (psa not vertical)
PCC	Crushed clasts
PMC	Matrix and clast re-alignment
PCF	Compressional fractures
S	**Simple shear**
SHZ	Shear zone comprising sheared (inclined, isoclinal) folds, boudins, tectonic laminae
SSP	Simple shear profiles
STW	Shear thrust wedges
SFD	Shear thrust fractures and dykes
SHY	Shear hydrofractures
SEC	Extensional clastic dykes
SPB	Sheared and plucked pre-glacial breccia
SPR	Sheared and plucked bedrock
C	**Compressional**
CNA	Nappes
CAS	Anticlinical and synclinal folding (longitudinal compression)
CFR	Compressional fractures
CDK	Compressional dykes
CHY	Compressional hydrofractures
V	**Vertical**
VDS	Descending clast stringers
VLO	Loadcasts
VDI	Diapirs
VFL	Flexures
VCO	Collapse structures
VEX	Extensional fractures
VPO	Pods, rafts and pseudonodules
VCS	Cone-shaped clast clusters
VSY	Synforms (no longitudinal compression)
VHF	High-angle unimodal fabrics
U	**Undeformed**
UHS	Horizontal bedding
ULA	Lamination (graded)
UCR	Cross bedding
UON	Onlaps and drapes
UGR	Gradational contacts

Strain elipse | Examples









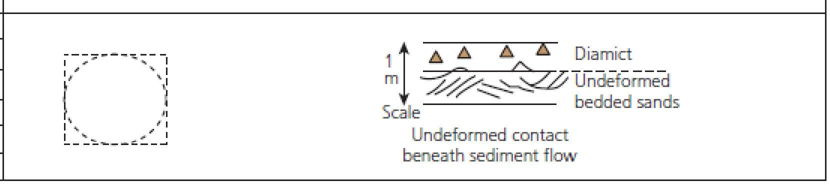


Table 3: Alternative terminology for poorly-sorted sediments (diamictons)

Engineering geology nomenclature	**Glacial sedimentology nomenclature** Scheme 1 (Eyles et al. 1983; Benn & Evans 1998, 2010)	Scheme 2 (Kruger & Kjaer 1999)
	Dmm – massive, matrix-supported diamicton (further descriptors can be added to all codes during logging to describe grain size of both matrix and larger clasts)	DmM – massive, homogenous, medium grained, silty-sandy diamict DmF - massive, homogenous, fine grained, clayey silty-diamict _ _ _ (m_1) clast poor matrix _ _ _ (m_2) moderate clast content _ _ _ (m_3) clast rich matrix _ _ _ (c) = all these codes can be clast-supported in this scheme
	Dms – stratified, matrix-supported diamicton	DgM – graded, medium grained, silty-sandy diamict DgF – graded, fine grained, clayey silty-diamict Db/sM – banded/stratified, medium grained, silty-sandy diamict Db/sF – banded/stratified, fine grained, clayey silty-diamict DhM – heterogeneous, medium grained, silty-sandy diamict DhF – heterogeneous, fine grained, clayey silty-diamict _ _ _ (m_1) clast poor matrix _ _ _ (m_2) moderate clast content _ _ _ (m_3) clast rich matrix _ _ _ (c) = all these codes can be clast-supported in this scheme
	Dcm – massive, clast-supported diamicton	DmC - massive, homogenous, coarse grained, sandy-gravelly diamict _ _ _ (c) = clast-supported
	Dcs – stratified, clast-supported diamicton	DgC – graded, coarse grained, sandy-gravelly diamict Db/sC – banded/stratified, coarse grained, sandy-gravelly diamict DhC – heterogeneous, coarse grained, sandy-gravelly diamict _ _ _ (c) = clast-supported
	Dml – laminated or banded, matrix-supported diamicton	Db/sM – banded/stratified, medium grained, silty-sandy diamict Db/sF – banded/stratified, fine grained, clayey silty-diamict _ _ _ (m_1) clast poor matrix

		_ _ _ (m_2) moderate clast content _ _ _ (m_3) clast rich matrix _ _ _ (c) = both codes can be clast-supported in this scheme
	_ _ _ (c) – evidence of current reworking _ _ _ (r) – evidence of re-sedimentation _ _ _ (s) – sheared or fissile _ _ _ (p) – includes clast pavement	