Use of Glaciogenic Sediment Origin for Ground Water Management During Earthworks Construction on the HS2 Project

Gerard McArdle
Technical Expert – Engineering Geologist

Mott Macdonald SYSTRA Design Joint Venture for lots N1 and N2

Date: 14th May 2024

Use of Glaciogenic Sediment Origin for Ground Water Management During Earthworks Construction on the HS2

1. Introduction
2. Location and Topography (Park Lane Cutting)
3. Geology
   a. Bedrock
   b. Glacial Environments
   c. Mid Pleistocene
   d. Geohazards
4. Ground Model - Park Lane Cutting
5. Summary

What do you think of the shape of the gravel?

1- Introduction

Introduction

Issues to be managed:

1. Laterally discontinuous fine-grained soils within glacial fluvial deposits
2. Refinement of geotechnical design model to support earthworks construction (within cuttings)
3. How does the origin of the glacial sediments affect their permeability and how do we take advantage of it?

2- Location and Topography

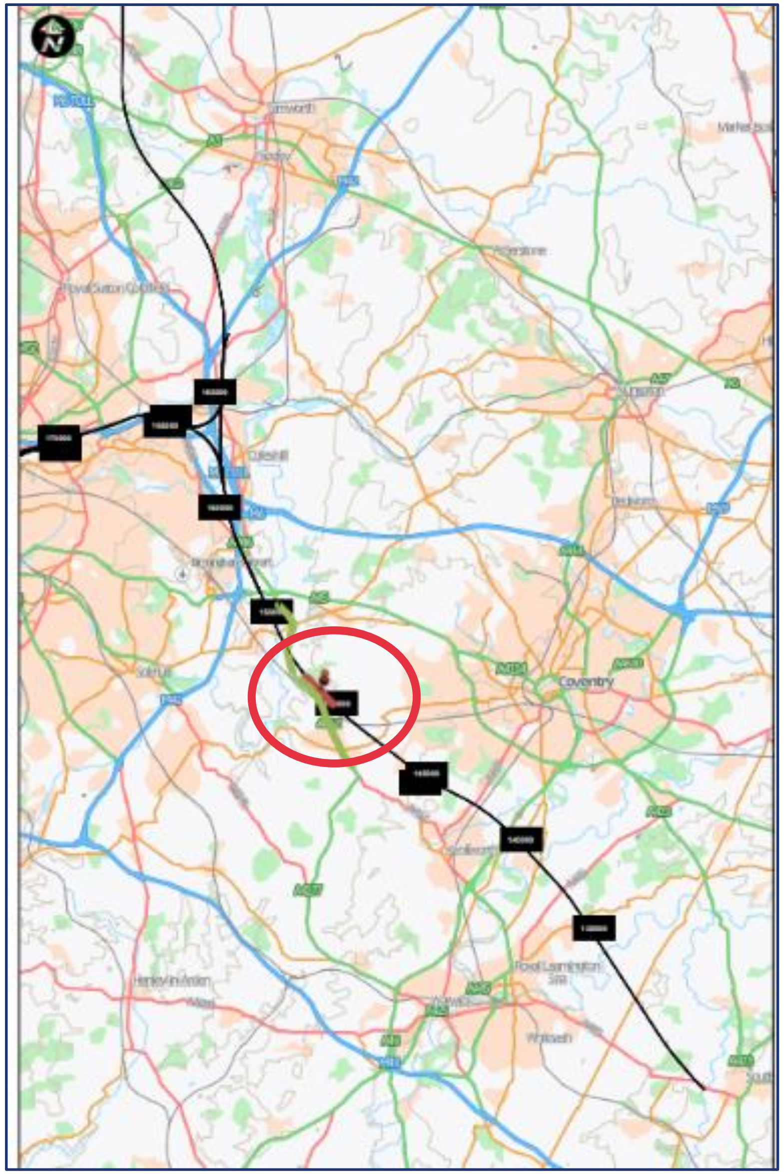
Location of the case study area

The case study area is located midway between Birmingham and Coventry and is part of the HS2 Lot N1/N2 earthworks.

Park Lane cutting is approximately 2km long and ranges in depth from 2m to 12m

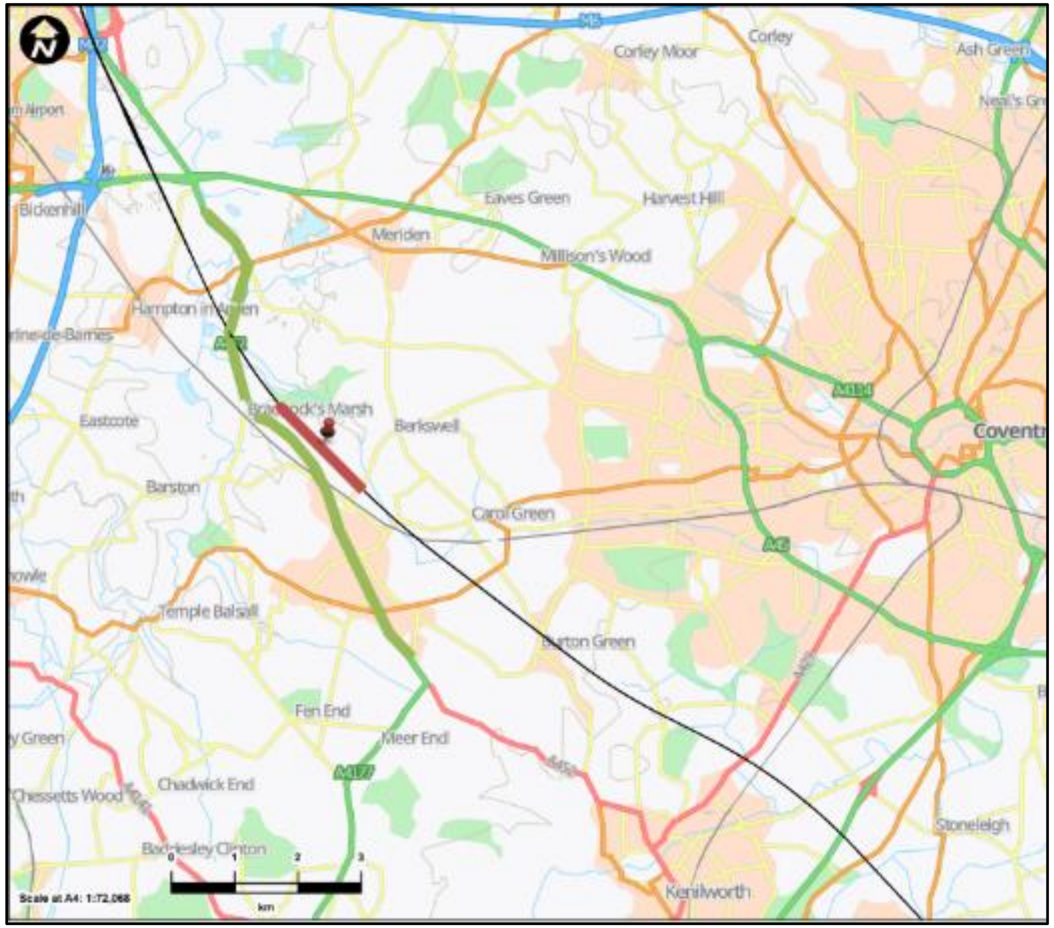
The cutting starts near Balsall Common and ends adjacent to Bradnock's Marsh

General location

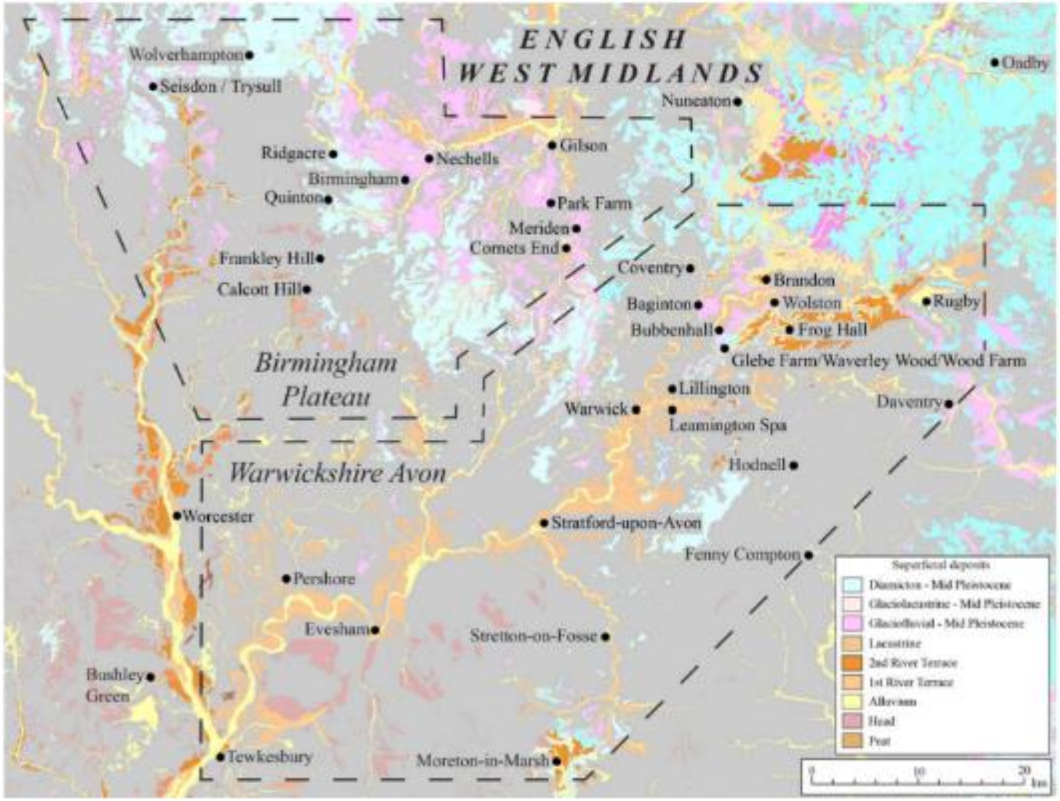


Park Lane Cutting

Location - Park Lane Cutting – Birmingham Plateau



Extract from BBV Ispatial platform showing general location of study site



11

royalsocietypublishing.org/journal/rsos *R. Soc. Open Sci.* 9: 220312

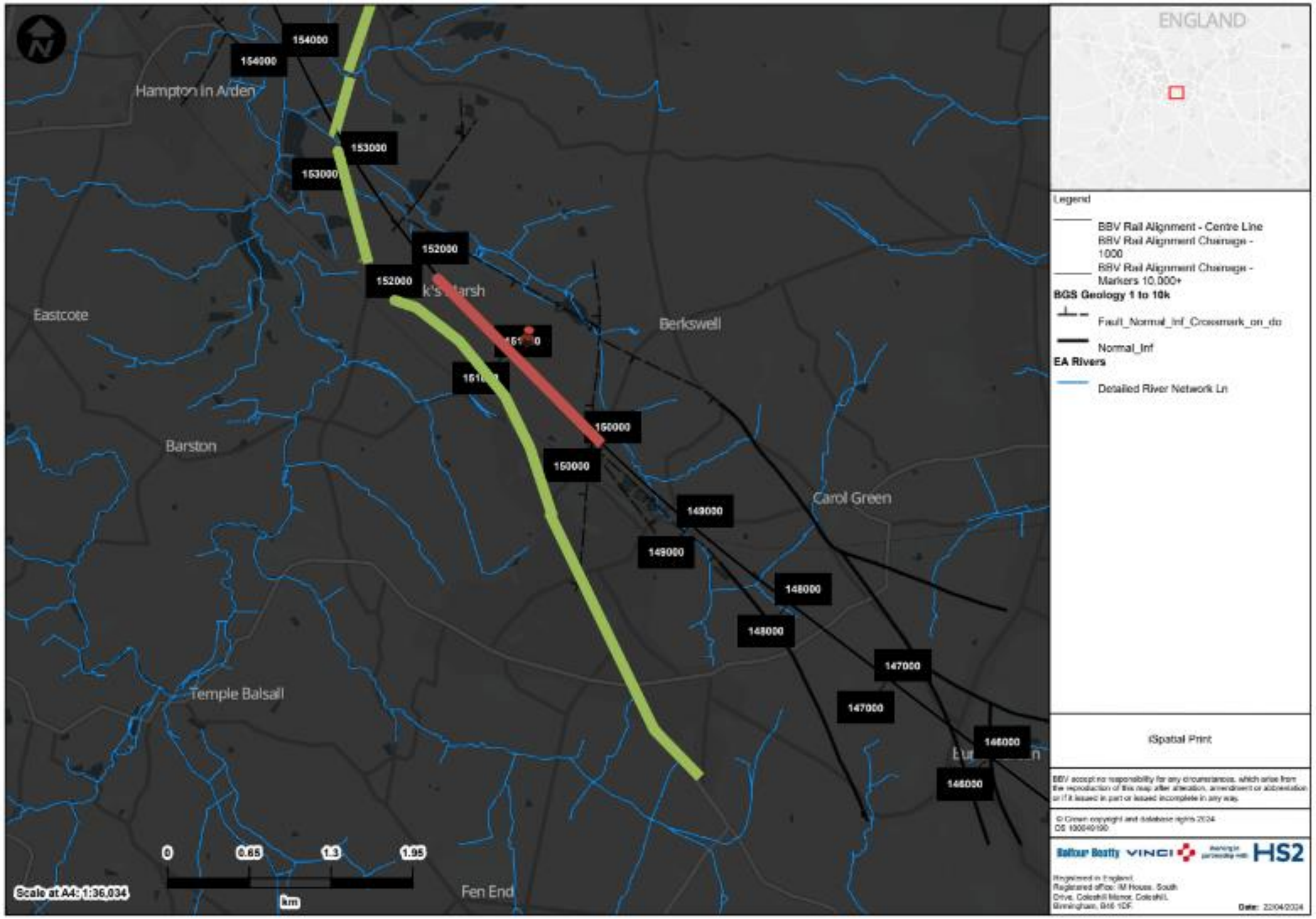
Figure 4. Map of the superficial deposits of the Birmingham plateau and Warwickshire Avon areas of the English West Midlands. The dashed line marks the boundary of the Birmingham and Warwickshire Avon areas discussed here. Modified from Digimap [74]. Light grey indicates an absence of superficial deposits.

Extract from Gibson et al 2022

Location

Slide illustrating the position of the A452 (Green line) Kenilworth Roads and HS2 alignment within the river system. Park Lane cutting is the red line

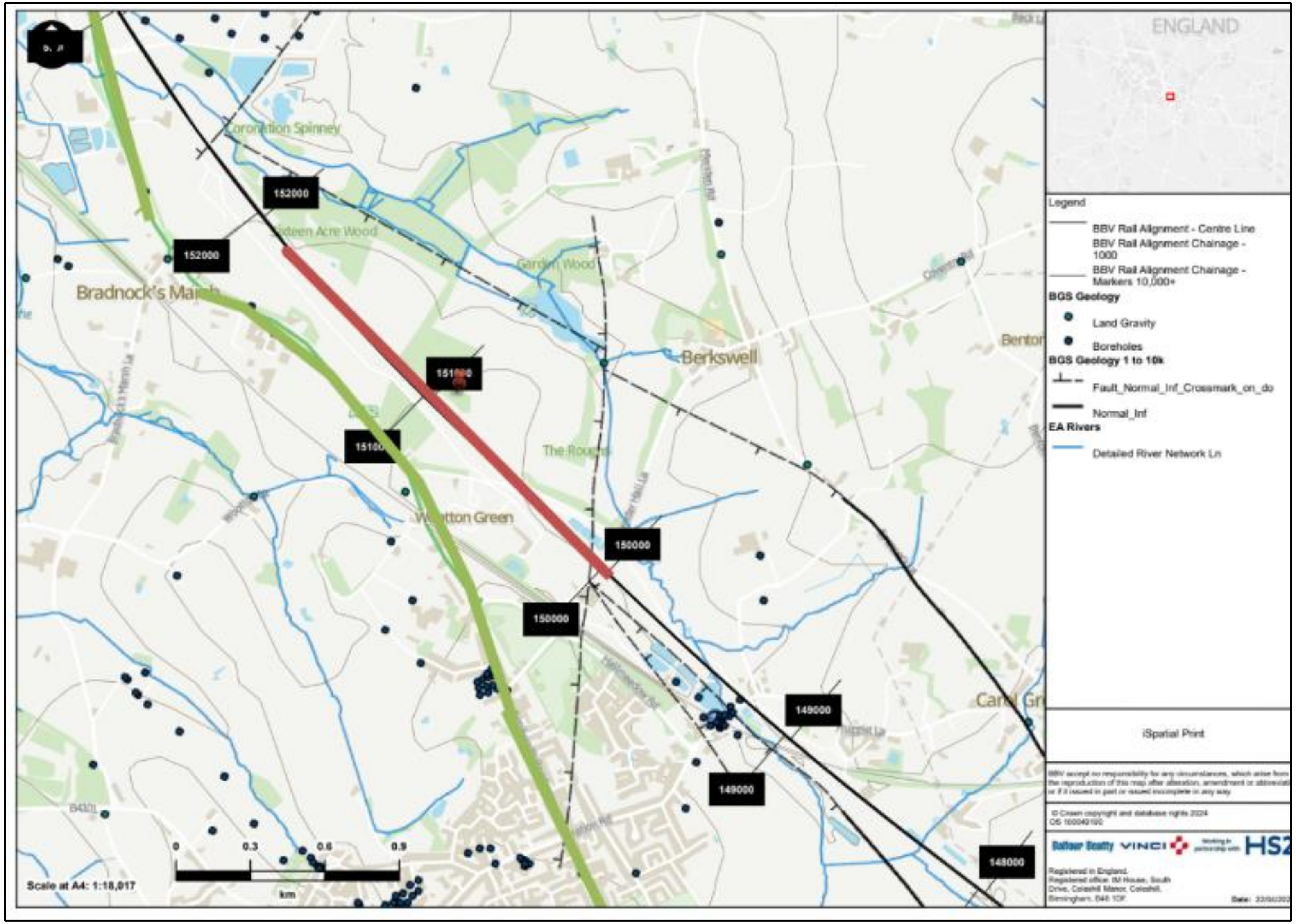
Extract from BBV Ispatial platform showing general location of study site



Location

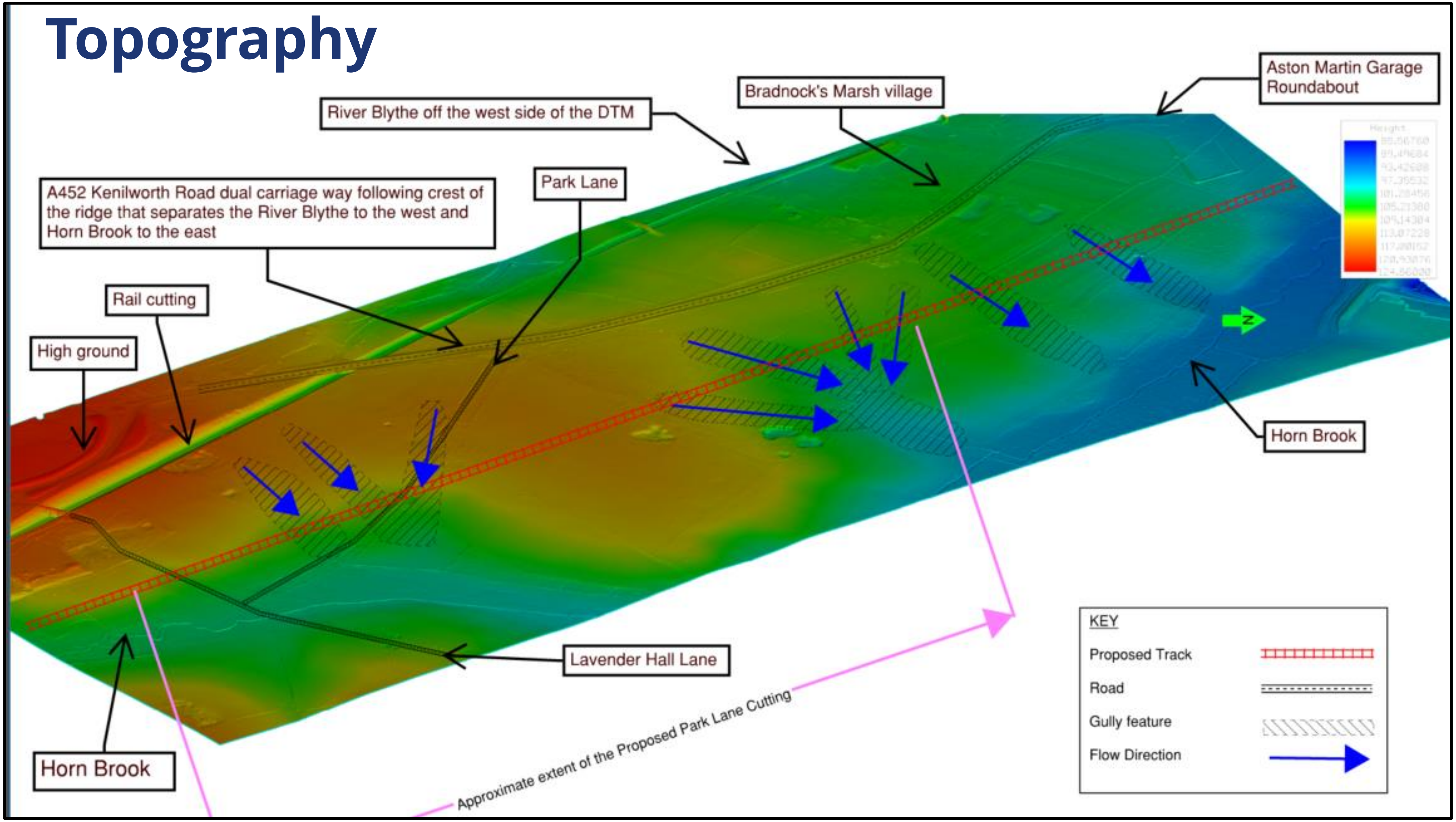
Horn Brook and bedrock Faults

A452 Road -Green line Park Lane cutting - red line



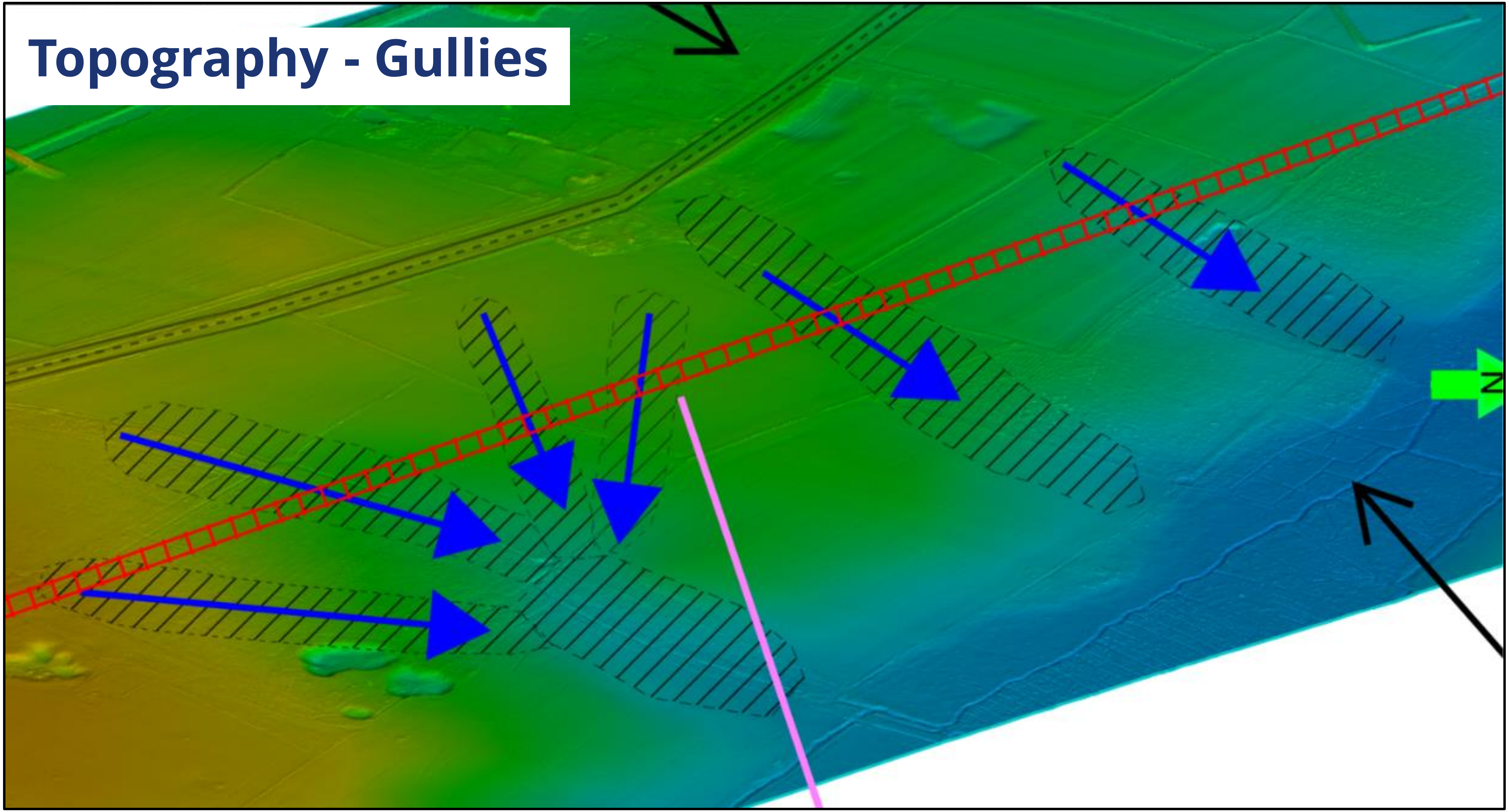
Extract from BBV Ispatial platform showing general location of study site

Topography



Extract from BBV digital terrain model prior to the start of the works. Balsall Common is on the high ground to the left

Topography - Gullies



3 – Geology

3a - Bedrock

Triassic Bedrock Origins

Pangea and UK

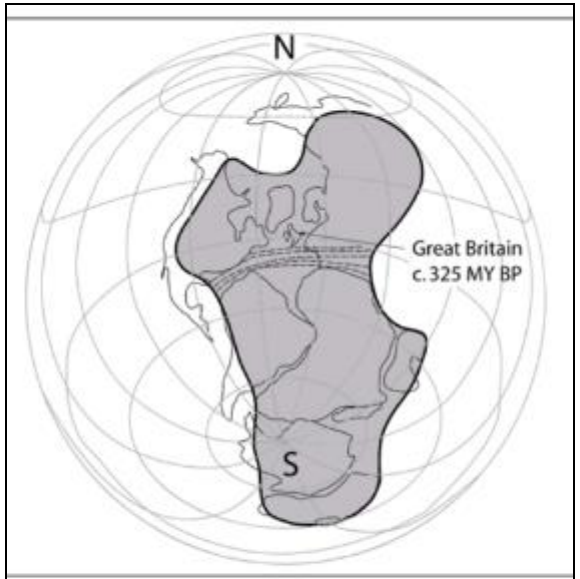


Figure 2.1 Supercontinent of Pangea in the late Carboniferous Period 325 million years ago formed by the collision of the continental masses of Laurasia and Gondwana (after Keary and Vine, 1990).

Permo-Trassic Basin Formation

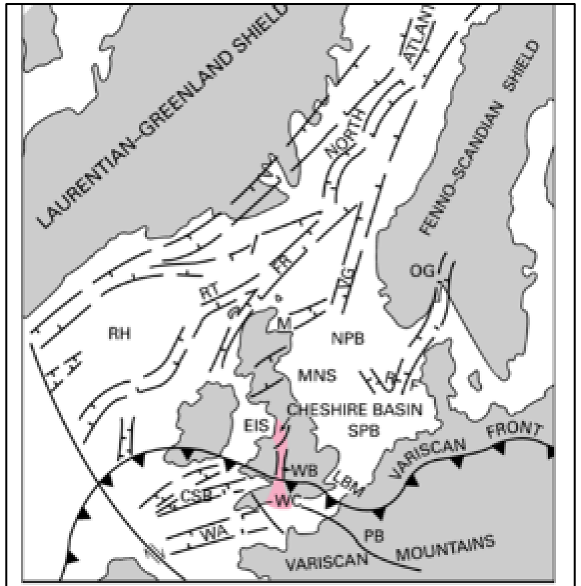
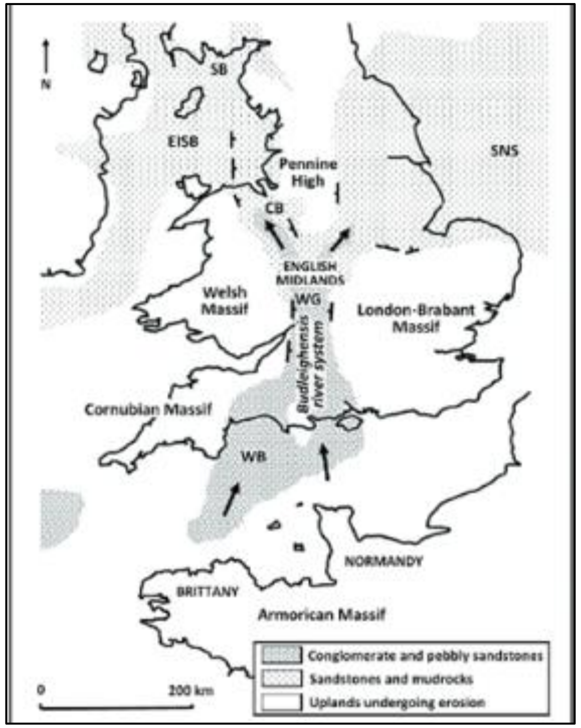


Figure 2.2 Permo-Triassic regional tectonic framework of the North Atlantic region. CB = Cheshire Basin, WB = Worcester Basin, WC = Wessex Basin, NPB = North Permian Basin, SPB = South Permian Basin, LBM = London Brabant Massif (after Chadwick and Evans, 1995).

Triassic Fluvial System



Stratigraphic Column

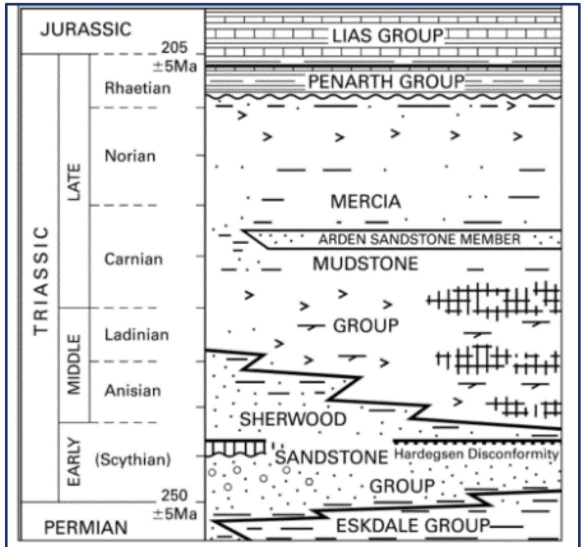


Figure 2.3 Triassic lithofacies in England and the Southern North Sea (after Warrington and Ivimey-Cook, 1992).

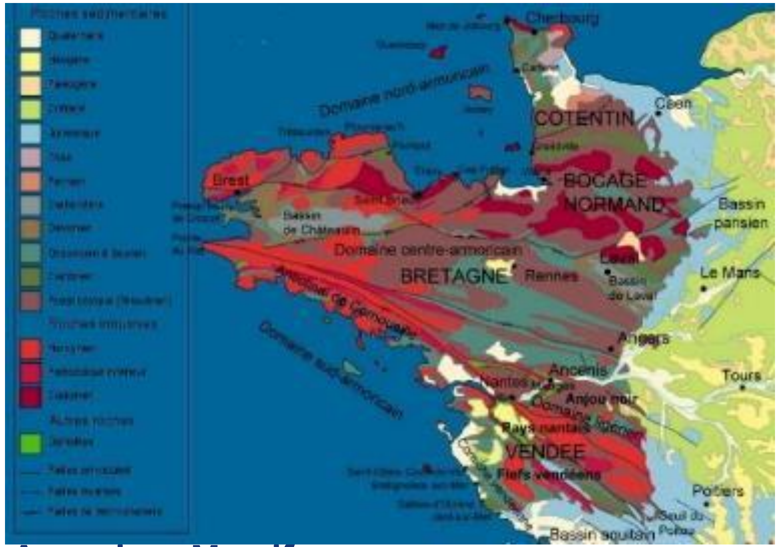
Extracts from BGS Research Report RR/01/02 Engineering Geology of the Mercia Mudstone Group

How far have I travelled

Chester formation (Chester Pebble Beds – Bunter Pebbles)

Photographs taken by G McArdle as part of DJV construction phase support activities

Brown or purple quartzite, with quartz conglomerate and vein quartz. Origin Armorican Massif in France



Armorican Massif [Le Massif armoricain (vinsvignesvignerons.com)](vinsvignesvignerons.com)

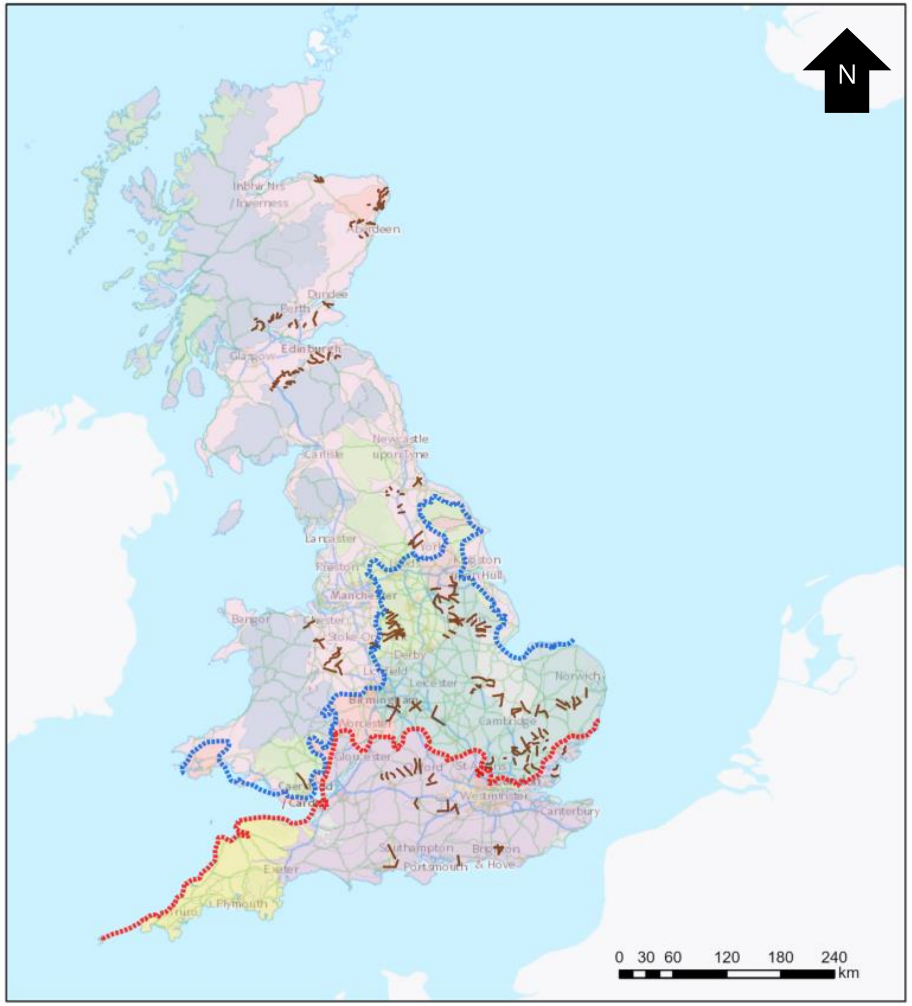
Chester Formation

Pile Arisings

3 – Geology

3b – Glacial Environments

Glacial limits and Glacial Ground Models –
Which Quaternary Domain is Applicable to Park Lane Cutting



Map Key

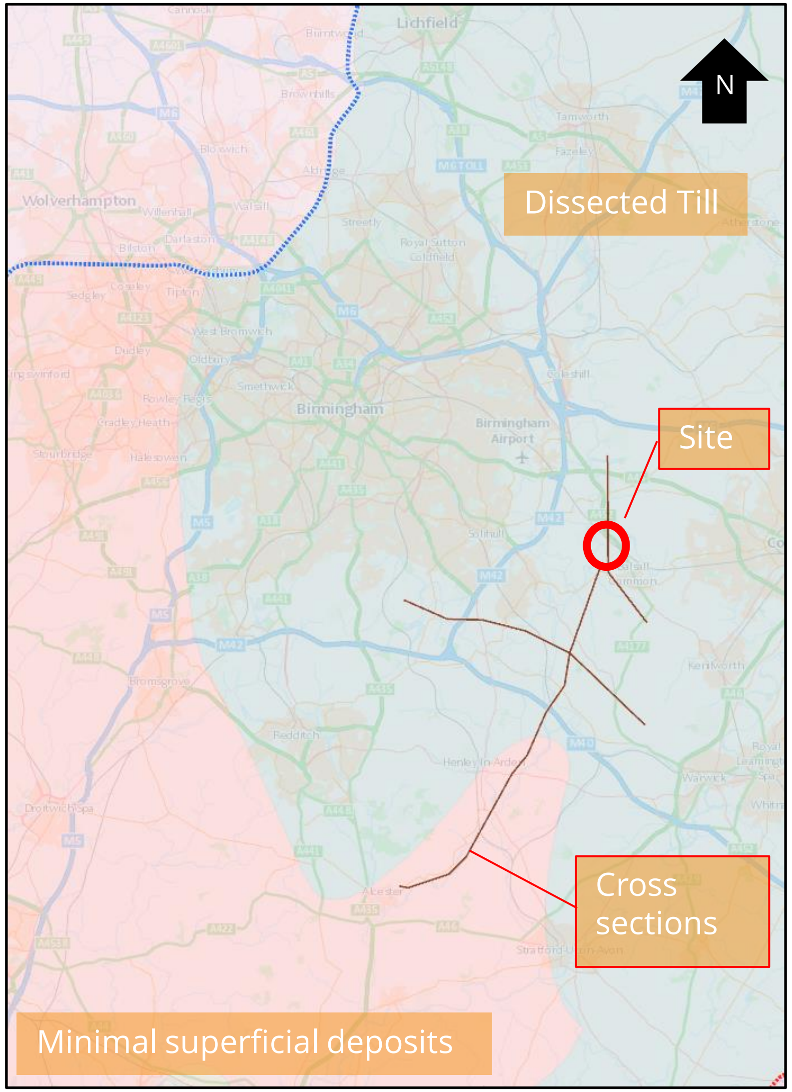
Quaternary Domains Descriptors

- Coastal and Estuarine
- Dissected Till
- Fluvial
- Ice-scoured Montane
- Lowland Basin
- Lowland Periglaciated
- Minimal Till
- Montane and Valley
- Plateau and Valley
- Till Dominant
- Upland Periglaciated

Geological Cross Sections

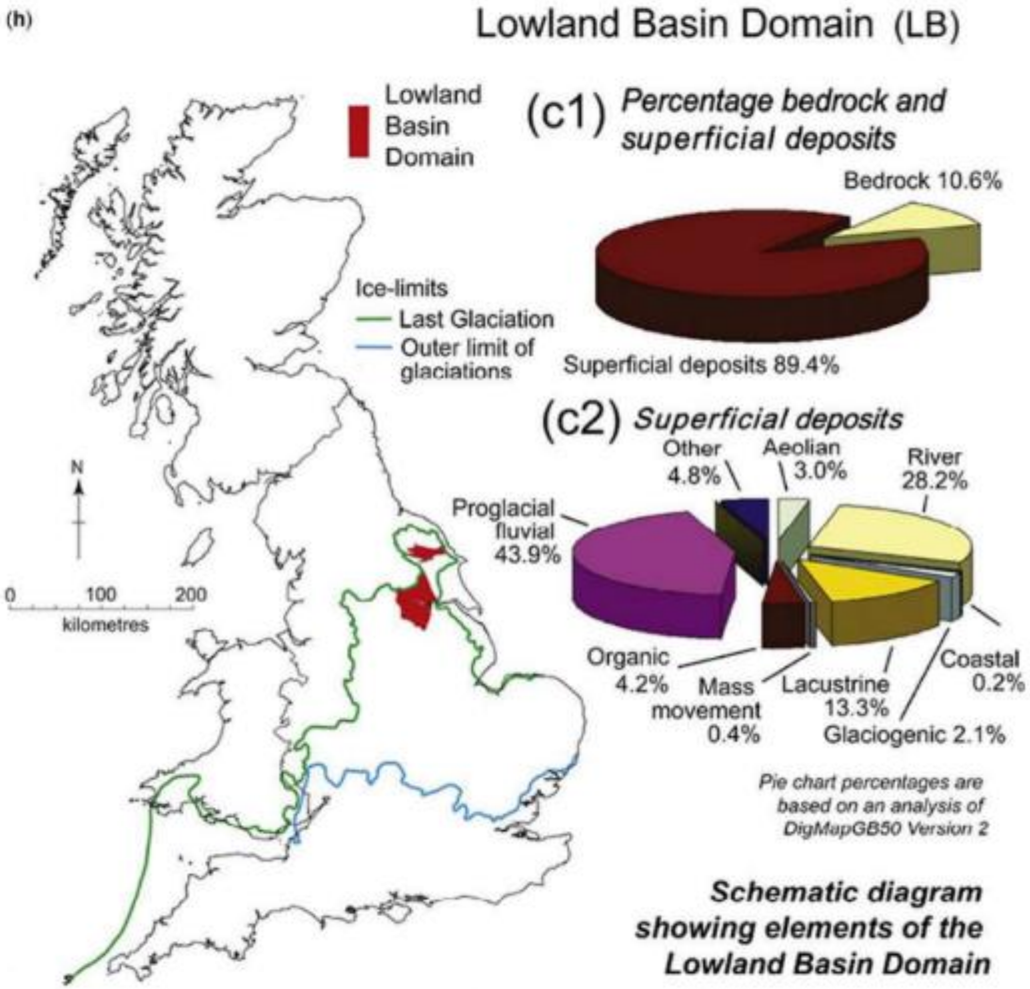
Glacial Limits

- Devensian/Anglian glaciation boundary
- Glaciated/Non-Glaciated boundary



Extracts from the BGS Onshore Index

Glacial limits and Glacial Ground Models – Glacial lakes – Vale of York



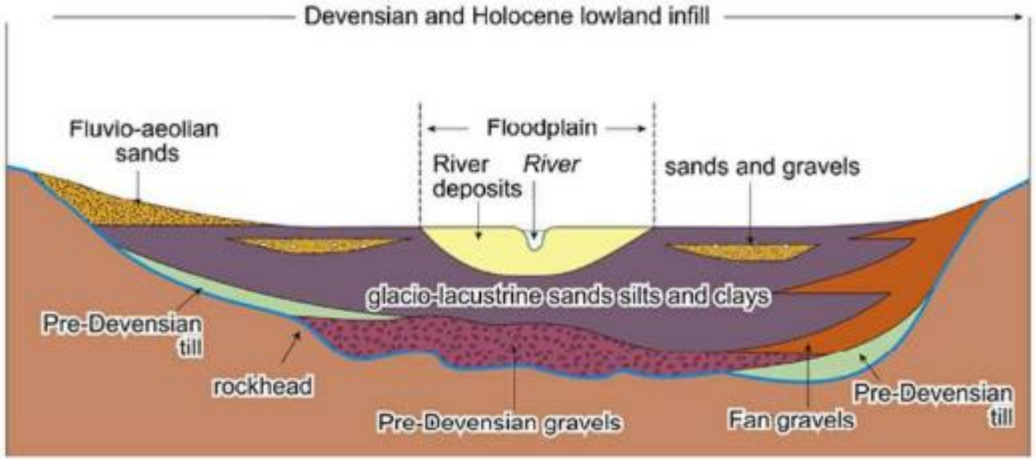
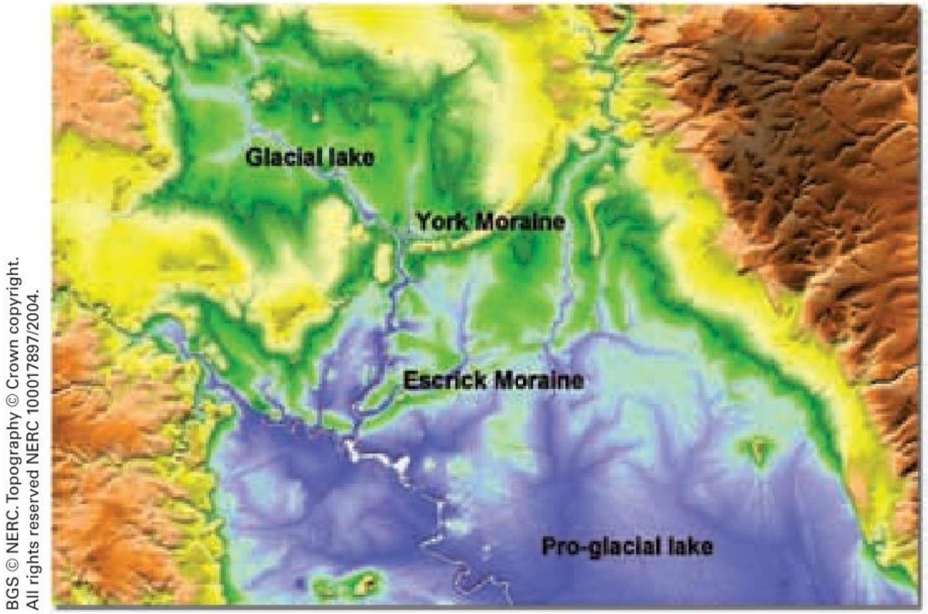


Fig. 4.72. *Continued.*



Extracts from BGS Vale of York

Extracts from Booth et al 2015 - Booth S., Merritt J. & Rose J. 2015. Quaternary Provinces and Domains

Glacial limits and Glacial Ground Models

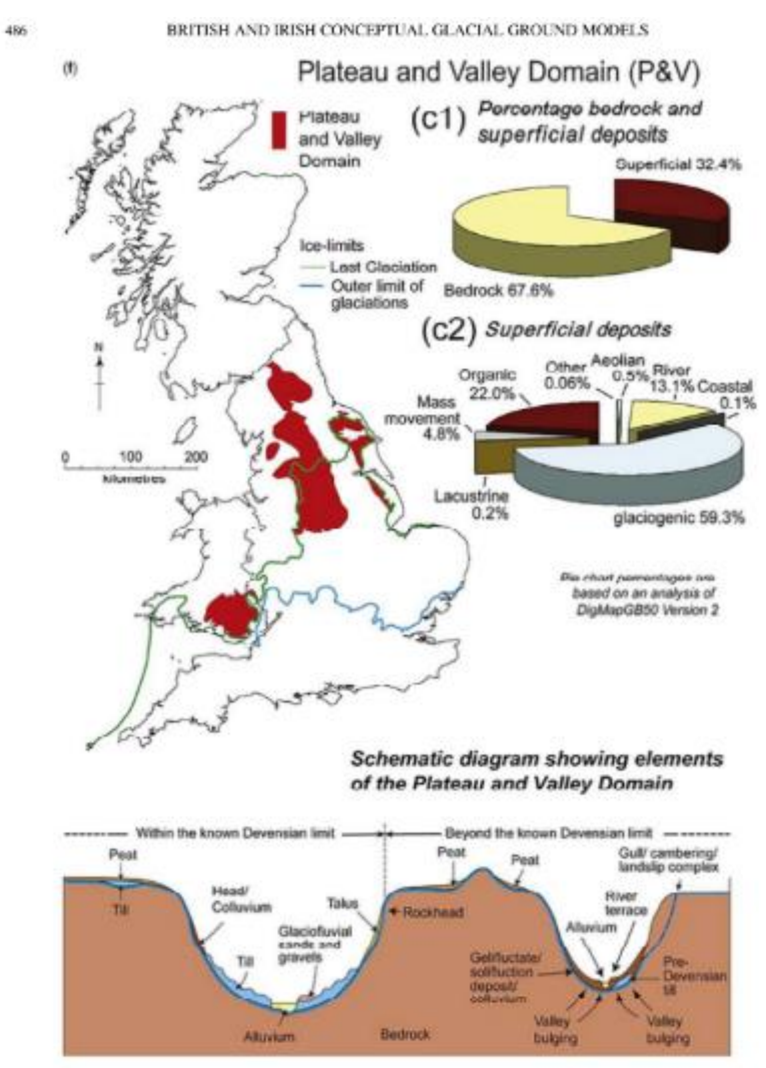


Fig. 4.72. Continued.

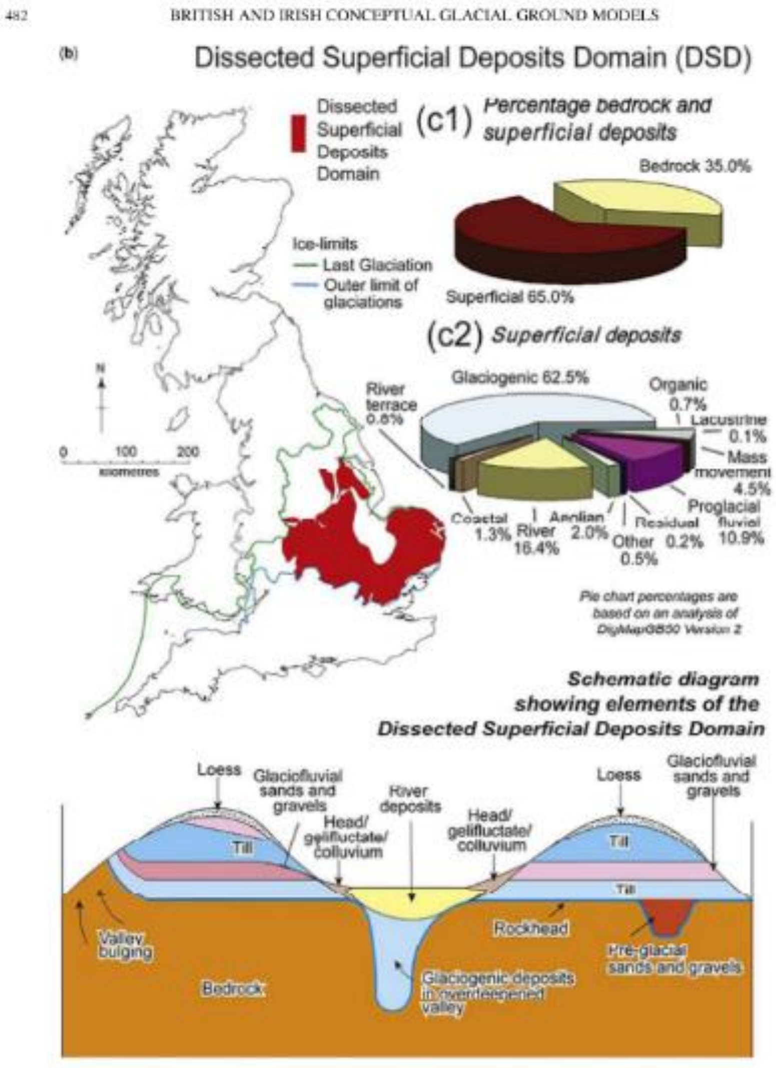


Fig. 4.72. Continued.

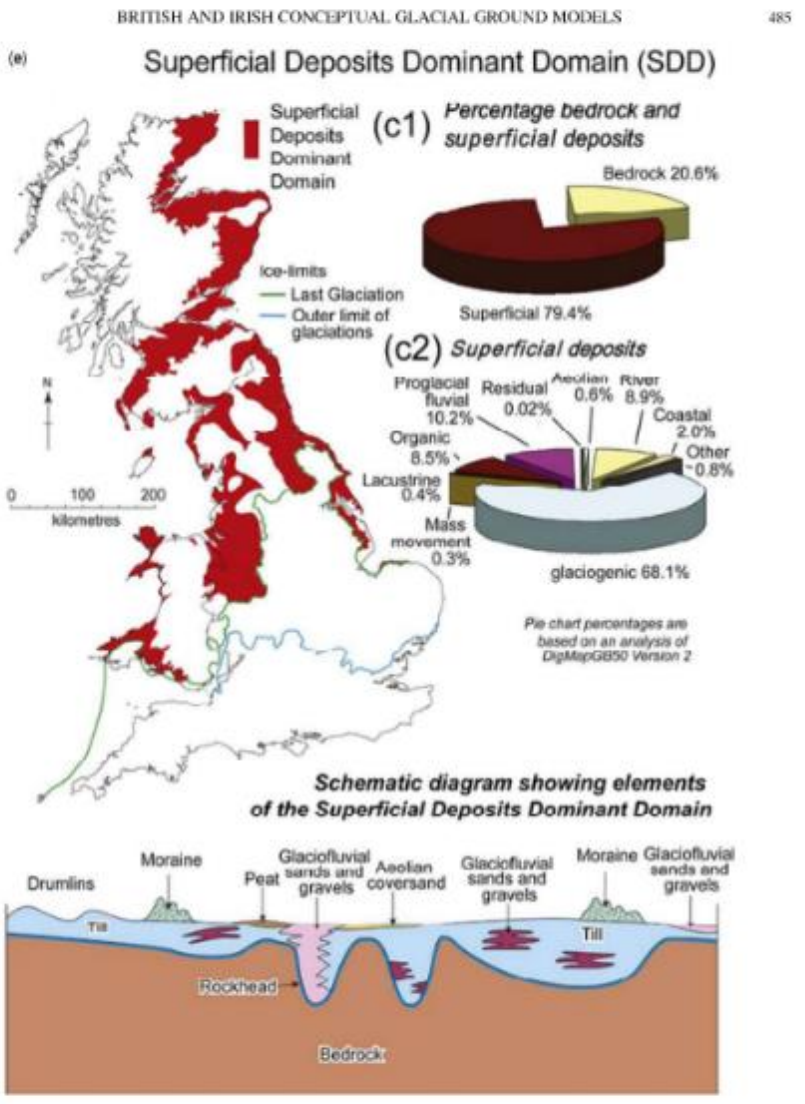
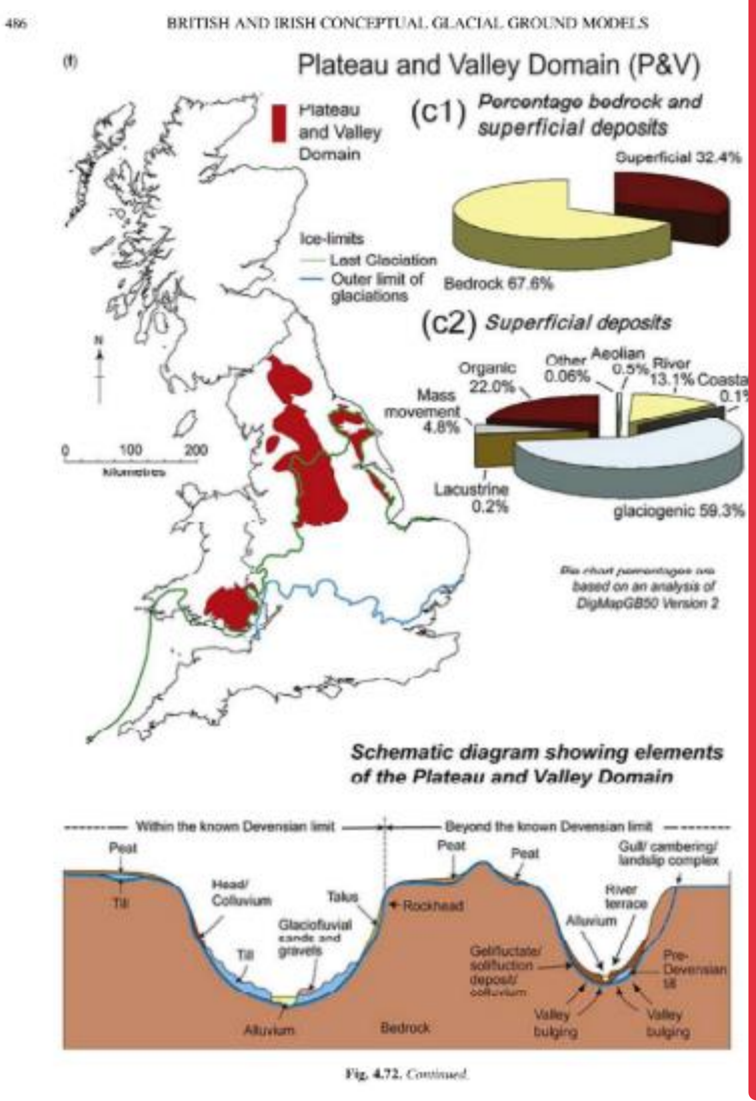
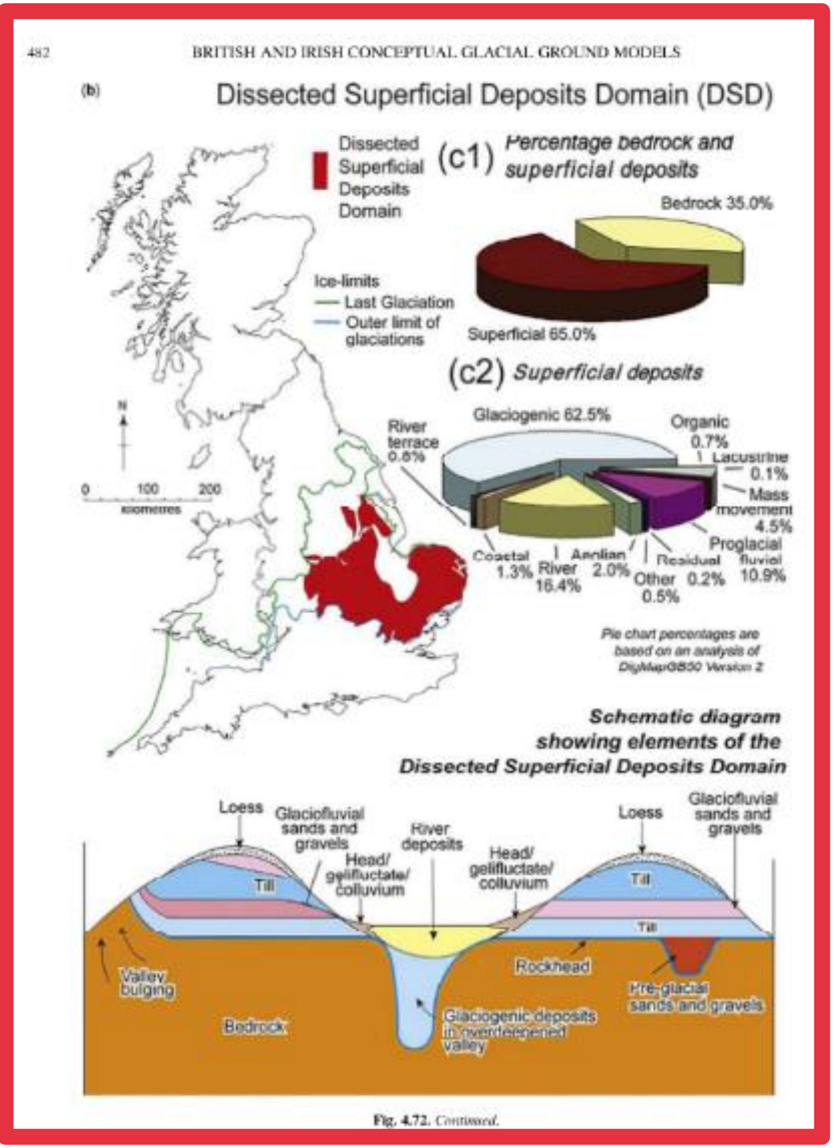


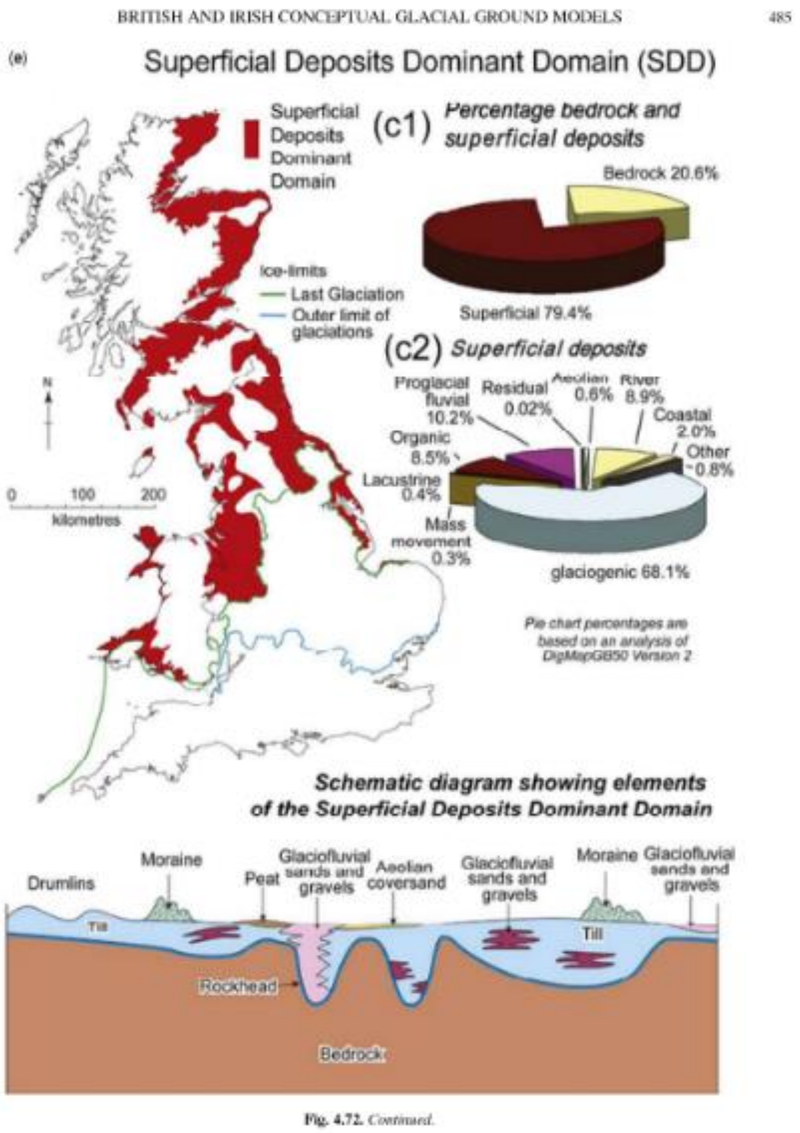
Fig. 4.72. Continued.

Extracts from Booth et al 2015 - Booth S., Merritt J. & Rose J. 2015. Quaternary Provinces and Domains

Glacial limits and Glacial Ground Models

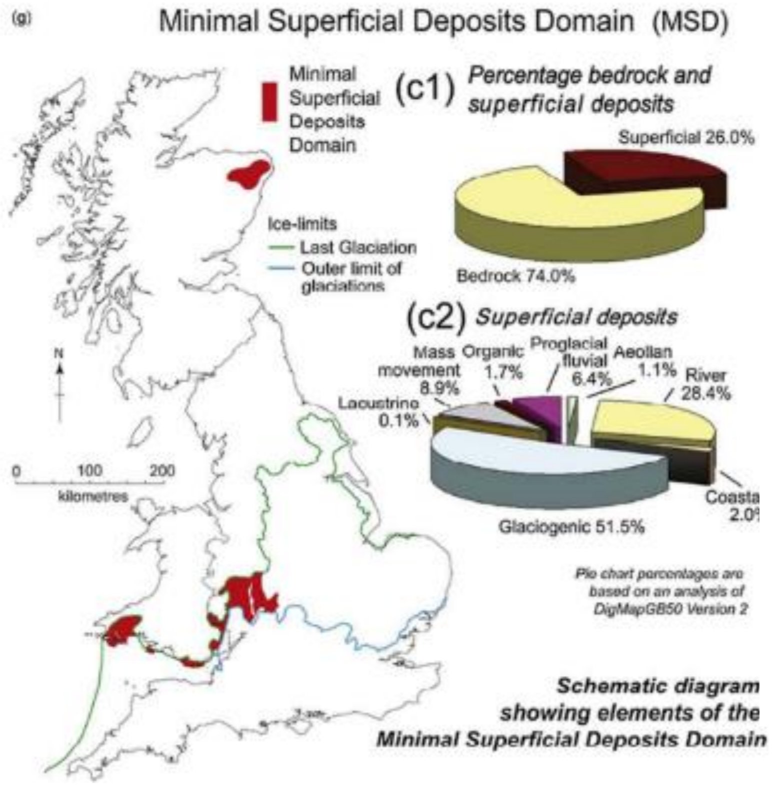


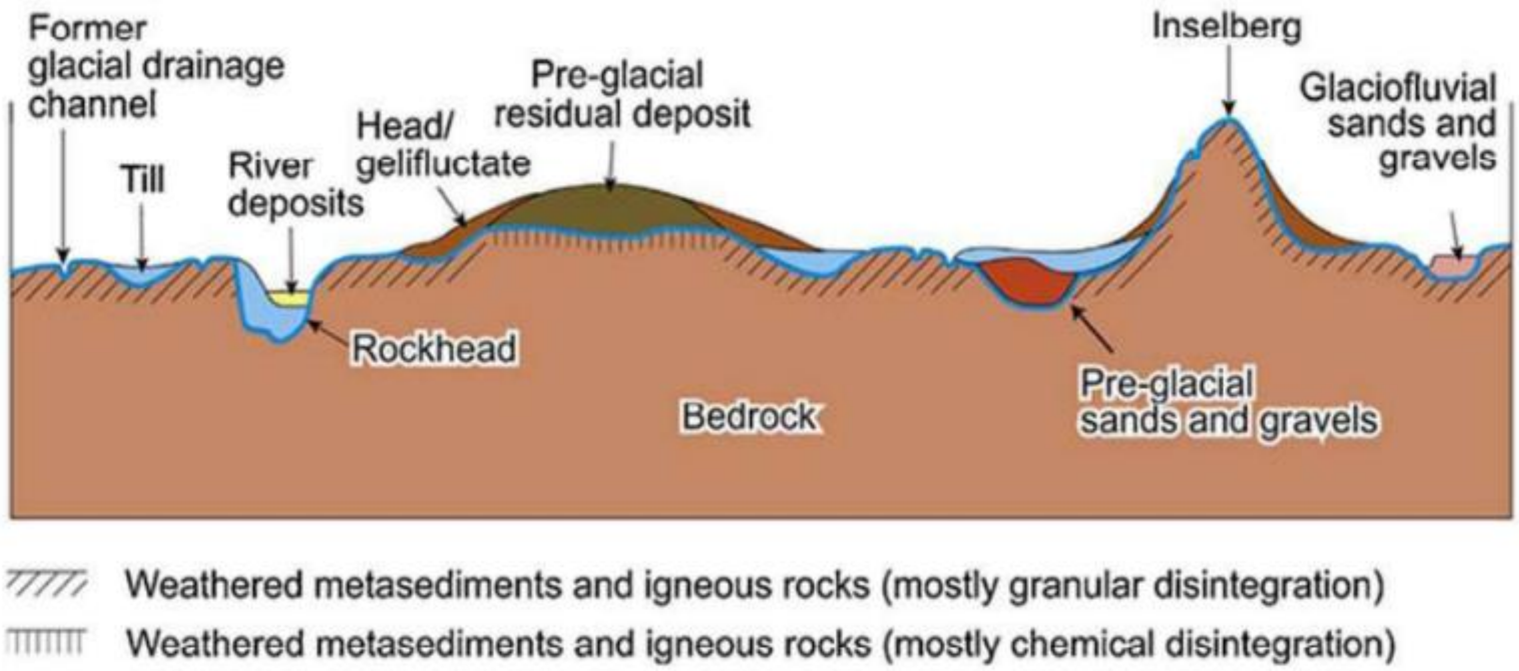




Extracts from Booth et al 2015 - Booth S., Merritt J. & Rose J. 2015. Quaternary Provinces and Domains

Park Lane Cutting - Glacial limits and Glacial Ground Models





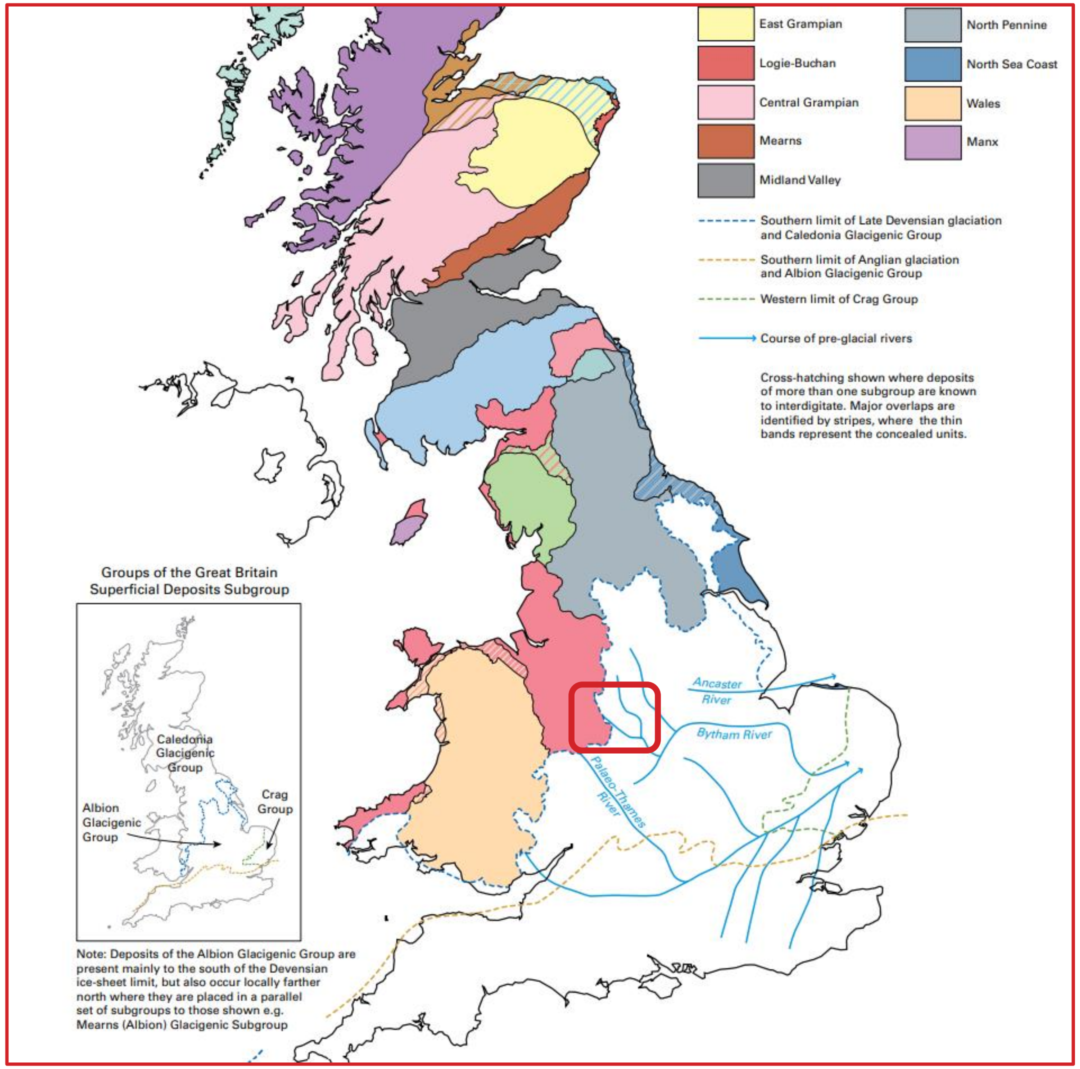
As can be seen from the map on the left the glacial domain between the Devensian and Anglian limit is different to most of the UK. This domain is more applicable to the site that the dissected Till Domain that is indicated in the literature.

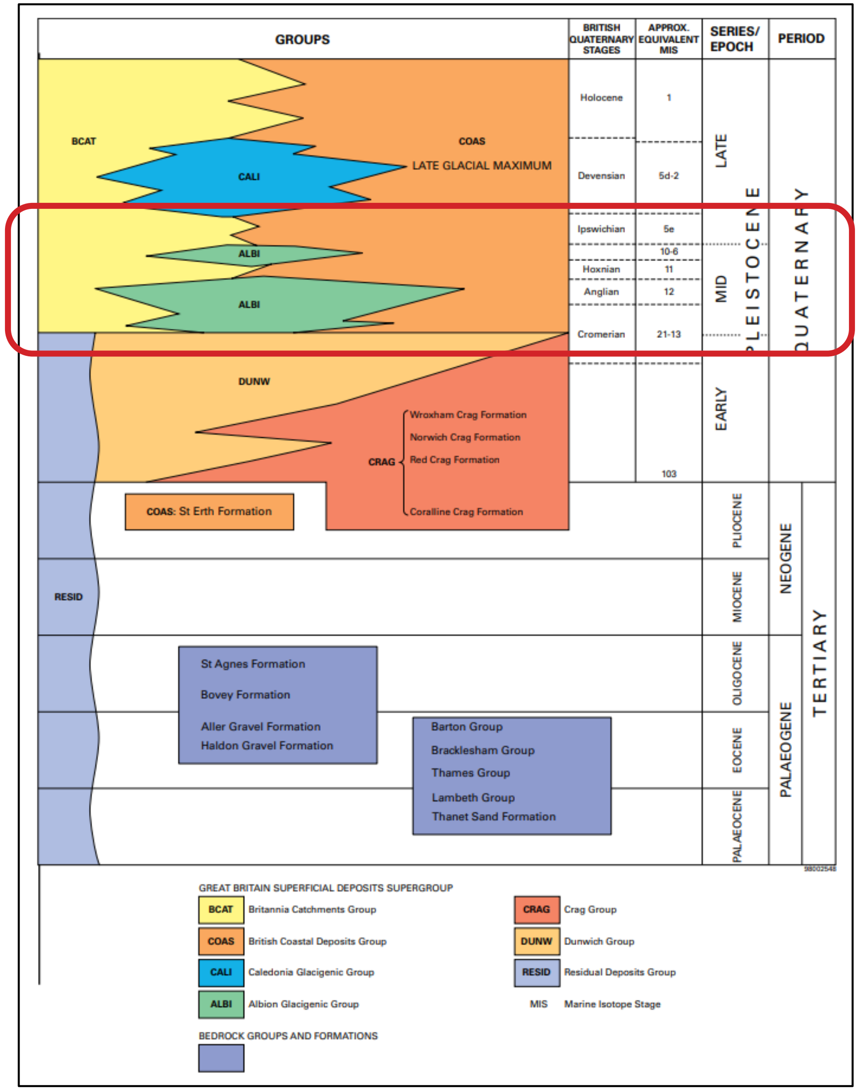
Extracts from BGS Research Report RR/10/03

3 – Geology

3c – Mid-Pleistocene

Park Lane Cutting – Engineering Geology/Ground Water Risk
Mid-Pleistocene – Glacial limits and Glaciogenic Groups





Extracts from BGS Research Report RR/10/03

Park Lane Cutting – Engineering Geology/Ground Water Risk
Mid-Pleistocene

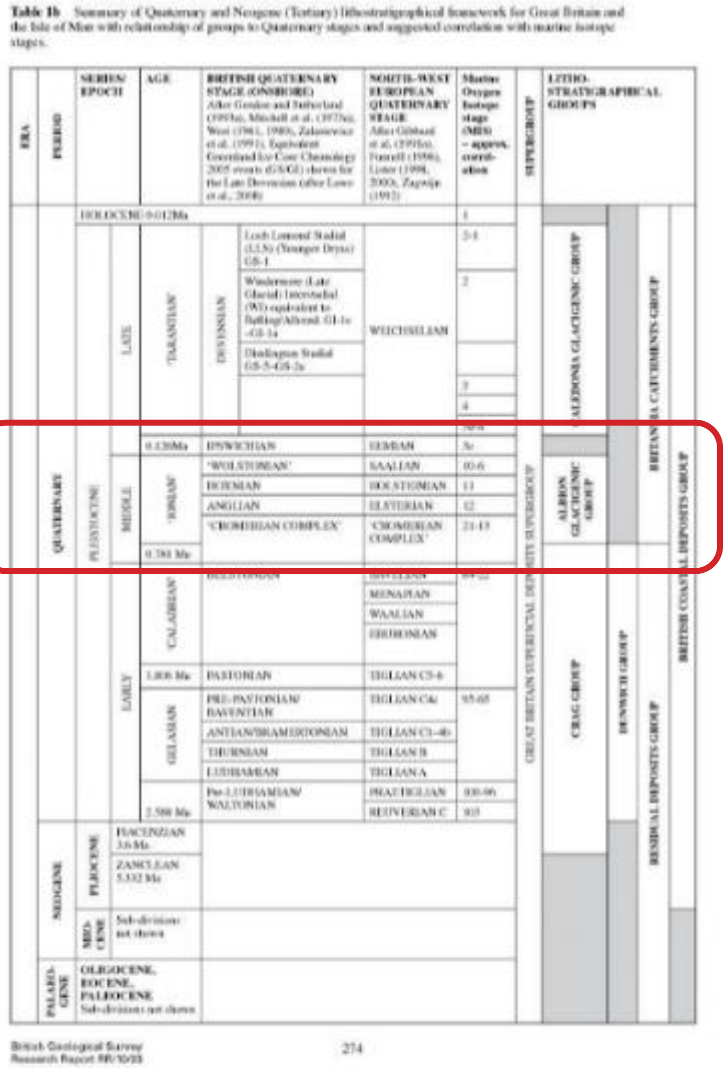


Table 1b Summary of Quaternary and Neogene (Tertiary) lithostratigraphical framework for Great Britain and the Isle of Man with relationship of groups to Quaternary stages and suggested correlation with marine isotope stages.

AGE	BRITISH QUATERNARY STAGE (ONSHORE)	NORTH-WEST EUROPEAN QUATERNARY STAGE	Marine Oxygen Isotope stage (MIS) – approx. correlation
HOLOCENE 0.012Ma			1
0.126Ma	IPSWICHIAN	EEMIAN	5e
	'WOLSTONIAN'	SAALIAN	10-6
	HOXNIAN	HOLSTEINIAN	11
	ANGLIAN	ELSTERIAN	12
0.781 Ma	'CROMERIAN COMPLEX'	'CROMERIAN COMPLEX'	21-13
	BEESTONIAN	BAVELIAN	64-22
		MENAPIAN	
		WAALIAN	
		EBURONIAN	
1.806 Ma	PASTONIAN	TIGLIAN C5-6	
	PRE-PASTONIAN/ BAVENTIAN	TIGLIAN C4c	95-65
	ANTIAN/BRAMERTONIAN	TIGLIAN C1-4b	
	THURNIAN	TIGLIAN B	
	LUDHAMIAN	TIGLIAN A	
2.588 Ma	Pre-LUDHAMIAN/ WALTONIAN	PRAETIGLIAN	100-96
		REUVERIAN C	103

British Geological Survey Research Report RR/10/03 274

PLEISTOCENE		0.126Ma	IPSWICHIAN	EEMIAN	5e	POSITS SUPERGROUP
	MIDDLE	'IONIAN'	'WOLSTONIAN'	SAALIAN	10-6	
			HOXNIAN	HOLSTEINIAN	11	
			ANGLIAN	ELSTERIAN	12	
			'CROMERIAN COMPLEX'	'CROMERIAN COMPLEX'	21-13	
		0.781 Ma				
			BEESTONIAN	BAVELIAN	64-22	

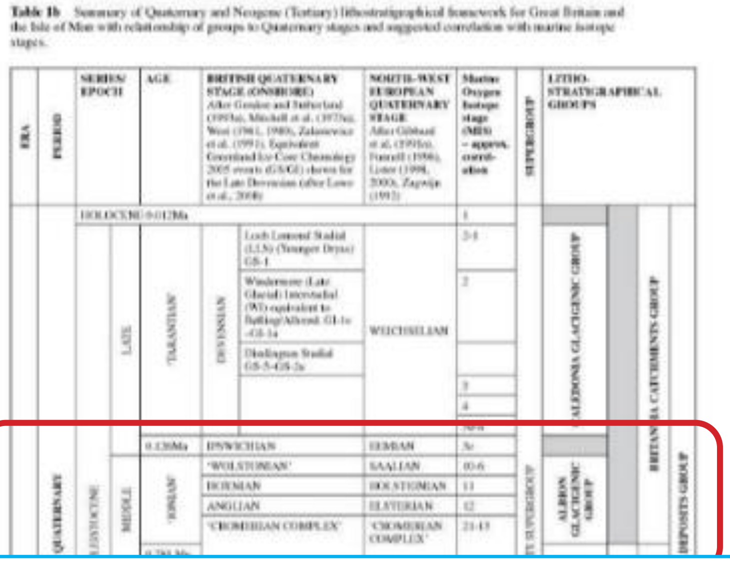
Mid-Pleistocene – 0.781Ma to 0.126Ma

Why does the addition of Mid-Pleistocene to Glacial Fluvial Deposits matter?

One answer is that there were several glaciations that resulted in a superficial soil group being categorised as **Undifferentiated Glacial Fluvial Deposits**

Extracts from BGS Research Report RR/10/03

Park Lane Cutting SL2N– Engineering Geology/Ground Water Risk Mid-Pleistocene



PLEISTOCENE		0.126Ma	IPSWICHIAN	EEMIAN	5e	SUPERGROUP
	MIDDLE	'IONIAN'	'WOLSTONIAN'	SAALIAN	10-6	
			HOXNIAN	HOLSTEINIAN	11	
			ANGLIAN	ELSTERIAN	12	
			'CROMERIAN COMPLEX'	'CROMERIAN COMPLEX'	21-13	
		0.781 Ma				

Glaciofluvial deposits, Mid Pleistocene

Computer Code:	GFDMP	**Preferred Map Code:**	notEntered
Status Code:	Index Level		
Age range:	Cromerian Stage (QC) — Ipswichian Stage (QI)		
Lithological Description:	See GFDU Glaciofluvial deposits. Sand and gravel. Cromerian to Oxygen Isotope Stage 6.		
Definition of Lower Boundary:	*none recorded or not applicable*		
Definition of Upper Boundary:	*none recorded or not applicable*		
Thickness:	*none recorded or not applicable*		
Geographical Limits:	*none recorded or not applicable*		
Parent Unit:	Glaciofluvial deposits (GFDU)		
Previous Name(s):	Glaciofluvial deposits, undifferentiated (Middle Pleistocene) [Obsolete Name and Code: Use GFDMP] (-925)		
Alternative Name(s):	*none recorded or not applicable*		

Park Lane Cutting – Engineering Geology/Ground Water Risk

Extract from BGS Onshore Index

Park Lane cutting HS2

Glacial Limits

- Devensian/Anglian glaciation boundary
- Glaciated/Non-Glaciated boundary

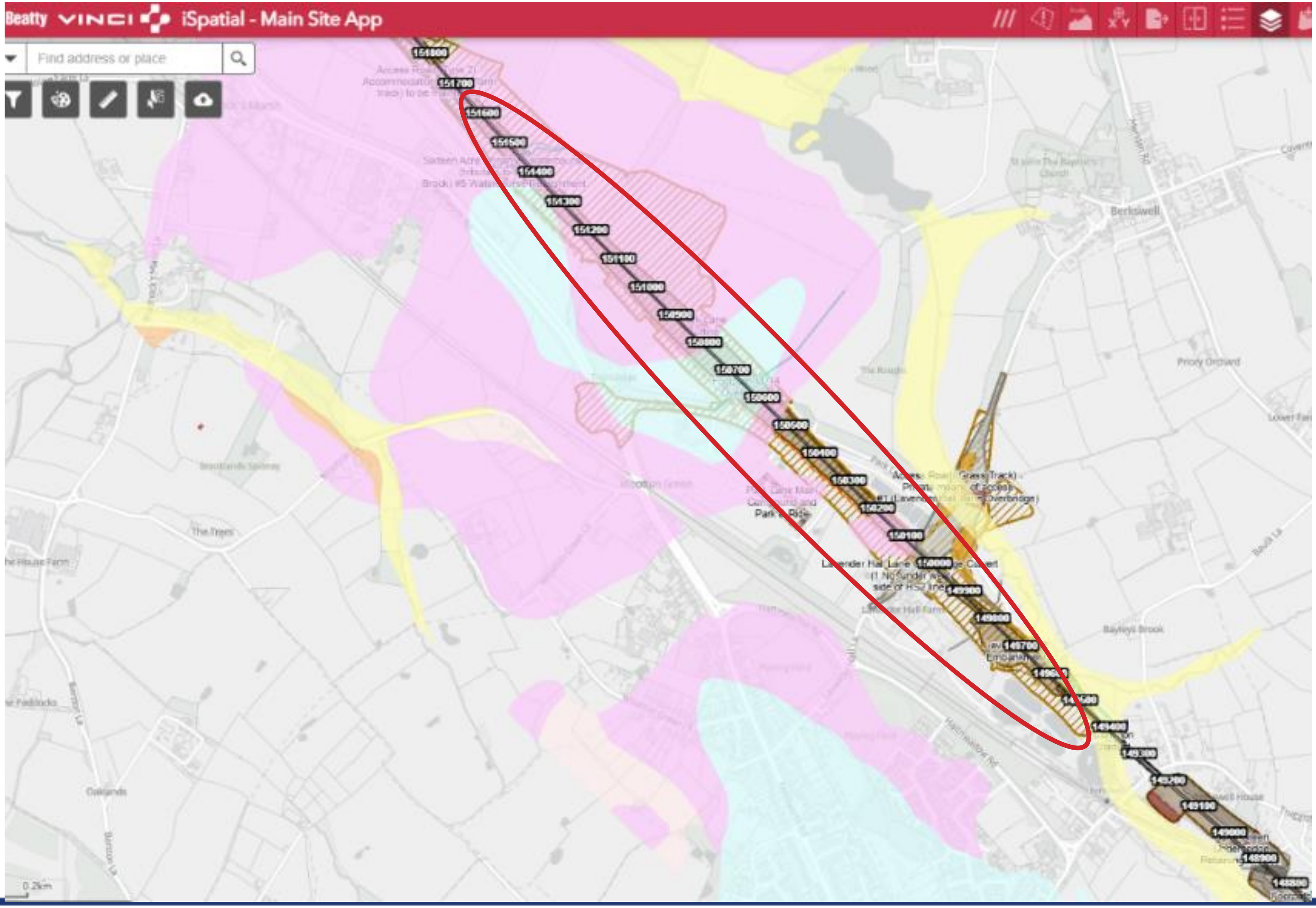
Superficial deposits 1:50,000 scale

- GLACIOFLUVIAL DEPOSITS, MID PLEISTOCENE - SAND AND GRAVEL
- GLACIOFLUVIAL TERRACE DEPOSITS, MID PLEISTOCENE - SAND AND GRAVEL
- BAGINTON SAND AND GRAVEL FORMATION - SAND AND GRAVEL
- TILL, MID PLEISTOCENE - DIAMICTON
- THRUSSINGTON MEMBER - DIAMICTON
- OADBY MEMBER - DIAMICTON
- GLACIOLACUSTRINE DEPOSITS, MID PLEISTOCENE - CLAY AND SILT
- ALLUVIUM - CLAY, SILT, SAND AND GRAVEL
- HEAD - CLAY, SILT, SAND AND GRAVEL
- RIVER TERRACE DEPOSITS, 1 - SAND AND GRAVEL
- RIVER TERRACE DEPOSITS, 2 - SAND AND GRAVEL

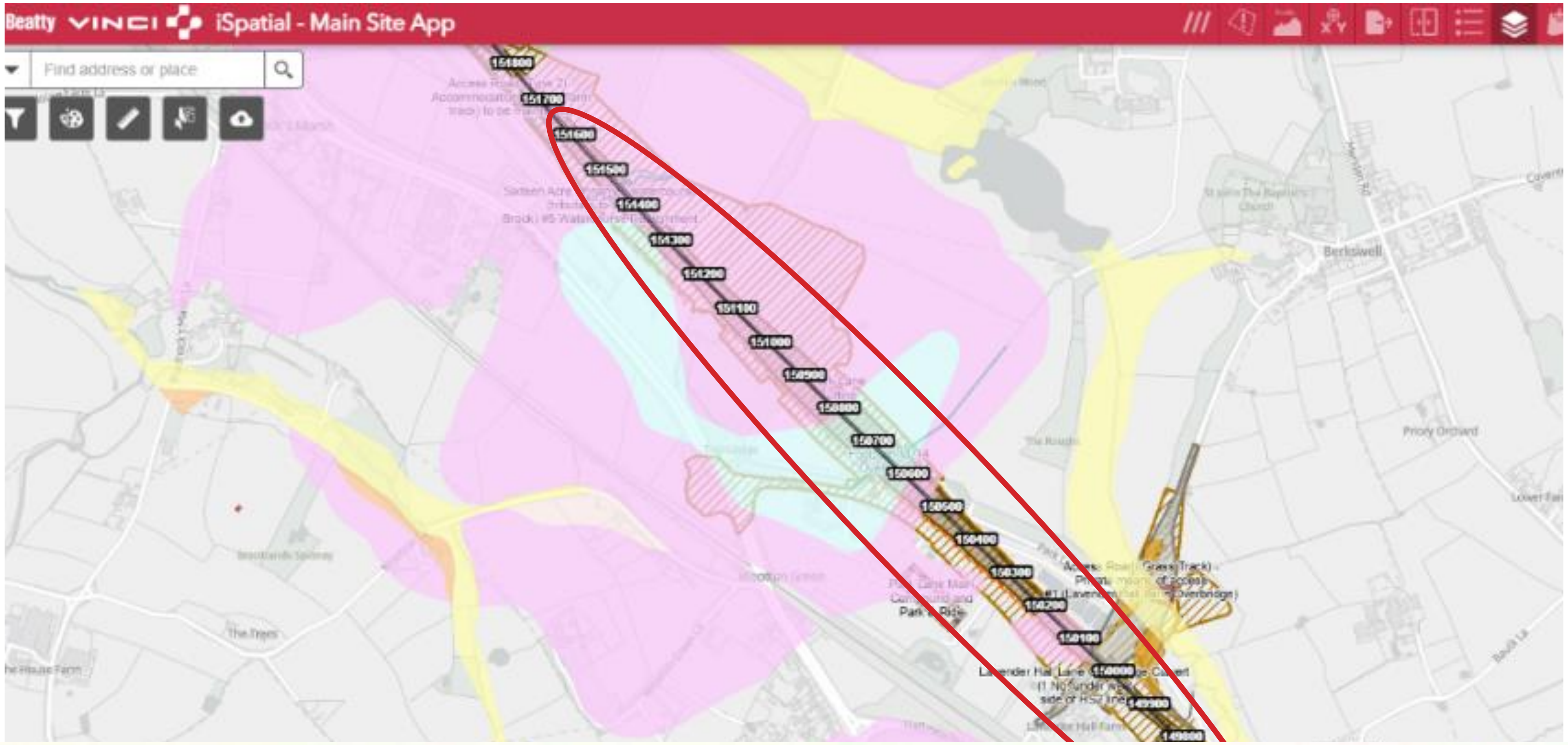
Park Lane Cutting – Engineering Geology/Ground Water Risk

Extract from Ispatial with 1 to 10,000

Superficial geology



Park Lane Cutting – Engineering Geology/Ground Water Risk



Extract from Ispatial with 1 to 10,000

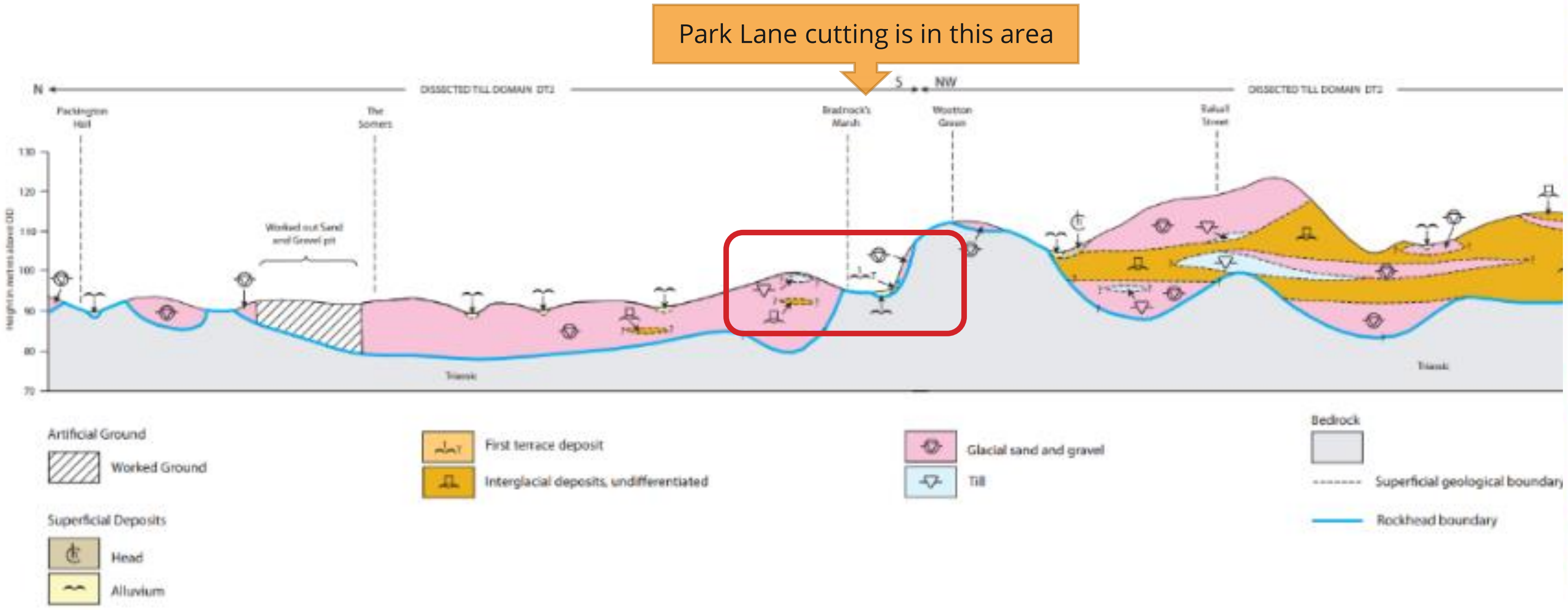
Superficial geology

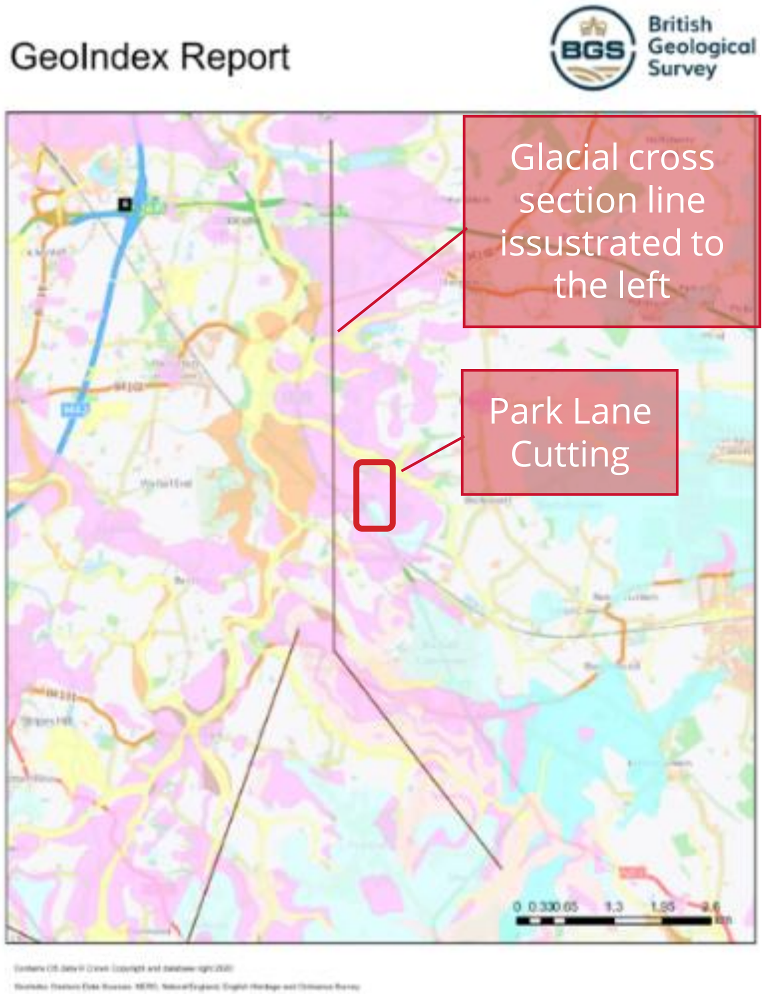
Your use of any information provided by the British Geological Survey (BGS) is at your own risk. Neither BGS nor the Natural Environment Research Council gives any warranty, condition or representation as to the quality, accuracy or completeness of the information or its suitability for any use or purpose. All implied conditions relating to the quality or suitability of the information, and all liabilities arising from the supply of the information (including any liability arising in negligence) are excluded to the fullest extent permitted by law.

Park Lane Cutting SL2N– Engineering Geology/Ground Water Risk
Mid-Pleistocene – Glacial Fluvial - Undifferentiated (?)

BGS cross section illustrates that the Glacial Sand and Gravel may contain Interglacial Deposits – Undifferentiated; and Glacial Till.

Interglacial deposits may include Head deposits. Both the Glacial Till and Head deposits may have been subject to cryoturbation.

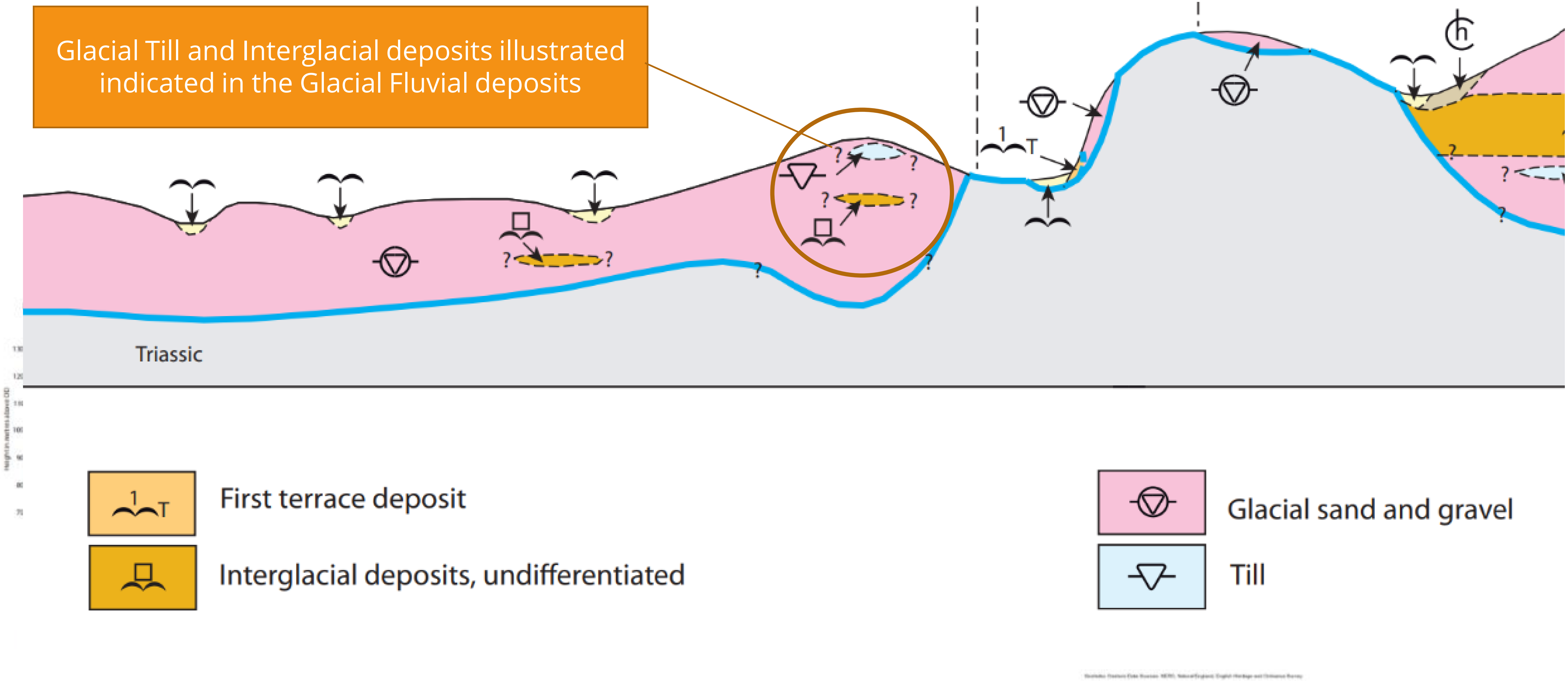




Extracts from BGS Onshore Index, Lexicon and Geology of the Birmingham area: Memoir for 1:50 000 Geological Sheet 168 (England and Wales)

Park Lane Cutting SL2N– Engineering Geology/Ground Water Risk
Mid-Pleistocene – Glacial Fluvial - Undifferentiated (?)

Glacial Till and Interglacial deposits illustrated indicated in the Glacial Fluvial deposits



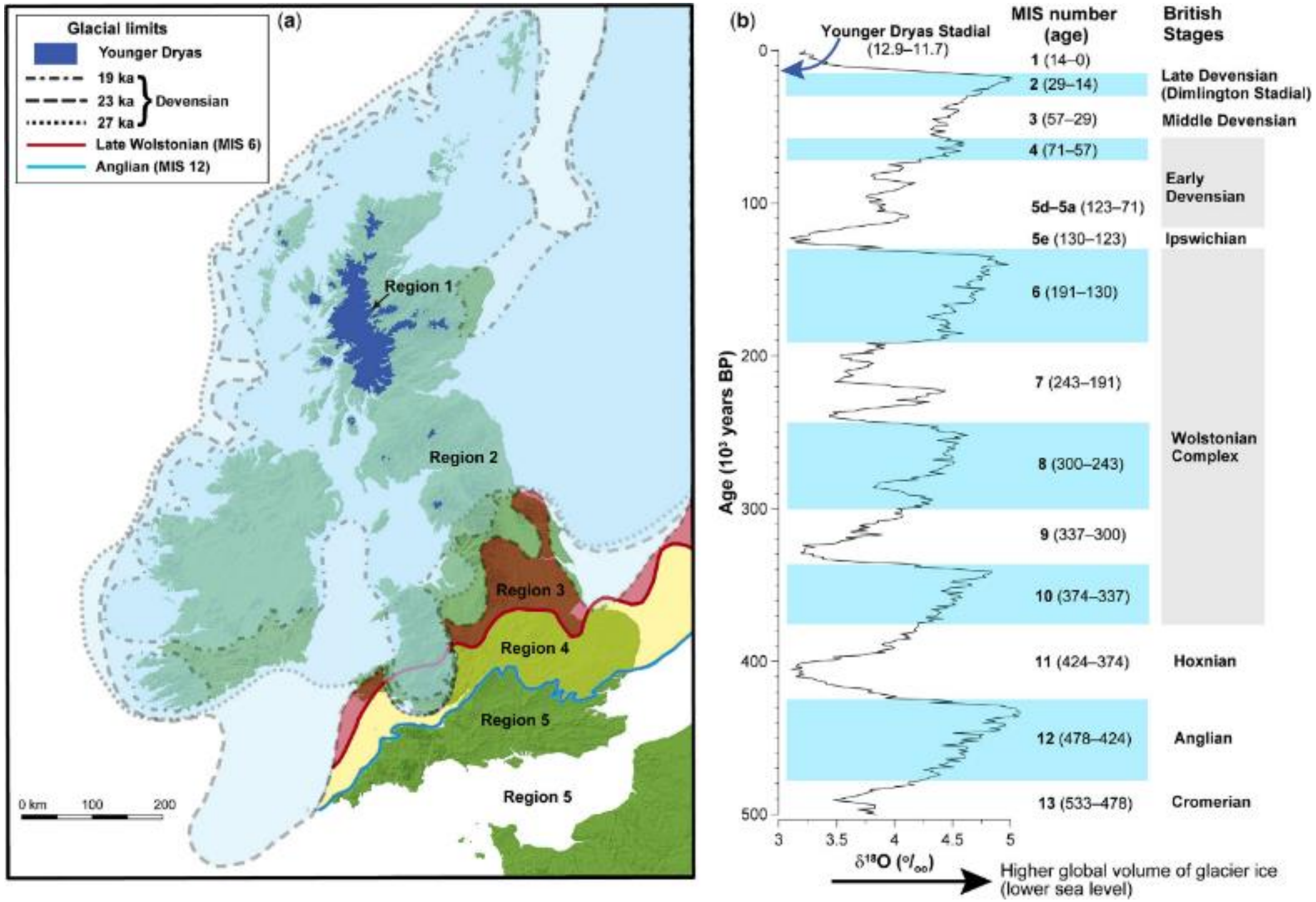
3 – Geology

3d - Geohazards

Periglacial regions of the UK and Ireland superimposed on a digital elevation model

Region 4 (yellow and olive green) experienced periglaciation during Anglian deglaciation and during the Wolstonian and Devensian

MURTON, J.B. & BALLANTYNE, C.K. 2017



Periglacial Geo Hazards

Aerial photographs can highlight the origin of glacial soils.

It's important to consider whether the soil deposition is from

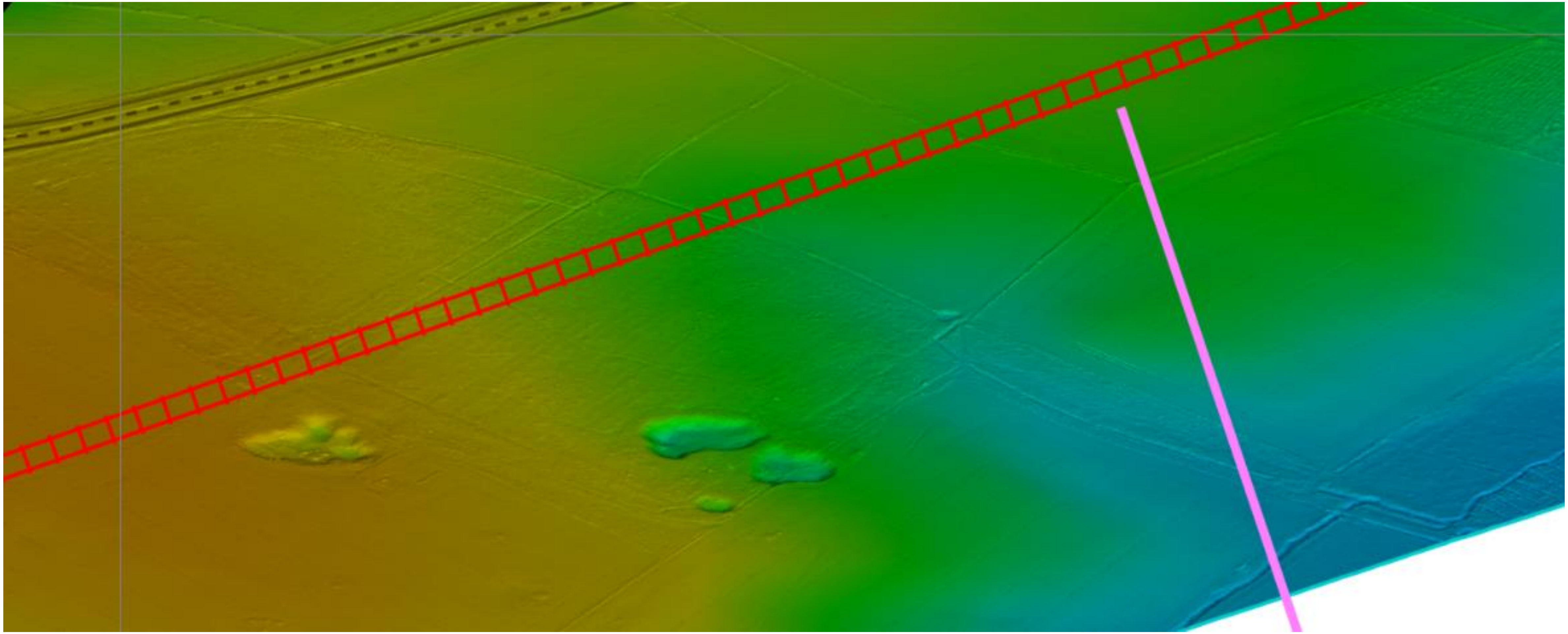
- Ice deposition
- Melt water
- Periglacial action

Image from Giles and Griffiths Geological Hazards of the UK, 2020

.6. Active-layer detachment slides (previously described as solifluction lobes) in Cretaceous Lower Greensand Formation, adjacent to the Sevenoaks Bypass, Kent. © Google Earth Pro, Getmapping PLC 2012.

Periglacial geo hazards –

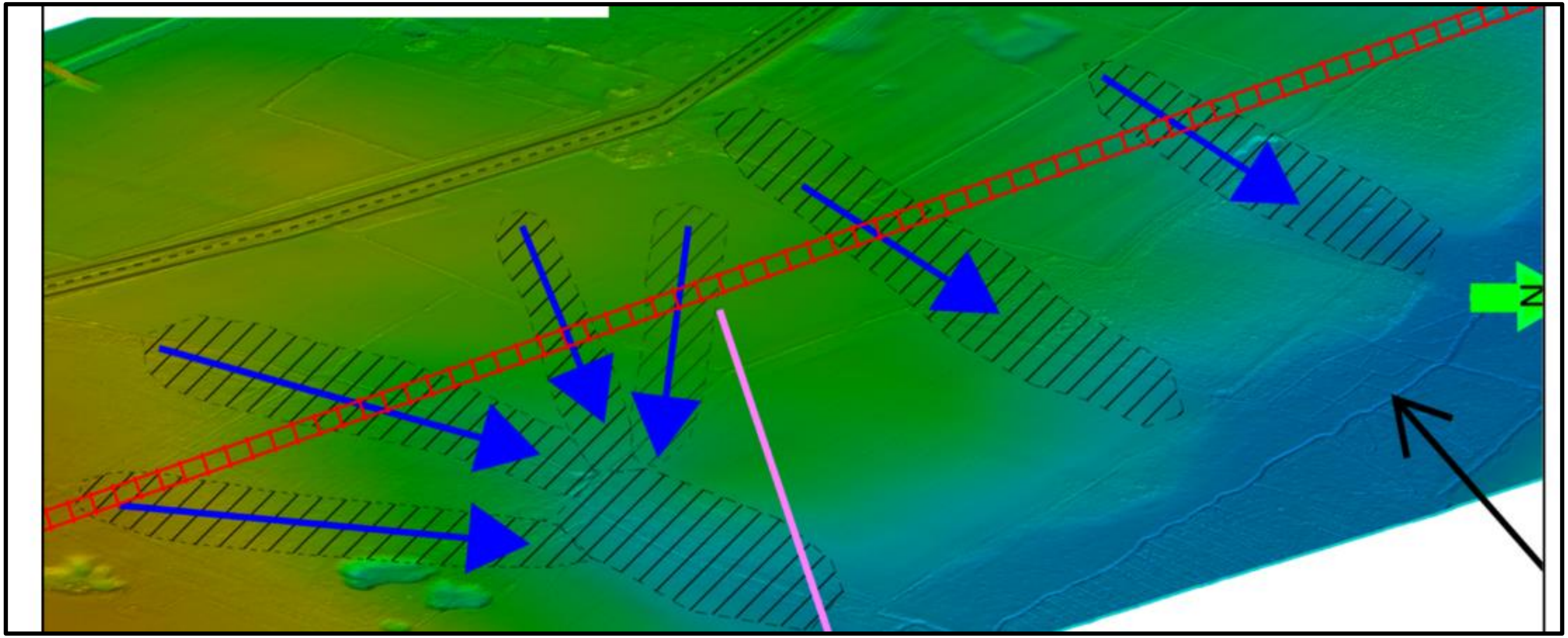
Solifluction lobes are absent from DTM, but gullies are present



Periglacial geo hazards –

Solifluction lobes are absent from DTM, but gullies are present

– Potential for active layer slip deposits in the gullies (Head deposits?)



Periglacial geo hazards –
Patterned ground absent from DTM and aerial photographs

Google Earth image (A452 in bottom left of image)

Polygonal patterned ground reflecting the presence of fossil ice wedge casts beneath the field

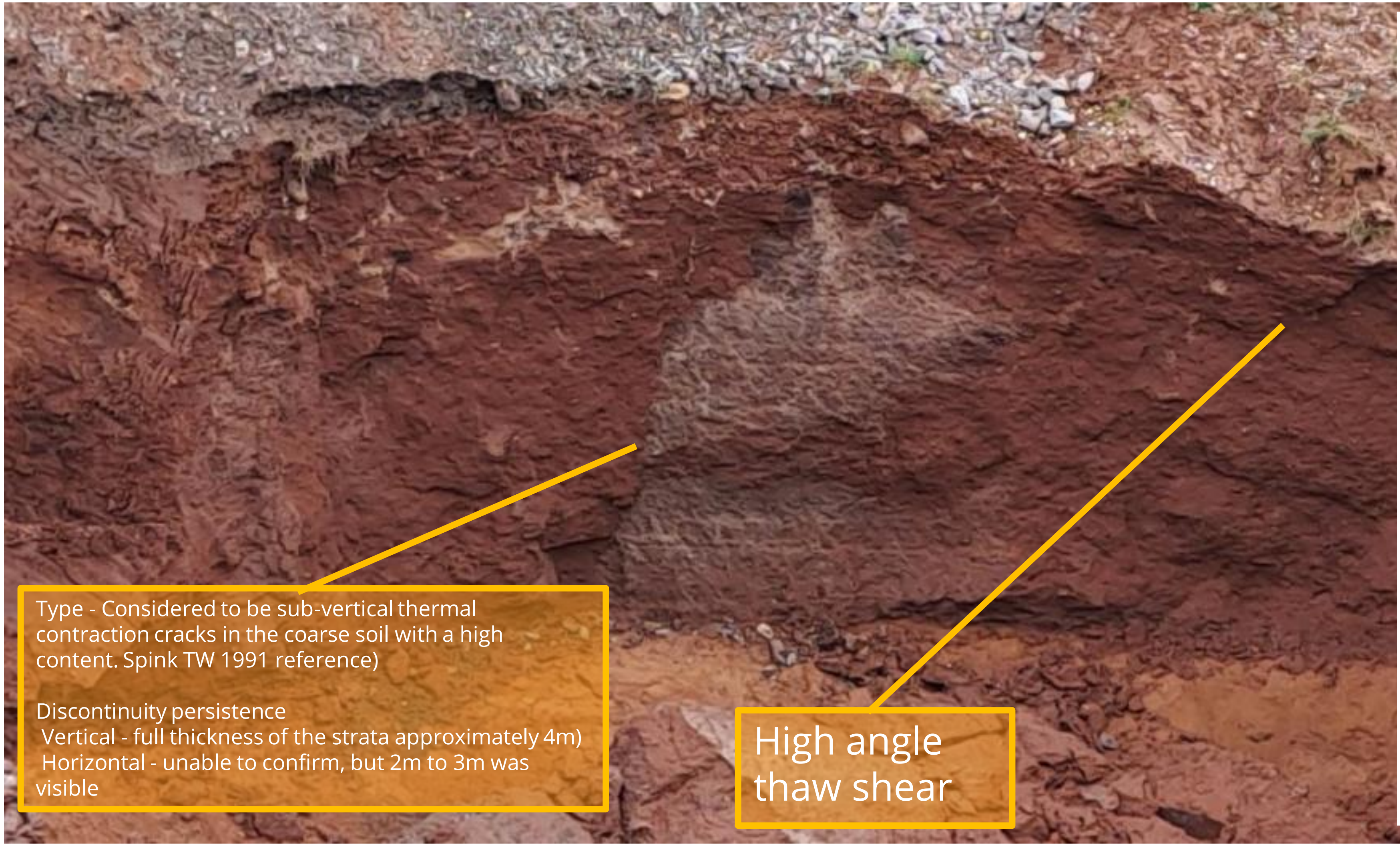
Engineering problems caused by fossil permafrost features in the English Midlands – Morgan 1971

Periglacial geo hazards

Excavation in Park Lane cutting – Periglacial discontinuities observed, but no fossilised ice wedges

Periglacial geo hazards –

Excavation in Park Lane cutting – Periglacial discontinuities observed, but no fossilised ice wedges



Type - Considered to be sub-vertical thermal contraction cracks in the coarse soil with a high content. Spink TW 1991 reference)

Discontinuity persistence
Vertical - full thickness of the strata approximately 4m)
Horizontal - unable to confirm, but 2m to 3m was visible

High angle thaw shear

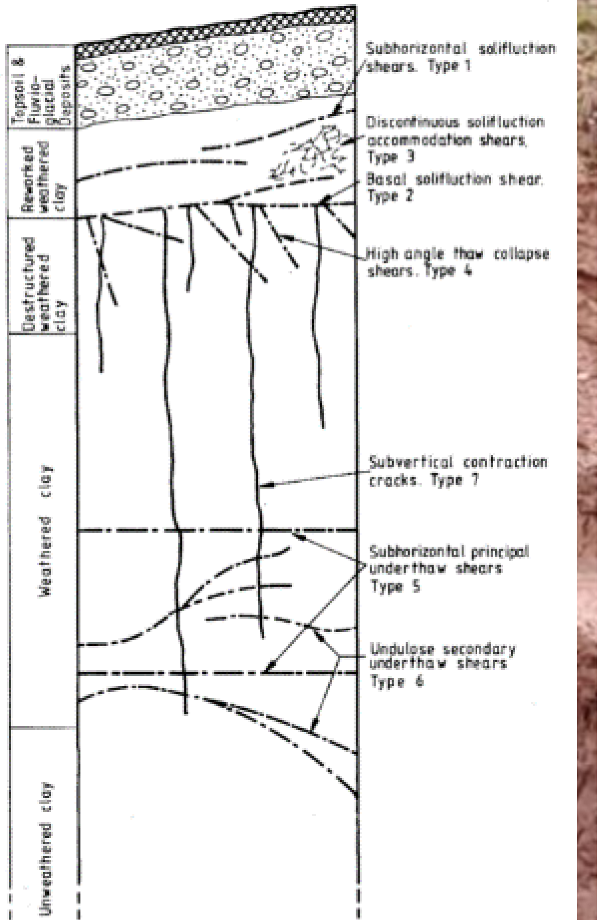


Fig. 2 Schematic profile through weathered Eocene clay illustrating periglacial discontinuity forms

Extract from above from: Spink TW (1991) Periglacial discontinuities in Eocene clays near Denham, Buckinghamshire. Engineering Geology Special Publications, v. 7, p. 389-396.

Periglacial geo hazards –

Excavation in Park Lane cutting – Periglacial discontinuities observed, but no fossilised ice wedges

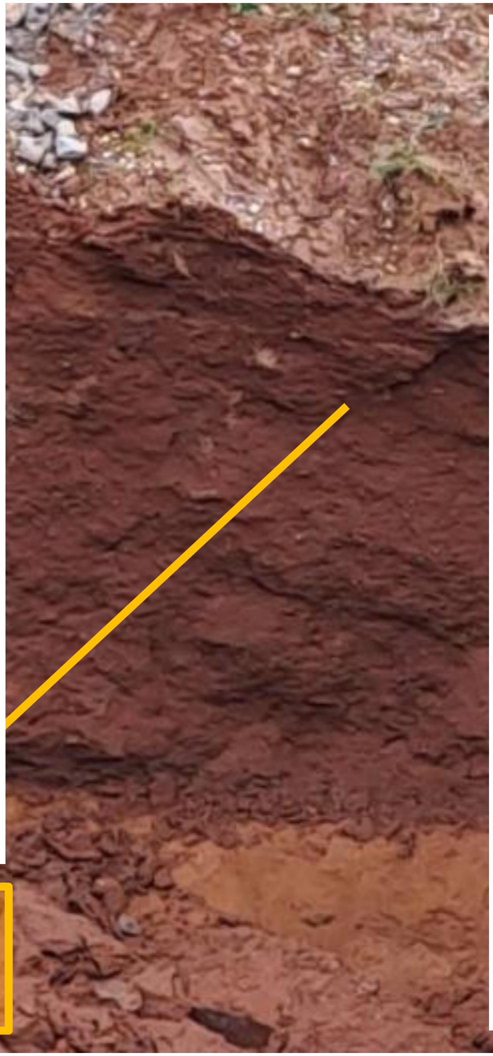
AS AFFECTING ENGINEERING STRUCTURES

Inside and outside the Arctic, active, present-day frost heave is probably the process most troublesome to Russian, northern European and North American engineers, producing differential heave and differential settlement of road and airfield pavements, railway tracks, pipelines and other shallow-founded structures. The pioneer work on these problems was carried out by Beskow (1935), who established both their nature and suitable counter-measures. These, and other engineering problems in frozen ground, were comprehensively reviewed by Corte (1969). In general, silts are particularly prone to frost heaving, as they have the optimum balance between suction potential at the freezing front (related inversely to grain size) and permeability (related directly to grain size), but many other soil types are affected. Considerable efforts have been directed towards the definition of criteria for susceptibility to frost heaving, generally based on particle size (Jones 1980, Johnston 1981), but completely satisfactory criteria have yet to

Extract (left) from:

Hutchinson JN (1991) Periglacial and Slope Processes Quaternary Engineering Geology, Geological Society Engineering Geology Special Publication No 7, lap 283-331

This paper highlights how soils with a high silt content are susceptible to heave in periglacial time periods.



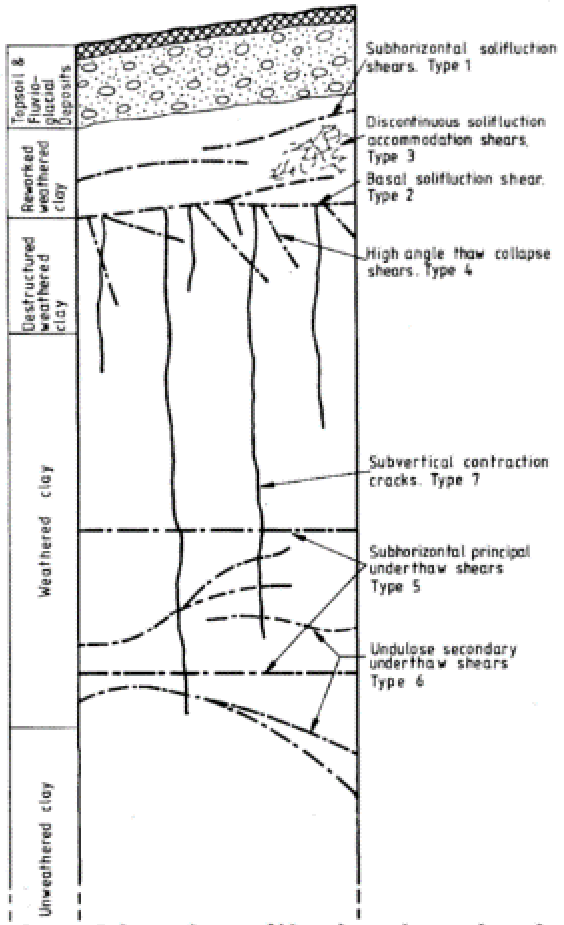


Fig. 2 Schematic profile through weathered Eocene clay illustrating periglacial discontinuity forms

Discontinuity persistence
Vertical - full thickness of the strata approximately 4m)
Horizontal - unable to confirm, but 2m to 3m was visible

Extract from above from: Spink TW (1991) Periglacial discontinuities in Eocene clays near Denham, Buckinghamshire. Engineering Geology Special Publications, v. 7, p. 389-396.

Periglacial geo hazards –

Excavation in Park Lane cutting – Periglacial discontinuities observed, but no fossilised ice wedges

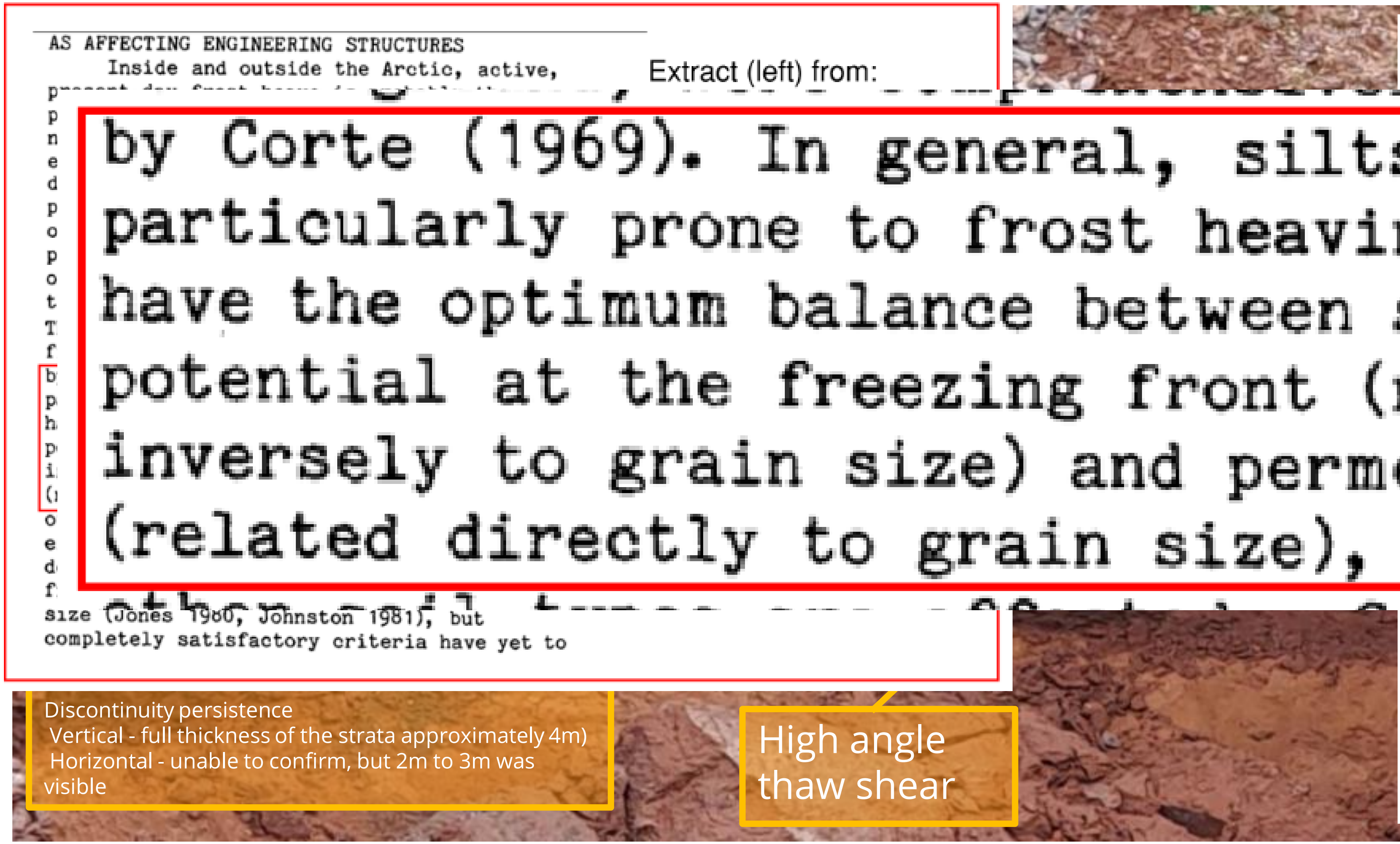
AS AFFECTING ENGINEERING STRUCTURES

Inside and outside the Arctic, active,

Extract (left) from:

by Corte (1969). In general, silts are particularly prone to frost heaving, as they have the optimum balance between suction potential at the freezing front (related inversely to grain size) and permeability (related directly to grain size), but many

size (Jones 1980, Johnston 1981), but completely satisfactory criteria have yet to



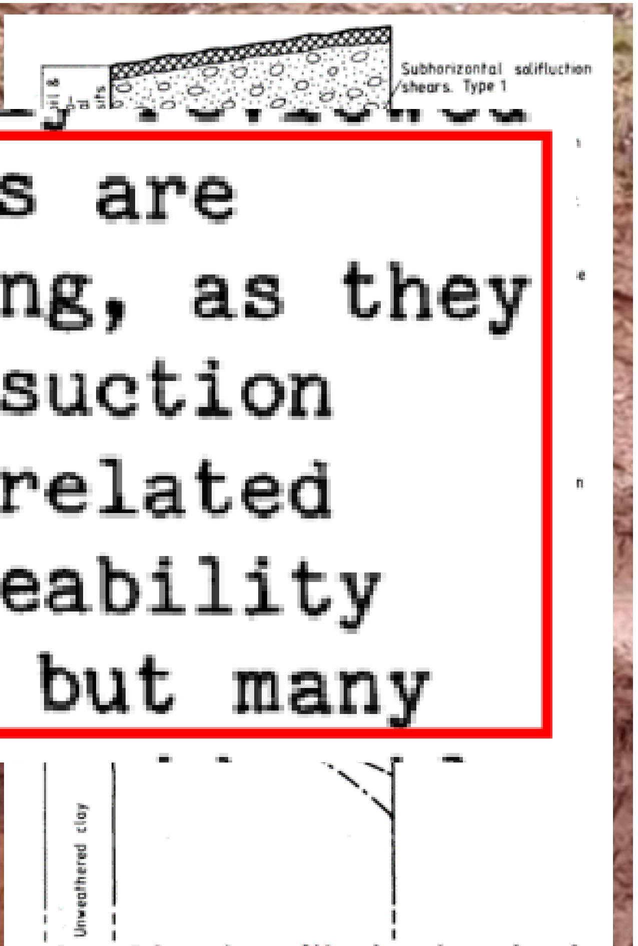
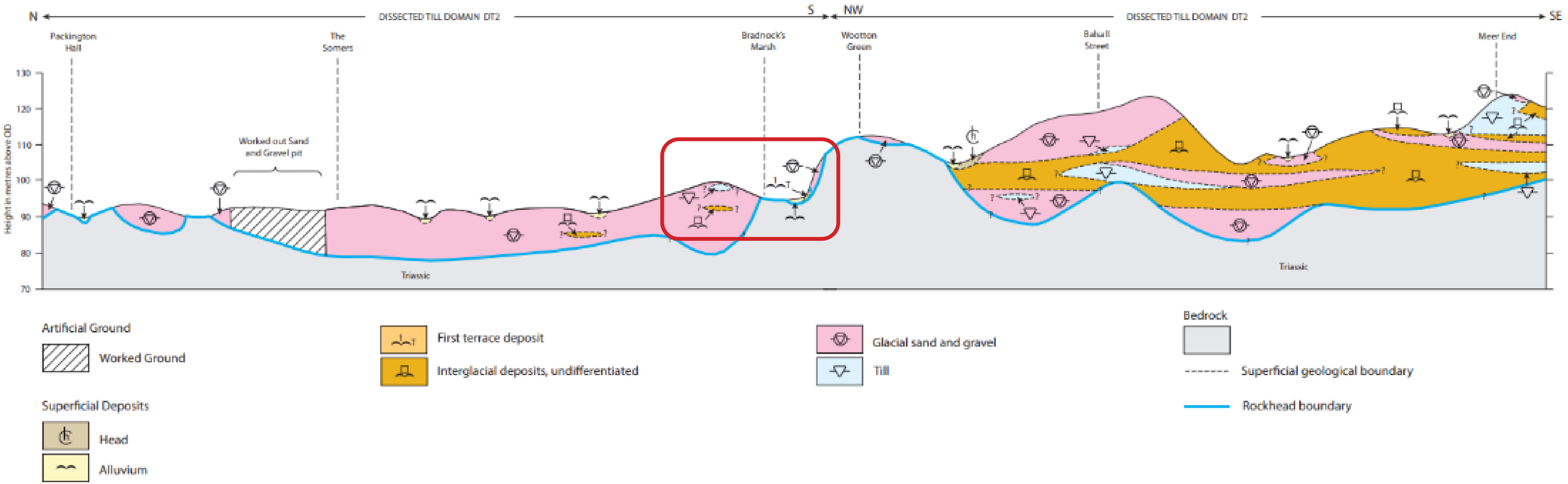


Fig. 2 Schematic profile through weathered Eocene clay illustrating periglacial discontinuity forms

Extract from above from: Spink TW (1991) Periglacial discontinuities in Eocene clays near Denham, Buckinghamshire. Engineering Geology Special Publications, v. 7, p. 389-396.

4- Ground Model - Park Lane Cutting

Park Lane Cutting SL2N– Engineering Geology/Ground Water Risk
Mid-Pleistocene – Glacial Fluvial



Extracts from BGS Onshore Index Glacial Cross Section

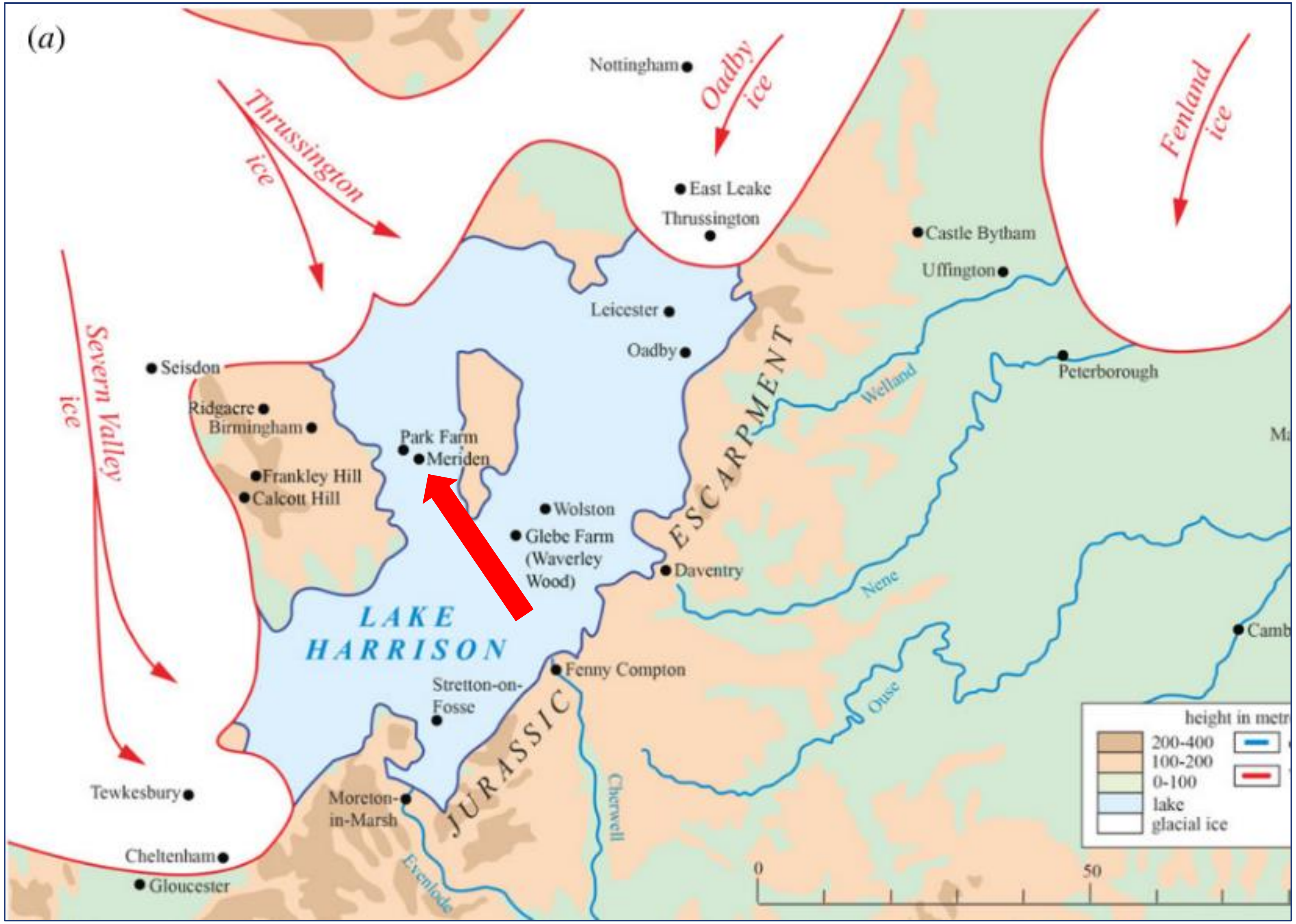
Park Lane Cutting Mid-Pleistocene Glacial Formation Correlations

The age and glacial strata correlations in the following slides has been inferred from the ***2022 paper by Gibson et al Timing and dynamics of Late Wolstonian Substage 'Moreton Stadial' (MIS 6) glaciation in the English West Midlands***

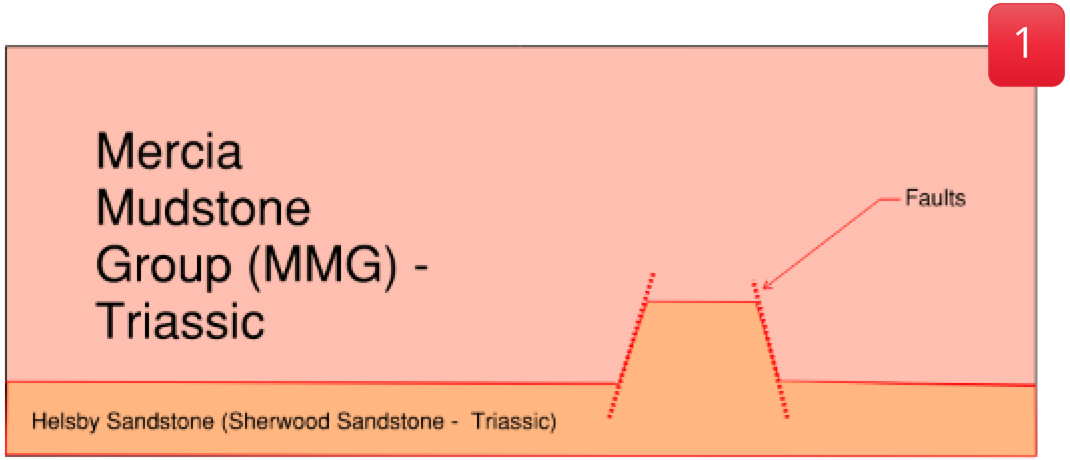
The elevation and descriptions of the strata from the Meriden site (discussed in the Gibson paper)

Gibson dated the glacial sediments using a luminescence technique

The image is an extract form the Gibson et al 2022 paper

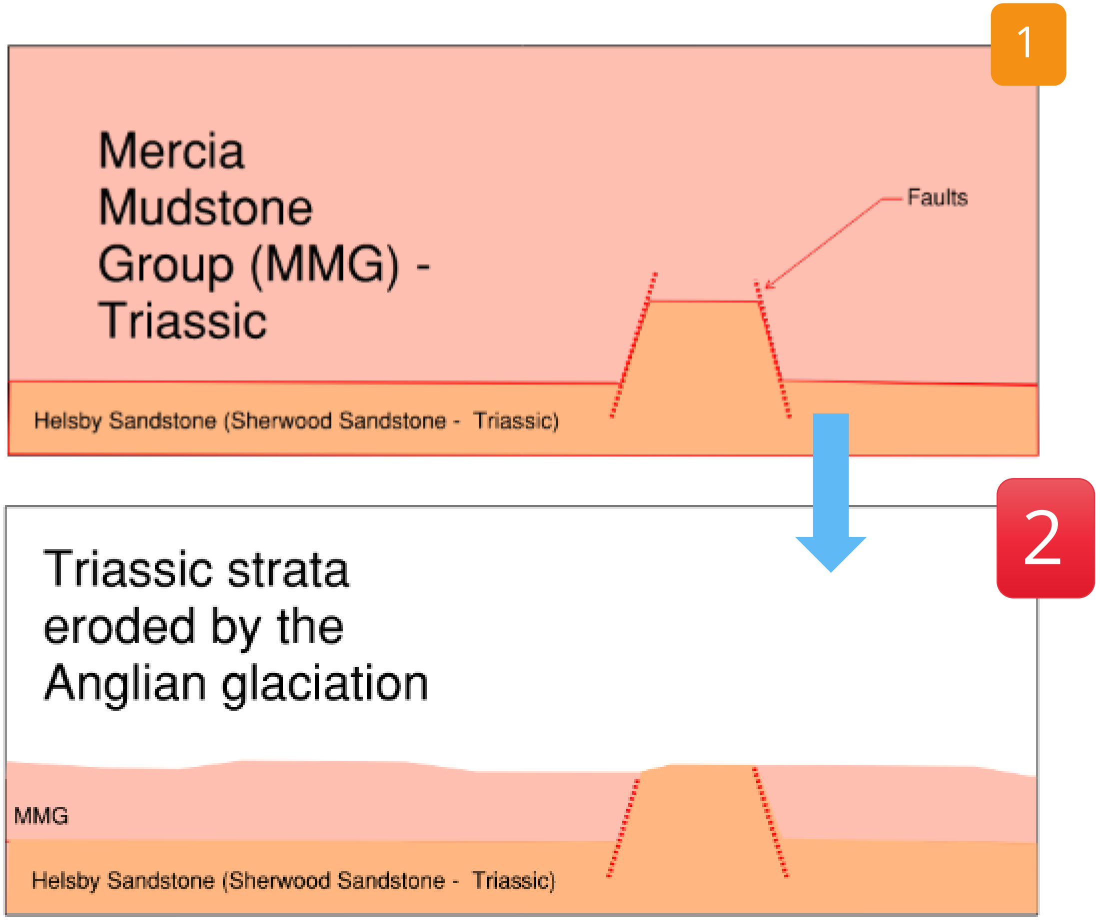


Ground Model Development- Park Lane Cutting



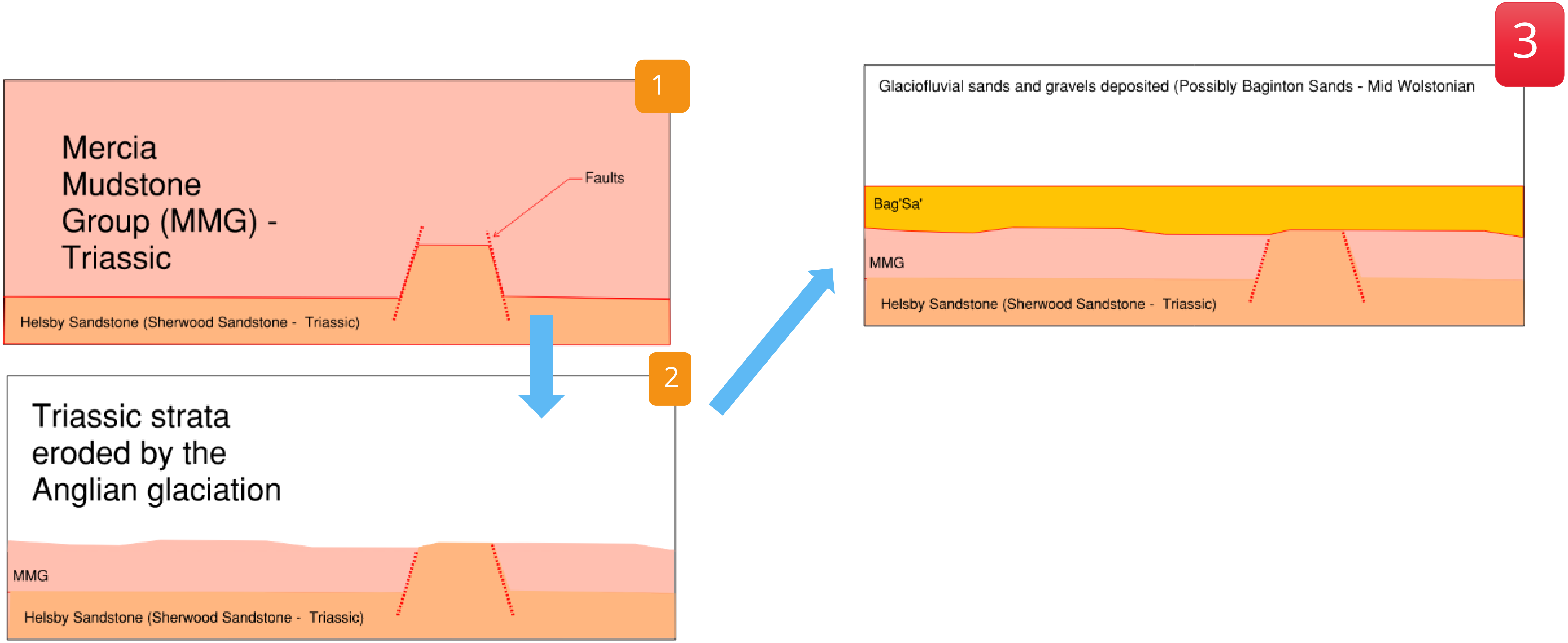
1. Sherwood Sandstone deposited in a fluvial environment
2. Depositional environment changes and the Merica Mudstone strata are deposited in flood sheet deposits
3. Faulting occurs

Ground Model Development- Park Lane Cutting

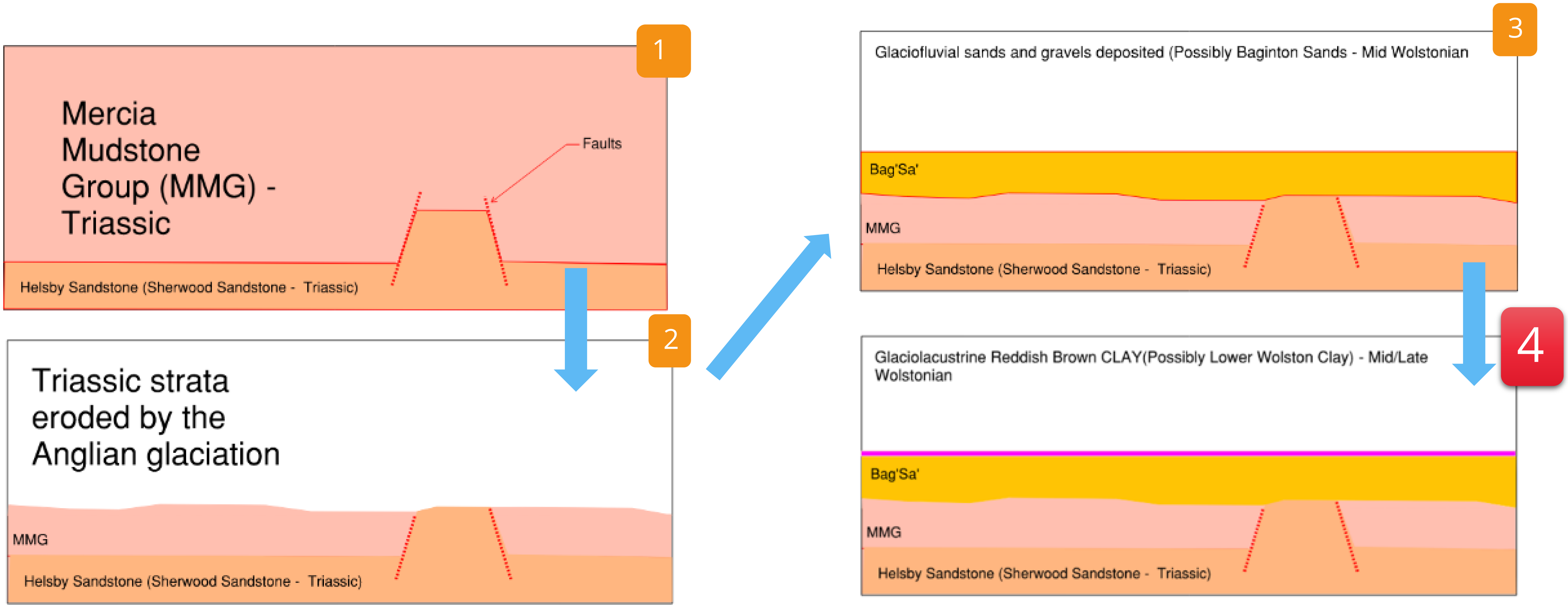


1. Sherwood Sandstone deposited in a fluvial environment
2. Depositional environment changes and the Merica Mudstone strata are deposited in flood sheet deposits
3. Faulting occurs
4. Surface of MMG is eroded including fluvial channels in the Anglian glaciation

Ground Model Development- Park Lane Cutting



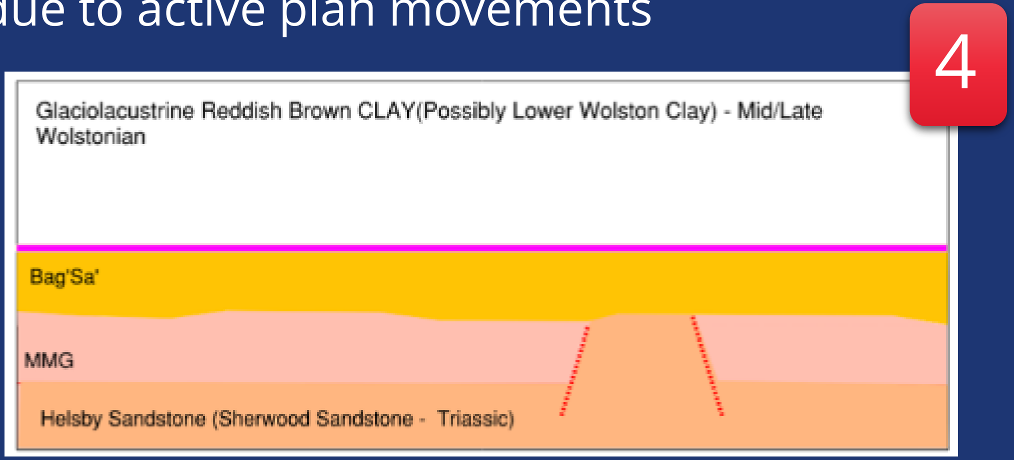
Ground Model Development- Park Lane Cutting



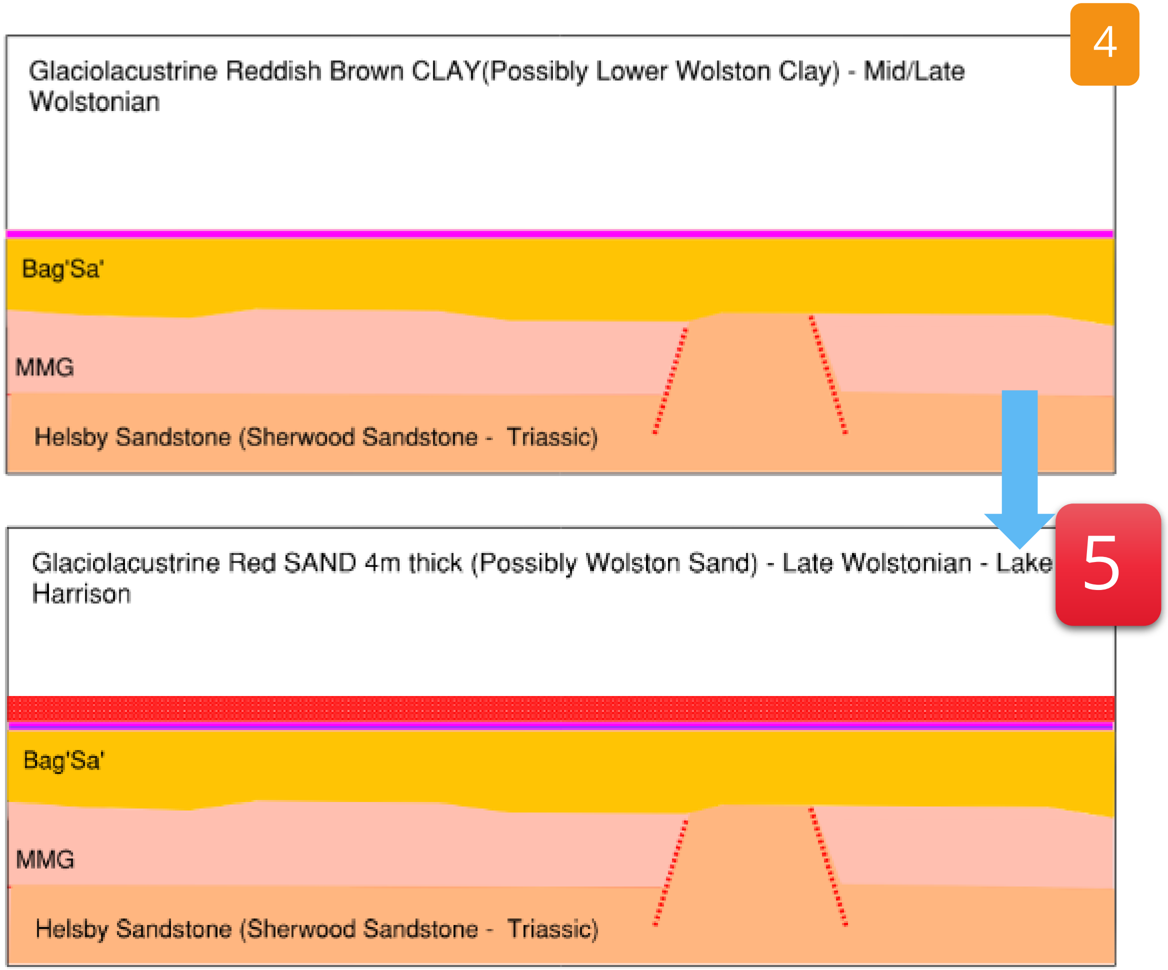
Ground Model Development- Park Lane Cutting

Photograph to the right captures the boundary between the Wolston Clay (?) and the Baginton Sand (?).
Perched water above the MMG within the Baginton Sand (?) is present in the photograph.

Photograph was taken at a distance during a trial excavation. It was not possible to get closer due to active plan movements



Ground Model Development- Park Lane Cutting



Ground Model Development- Park Lane Cutting

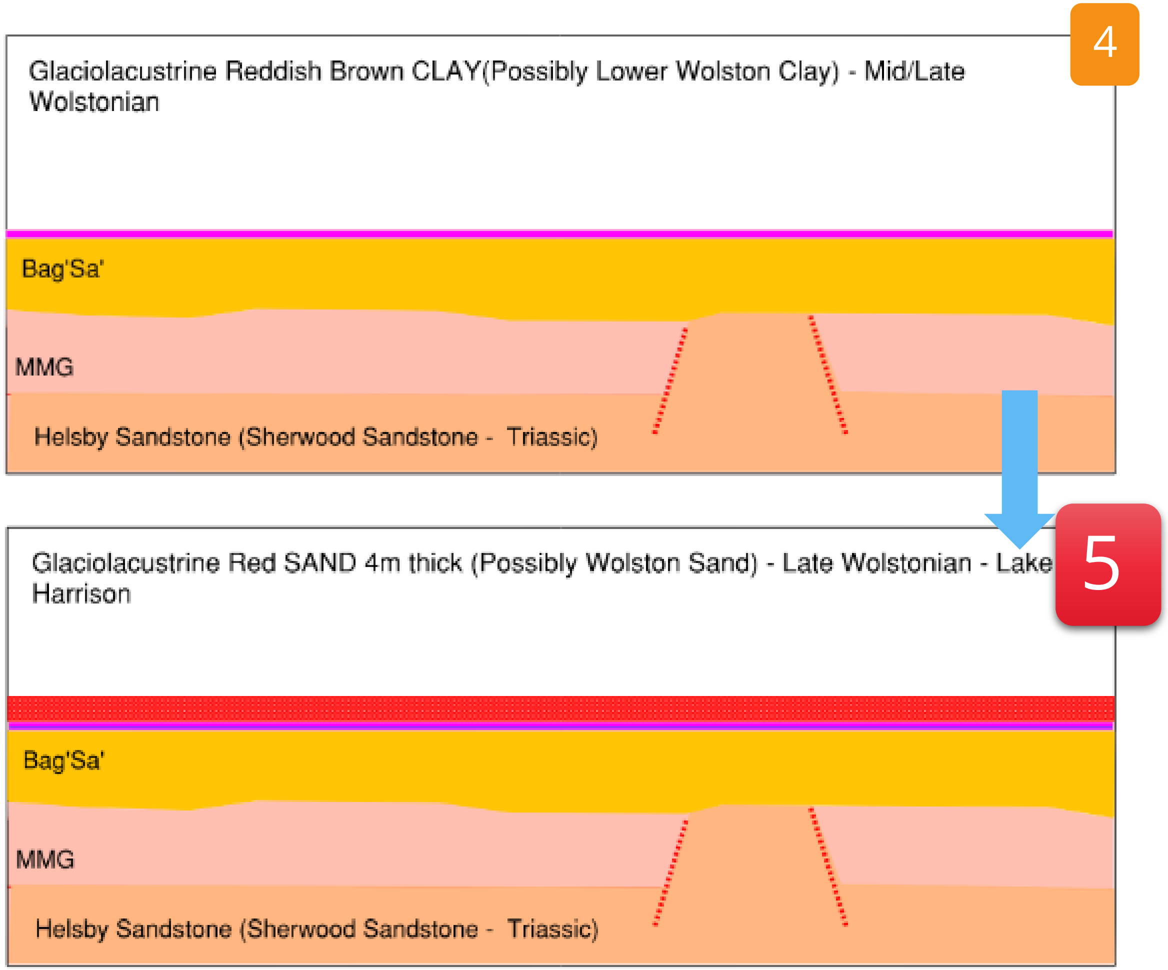
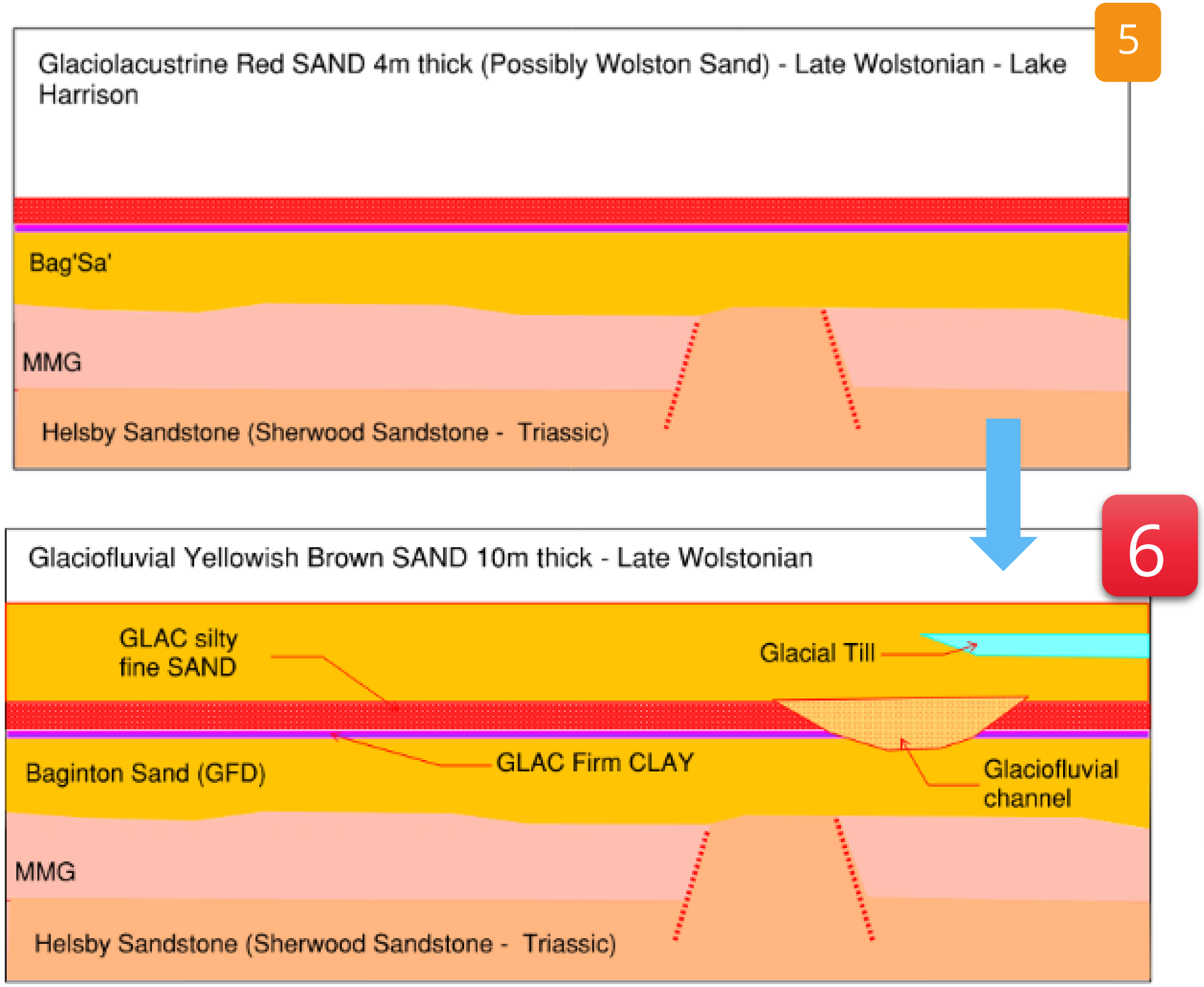


Image - Trial pit in Park Lane Cutting

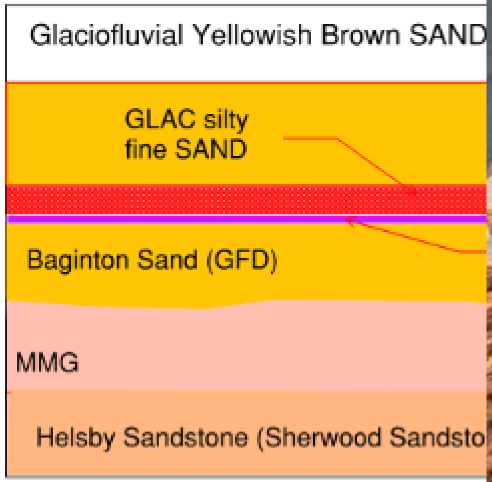
Ground Model Development- Park Lane Cutting



There is a high probability that the Mercia Mudstone Group is the origin of the Lower Wolston Clay; and the Sherwood Sandstone is the origin of the Wolston Sand.

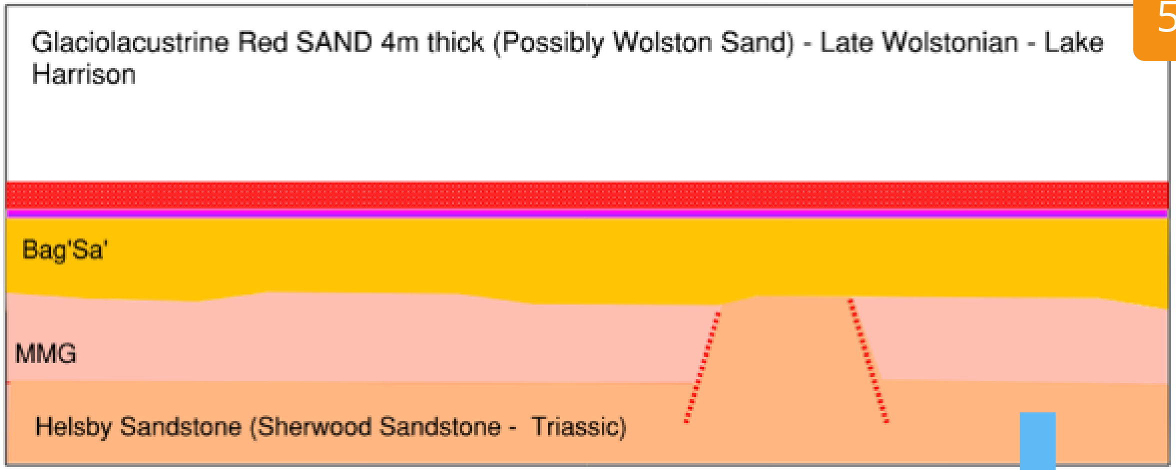
Both glacial deposits have experienced short journeys from erosion to deposit. It could also be said they have not been reworked again and cleaned like the other glacial fluvial deposits

Ground Model Development- Park Lane Cutting

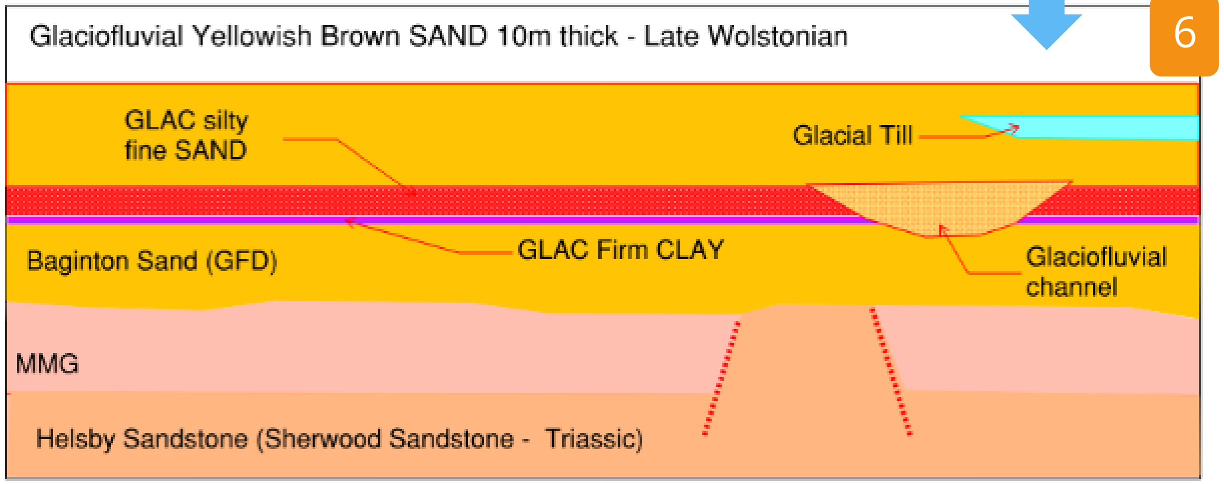


Ground Model Development- Park Lane Cutting

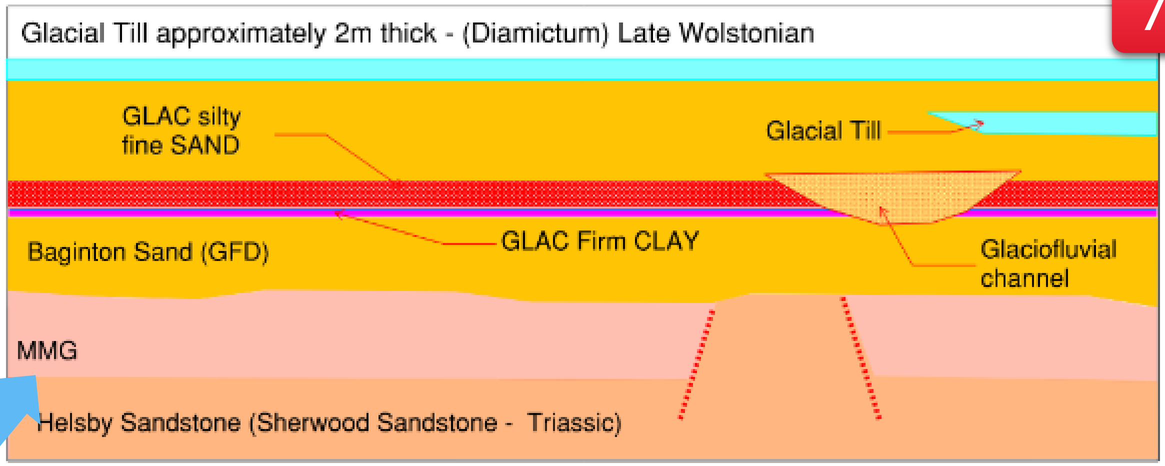
5



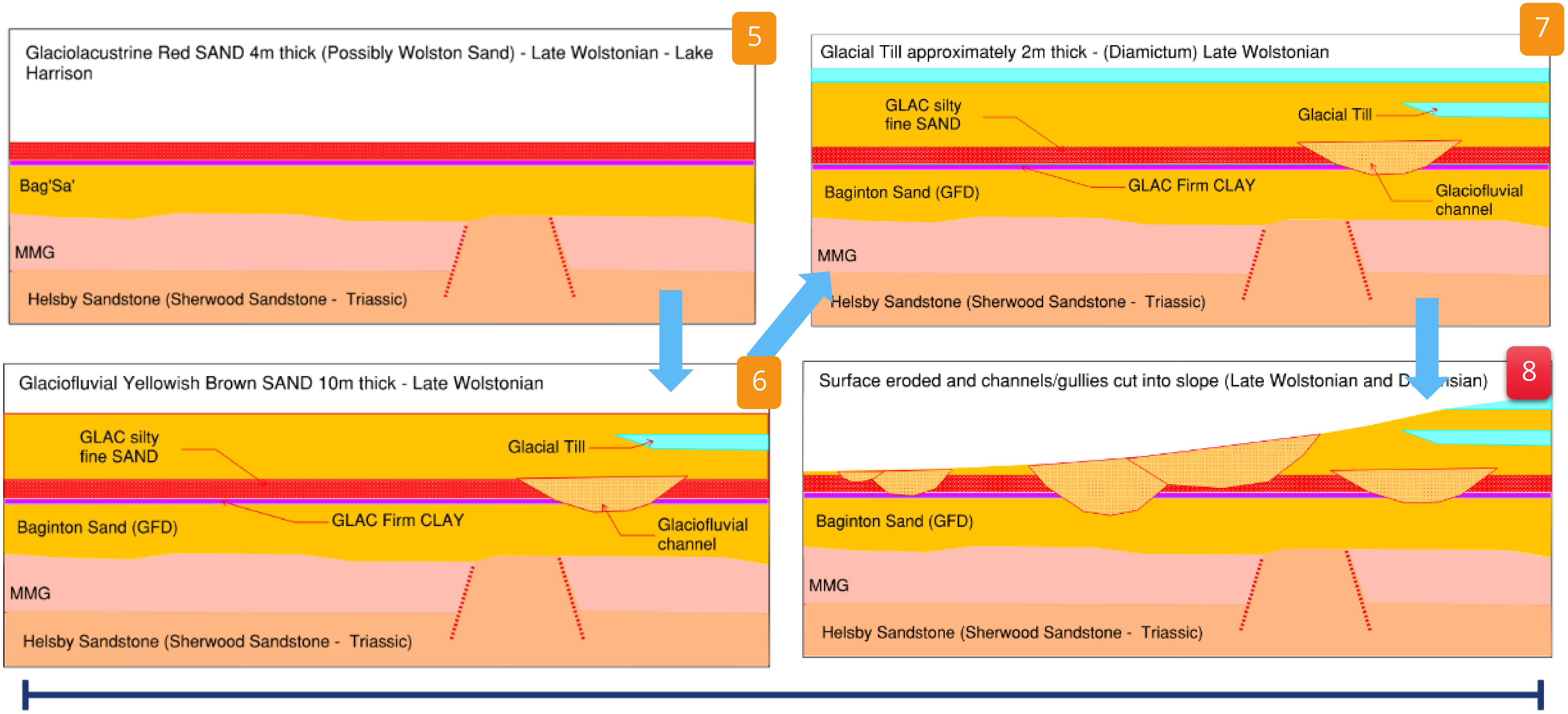
6



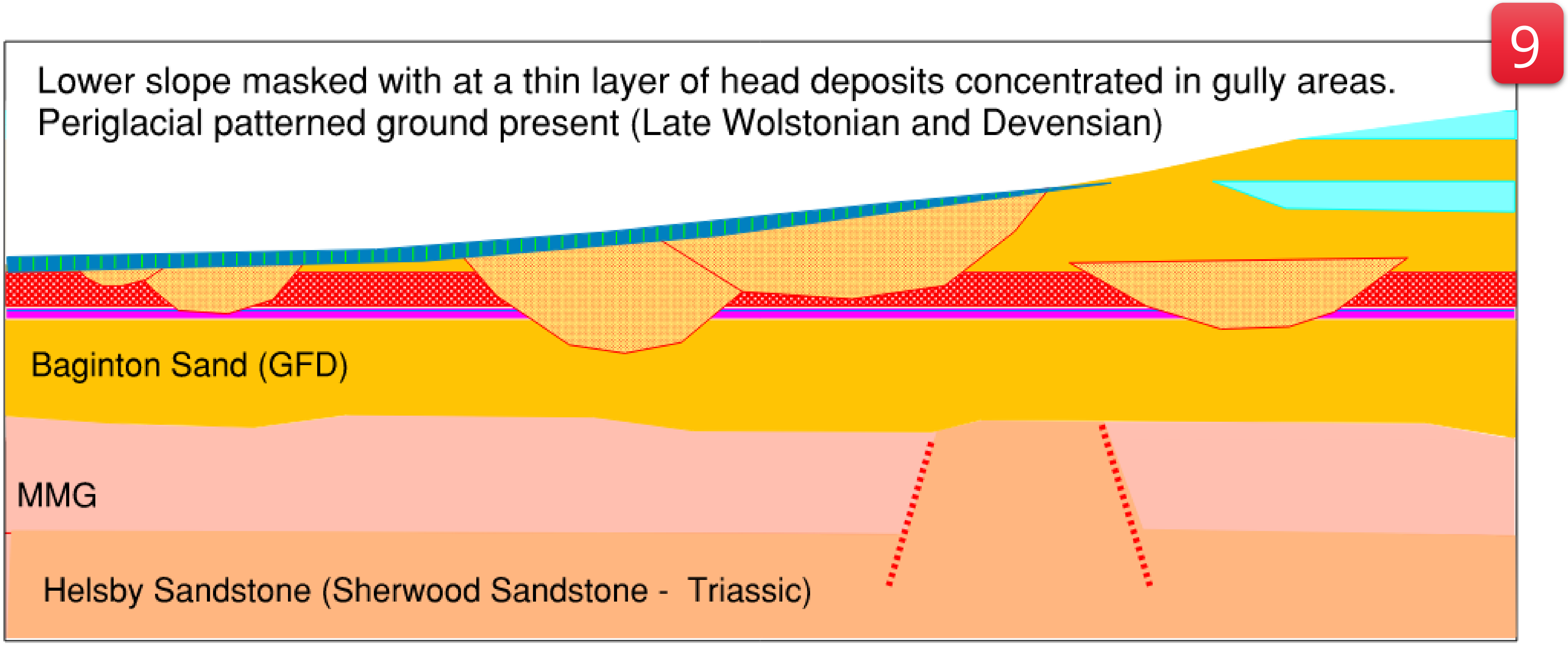
7



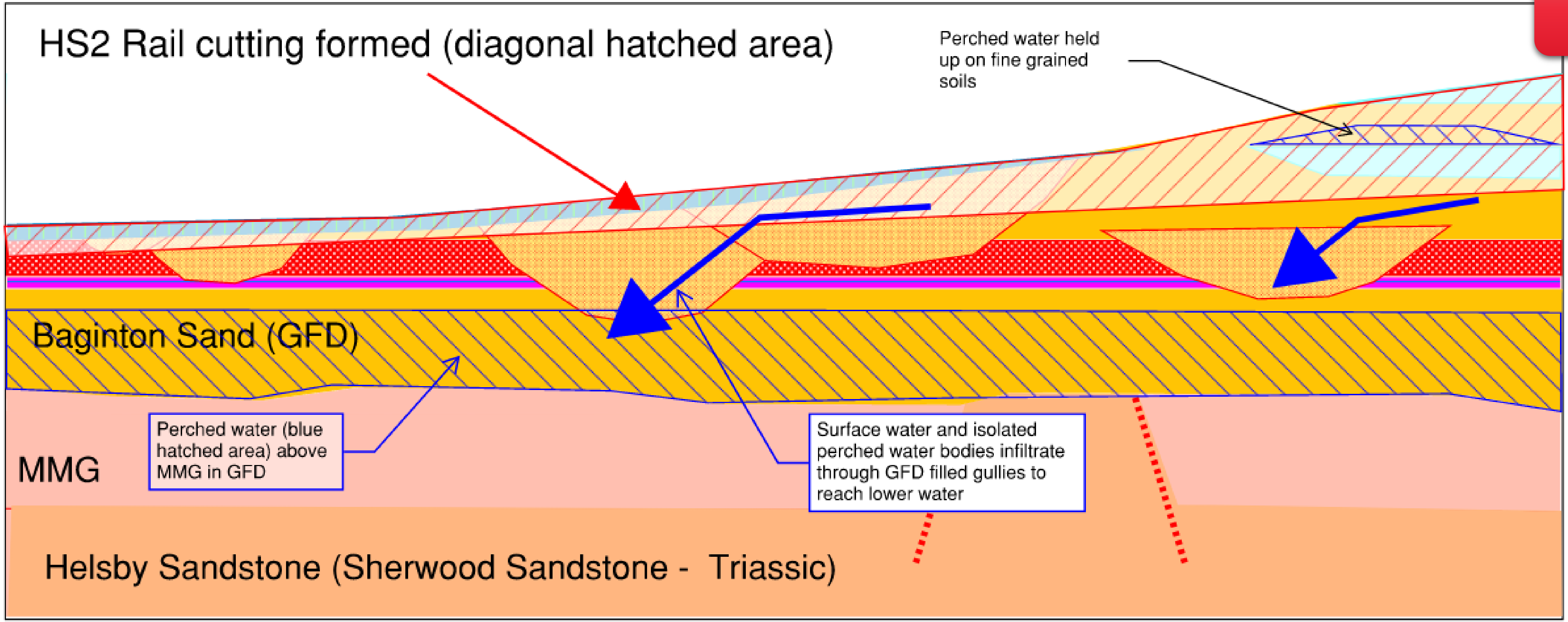
Ground Model Development- Park Lane Cutting



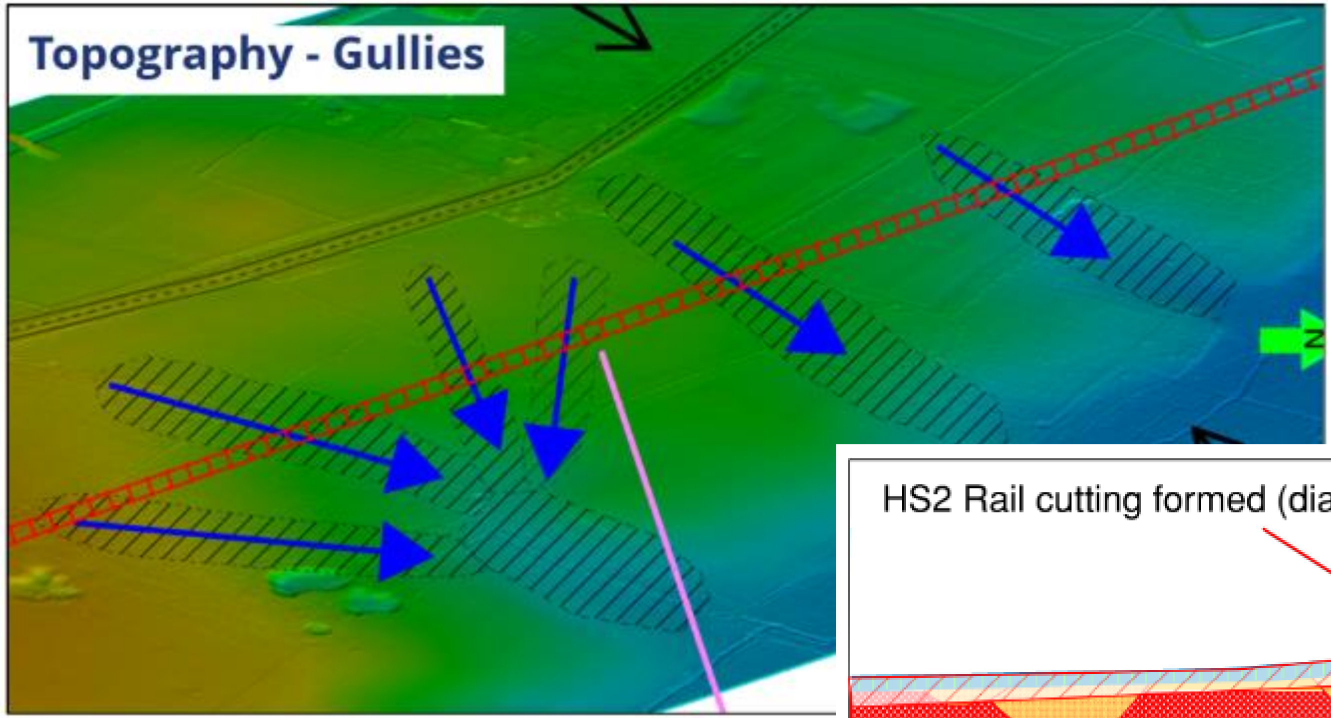
Ground Model Development- Park Lane Cutting

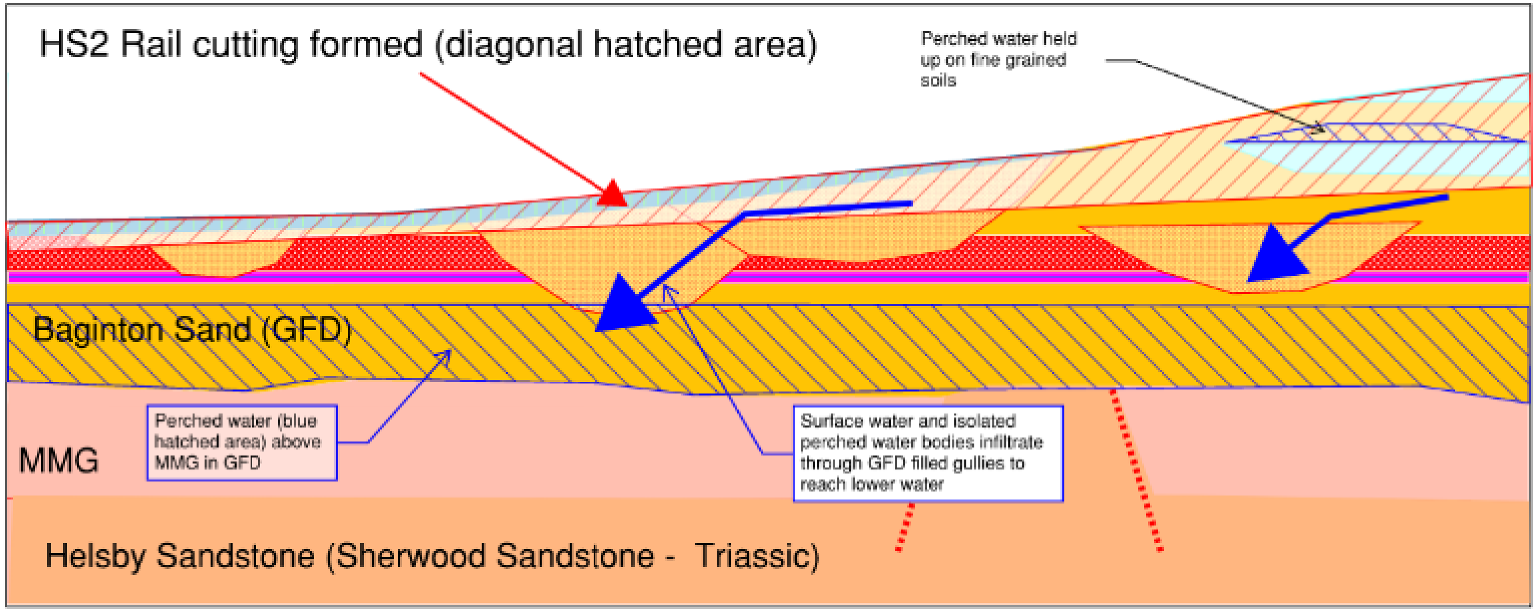


Ground Model Development- Park Lane Cutting



Glacial/Periglacial Gully Development- Park Lane Cutting





Glacial/Periglacial Gully Development- Park Lane Cutting

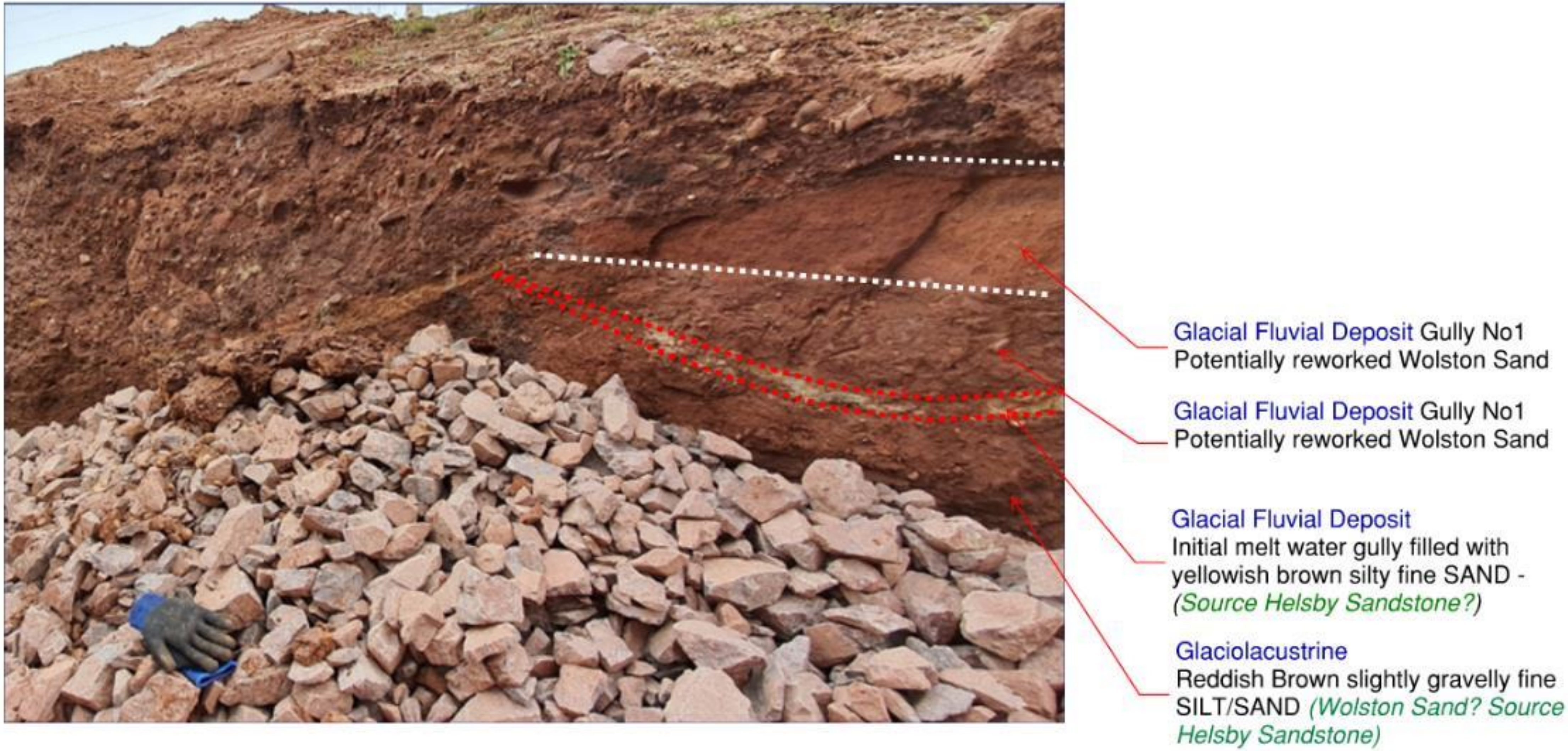
Glaciolacustrine
Reddish Brown slightly gravelly fine SILT/SAND *(Wolston Sand? Source Helsby Sandstone)*

Glacial/Periglacial Gully Development- Park Lane Cutting

Glacial Fluvial Deposit
Initial melt water gully filled with yellowish brown silty fine SAND - *(Source Helsby Sandstone?)*

Glaciolacustrine
Reddish Brown slightly gravelly fine SILT/SAND *(Wolston Sand? Source Helsby Sandstone)*

Glacial/Periglacial Gully Development- Park Lane Cutting



Glacial/Periglacial Gully Development- Park Lane Cutting

Periglacial Deposit Gully No2
Reworked Glacial Till from higher ground from ridge of slope. (Considered to be an active slide debris flow as opposed to solifucted soil. This is because the deposits appear to be confined to the gully areas)

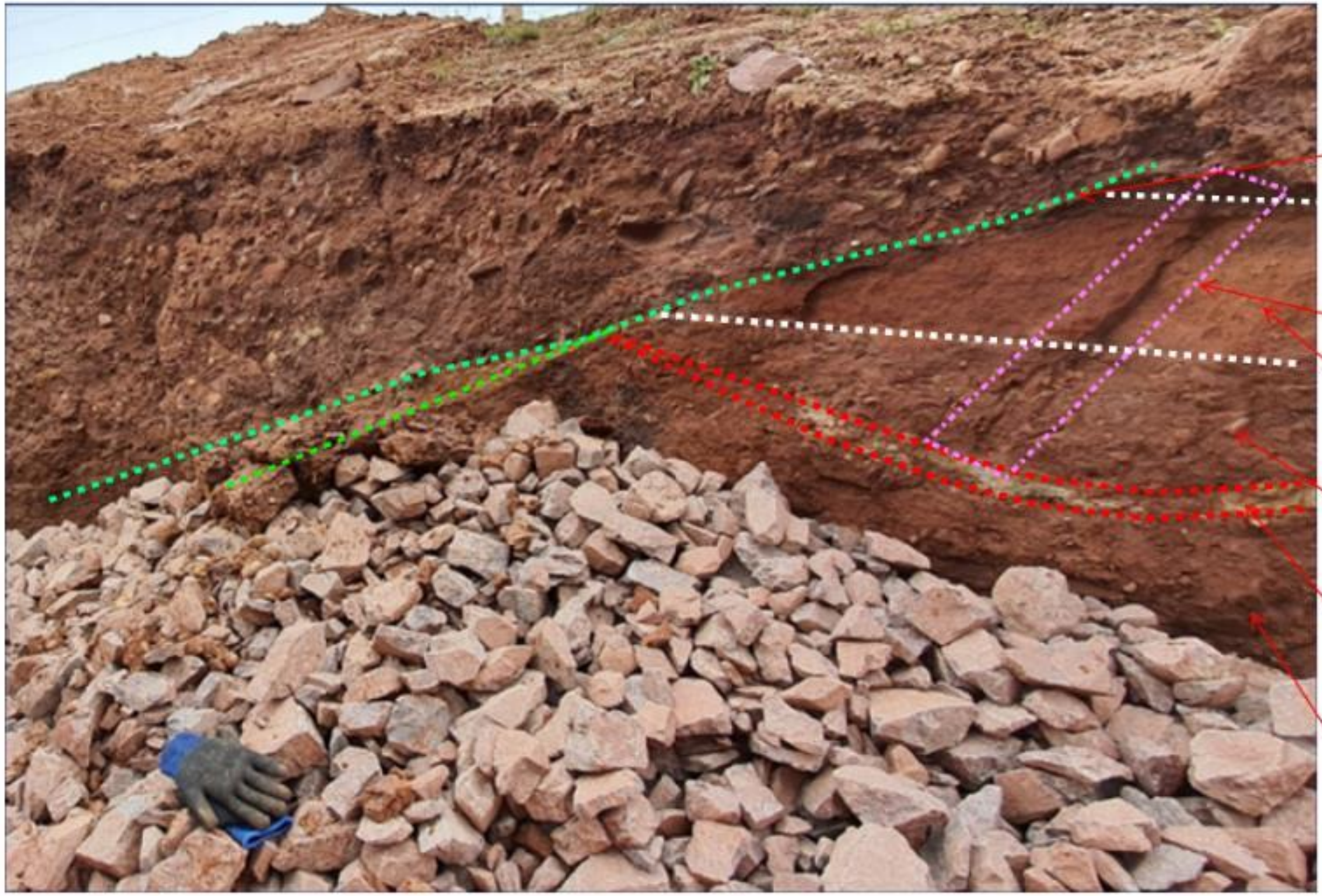
Glacial Fluvial Deposit Gully No1
Potentially reworked Wolston Sand

Glacial Fluvial Deposit Gully No1
Potentially reworked Wolston Sand

Glacial Fluvial Deposit
Initial melt water gully filled with yellowish brown silty fine SAND - *(Source Helsby Sandstone?)*

Glaciolacustrine
Reddish Brown slightly gravelly fine SILT/SAND *(Wolston Sand? Source Helsby Sandstone)*

Glacial/Periglacial Gully Development- Park Lane Cutting



Periglacial Deposit Gully No2
Reworked Glacial Till from higher ground from ridge of slope. (Considered to be an active slide debris flow as opposed to solifucted soil. This is because the deposits appear to be confined to the gully areas)

Periglacial thaw shear Late Wolstonian or Devensian

Glacial Fluvial Deposit Gully No1
Potentially reworked Wolston Sand

Glacial Fluvial Deposit Gully No1
Potentially reworked Wolston Sand

Glacial Fluvial Deposit
Initial melt water gully filled with yellowish brown silty fine SAND - *(Source Helsby Sandstone?)*

Glaciolacustrine
Reddish Brown slightly gravelly fine SILT/SAND *(Wolston Sand? Source Helsby Sandstone)*

Park Lane Cutting – Higher permeability Glacial Fluvial Sands

Park Lane Cutting SL2N– Engineering Geology/Ground Water Risk

5- Summary

Summary

1) **Value Engineering** - Budget constraints on projects mean that you have to be flexible in your thinking and approach.
2) **Applied Science** – Engineering Geology is an applied science subject and is heavily reliant on the work of pure geologists. Therefore challenge your our knowledge level and get reading!
3) **Observation Skills** – A cornerstone to being an engineering geologist. Practice basic skills and try and get something out of all your projects and site visits. It's rewarding!
4) **Origin of Soil and Rock** – Essential to know about your site because it could bring significant financial value to the project.
5) **Geological Maps** - A starting point. Just because they are digital doesn't mean that they hold all the answers. This is especially true in areas of glacial margins.
6) **Groundwater** – Management of groundwater in construction is expensive and when you bring environmental constraints into the programme, there is always a significant impact to manage.
7) **Engineering Geologists** – Have knowledge of the above and so can apply these skills within the construction phase of a project to look for value engineering opportunities.

References

1) BBV ispatial GIS platform
2) Gibson SM, Bateman MD, Murton JB, Barrows TT, Fifield LK, Gibbard PL. 2022 Timing and dynamics of Late Wolstonian Substage 'Moreton Stadial' (MIS 6) glaciation in the English West Midlands, UK. R. Soc. Open Sci. 9: 220312. https://doi.org/10.1098/rsos.220312
3) HOBBS, P R N AND8 OTHERS.2002. Engineering geology of British rocks and soils — Mudstones of the Mercia Mudstone Group. British Geological Survey Research Report, RR/01/02
4) Jonathan D. Radleya,*, Robert A. Coram 2016 The Chester Formation (Early Triassic, southern Britain): sedimentary response to extreme greenhouse climate? Proceedings of the Geologists' Association
5) Le Massif armoricain (vinsvignesvignerons.com)
6) Booth et al 2015 - Booth S., Merritt J. & Rose J. 2015. Quaternary Provinces and Domains – a quantitative and qualitative description of British landscape types. *Proceedings of the Geologists' Association*, 126, 163–187.
7) BGS Vale of York Glaciation
8) McMillan, a a, HaMblin, R J O, MeRRitt, J W. 2011. A litho-stratigraphical framework for onshore Quaternary and Neogene (Tertiary) superficial deposits of Great Britain and the Isle of Man. British Geological Survey Research Report, RR/10/03. 343pp.
9) British geological Survey On shore Index GeoIndex - British Geological Survey (bgs.ac.uk)
10) British Geological Survey: Birmingham Geology of the Birmingham area: Memoir for 1:50 000 Geological Sheet 168 (England and Wales)
11) MURTON, J.B. & BALLANTYNE, C.K. 2017. Periglacial and permafrost ground models for Great Britain. In: GRIFFITHS, J.S. &MARTIN, C.J. (eds) Engineering Geology and Geomor-phology of Glaciated and Periglaciated Terrains. Engi-neering Group Working Party Report. Geological Societyof London, Engineering Geology Special Publication No. 28,501–597.
12) Hutchinson JN (1991) Periglacial and Slope Processes Quaternary Engineering Geology, Geological Society Engineering Geology Special Publication No 7, lap 283-331
13) Spink TW (1991) Periglacial discontinuities in Eocene clays near Denham, Buckinghamshire. Engineering Geology Special Publications, v. 7, p. 389-396.

6- Questions

Definition of an Engineer (Noun) – Person who solves problems that others didn't know existed!

Engineer (Verb) - To try to arrange for something to happen, usually something complicated or difficult