Drift filled hollows and piling

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Introduction

- What ground issues do DFHs present for foundation design?
- Why is there a DFH on this site – can we predict them?
- Which piling method?
- Case studies – common types
- Conclusions

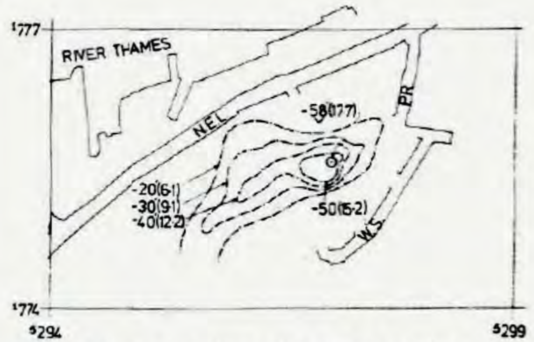
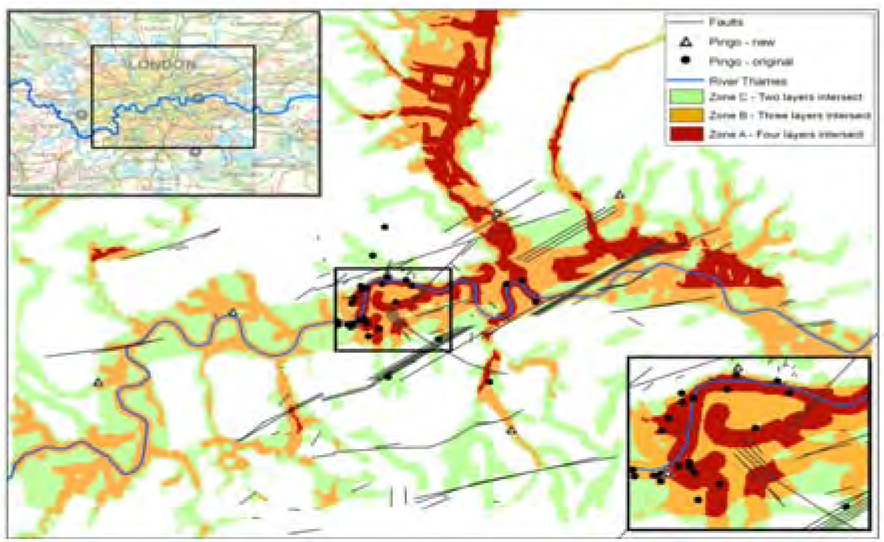


FIG. 6. Battersea Gas Works (1d). NEL = Nine Elms Lane; PR = Ponton Road; WS = Wardgate Street. Based on 29 borehole records.

From Berry, 1979

Drift Filled Hollows in London

- Often considered as ‘holes in top of London Clay’ or ‘diapirs’
- Relatively common in projects..but
- Frequently unreported
- May be under-investigated
- Could lead to unexplained pile failures



British Geological Survey

DFHs – foundation issues

- Size and complexity of project important
- Affected nearby services/tunnels?
- Size and morphology of DFH – steep sided/depth?
- Infill – coarse/fine/mixed/soft/organic?
- Water bearing layers?
- Surrounding ground and below – e.g. 'disturbed London Clay'
- Wider issues for neighbouring sites?

DFHs – why is it on this site?

- BGS research – DFHs related to ‘lost’ rivers, faulting – but..
- Many minor ‘lost rivers’ and faults unmapped
- Lost rivers however do appear to frequently occur where faulting is present
- Faulting may be present where *no* distinct Holocene river channel present

DFHs & faulting together– risks for piling

- Faulted/soft/disturbed ground
- Poor end bearing or shaft friction capacity?
- Water bearing clays or sands, instability?

in open bored piles?

- Confusing faulted/disturbed ground – strata/thinned, unexpected depths for designed piles?
- Large sand units in Lambeth Group also associated with faulting/lost rivers – high water pressures – flowing sand?

DFHs – site investigations

- *Good site investigation is essential*
- Steep sided nature may evade attention until project has started and piling has commenced
- Extent/methods will depend on the project size and sensitive structures

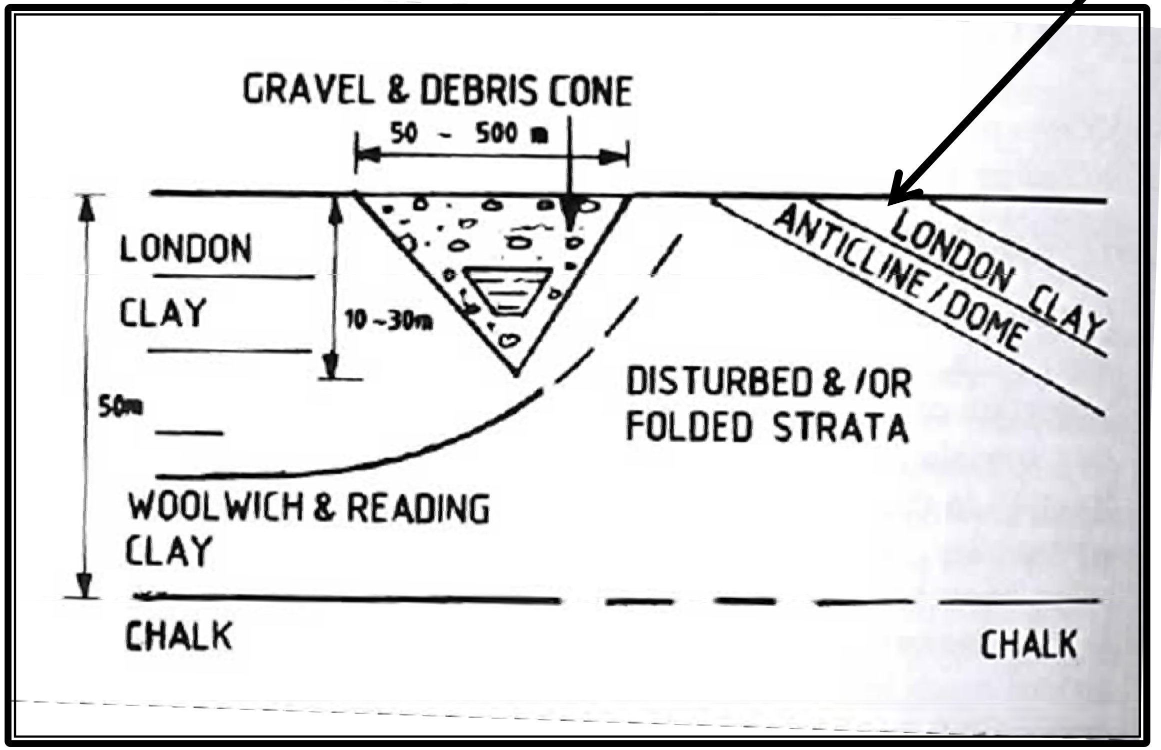
DFHs – which method is appropriate?

- *Dependant on good SI and testing*
- Many shallow piles/raft?
- Deeper piles to competent strata?
- CFA
- Casing
- Water control necessary?
- Bentonite support?
- Flexibility may be needed in planning for ‘unexpected’ ground conditions

D W Cox – 'Piling in an around scour hollows in London and probable effects of rising ground water' 1992

- 'Typical features of a scour hole'

Is this diapiric or faulted ground?



Scour hollow near Gt Portland Street LUL Station

- SI showed steep anticline in London Clay
- Lambeth Gp near surface
- S of site – gravel filled hollow
- Water-bearing Harwich Fm; water 'boiling' into bored piles – instability
- Pile casing and bentonite used but expensive
- Alternative design used strip footings and raft

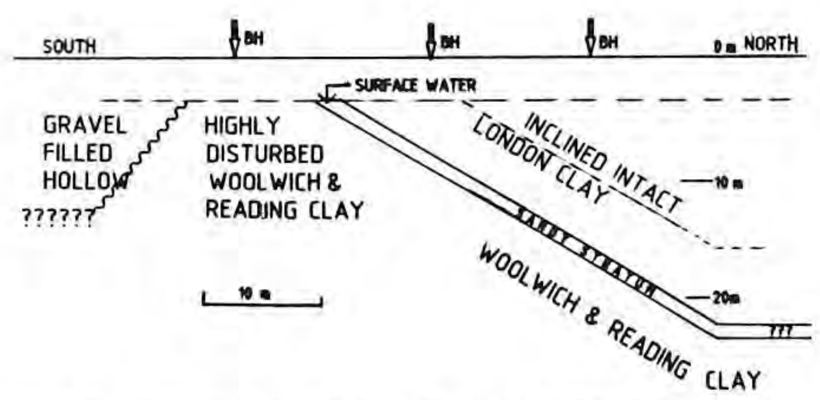
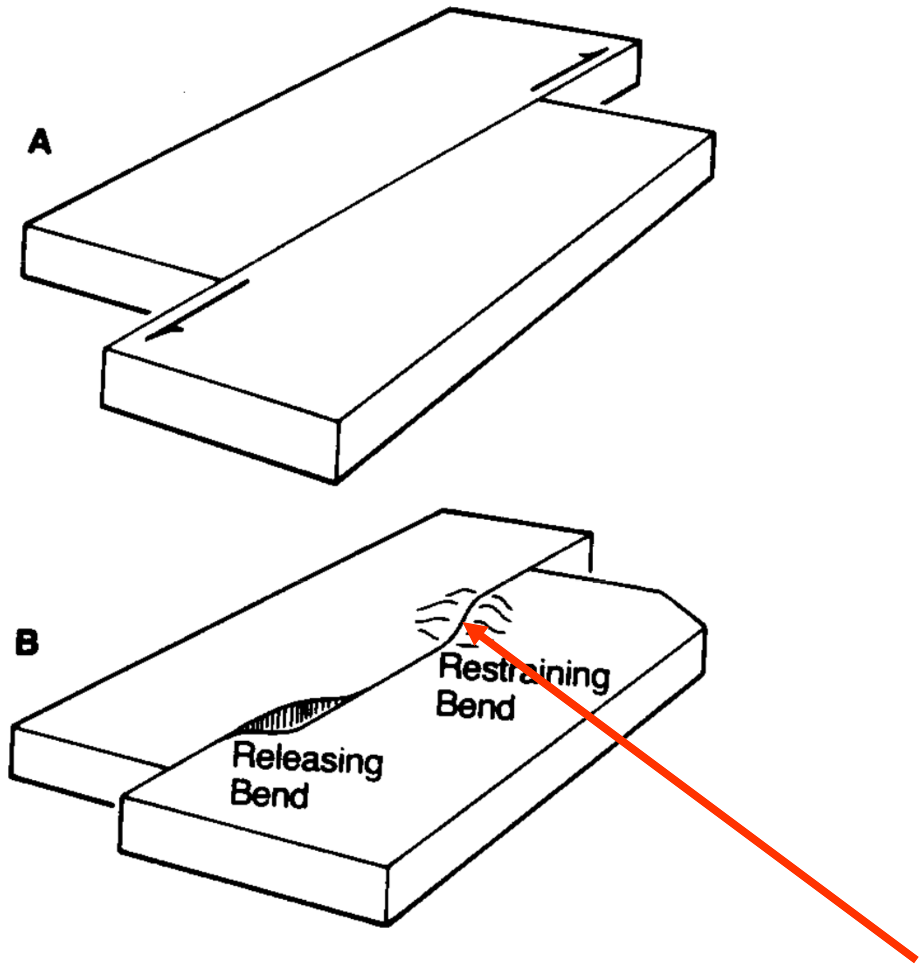
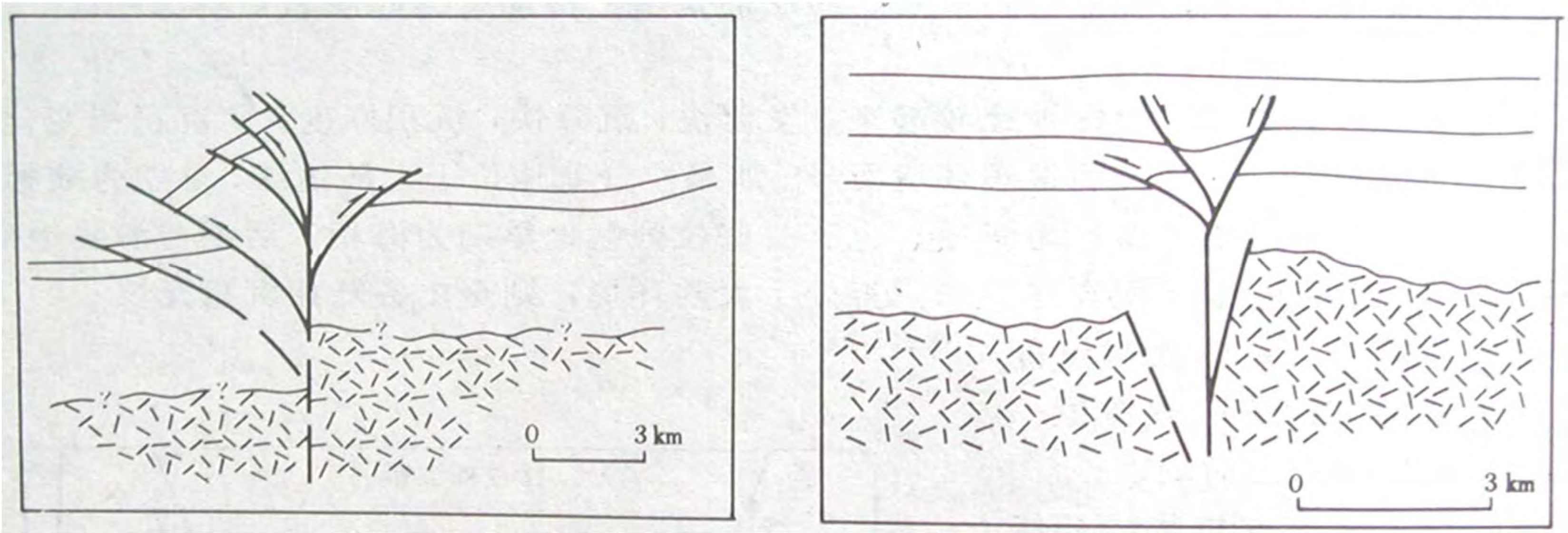


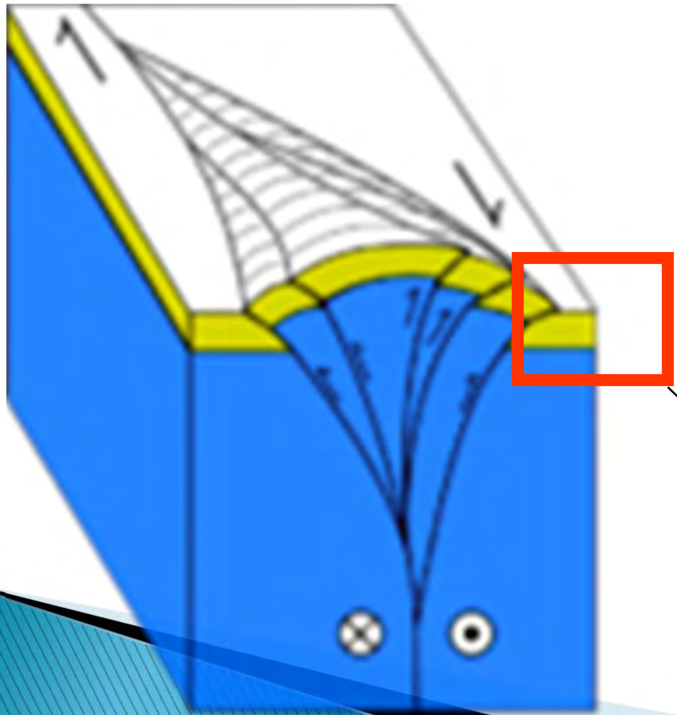
Fig 5 Scour hole 200m SE Gt Portland St Stat.

Gt Portland St site is within a zone of unusual ground conditions with complex faulting of London Clay and sand channels in the Lambeth Group and Harwich Fm (red circles). Yellow circles show 2 areas where uplifted strata and associated scour hollows were described in Cox 1992. Both are associated with known extreme faulting.



Strike-slip structural ground model – explains positive 'up-faulted' areas of ground

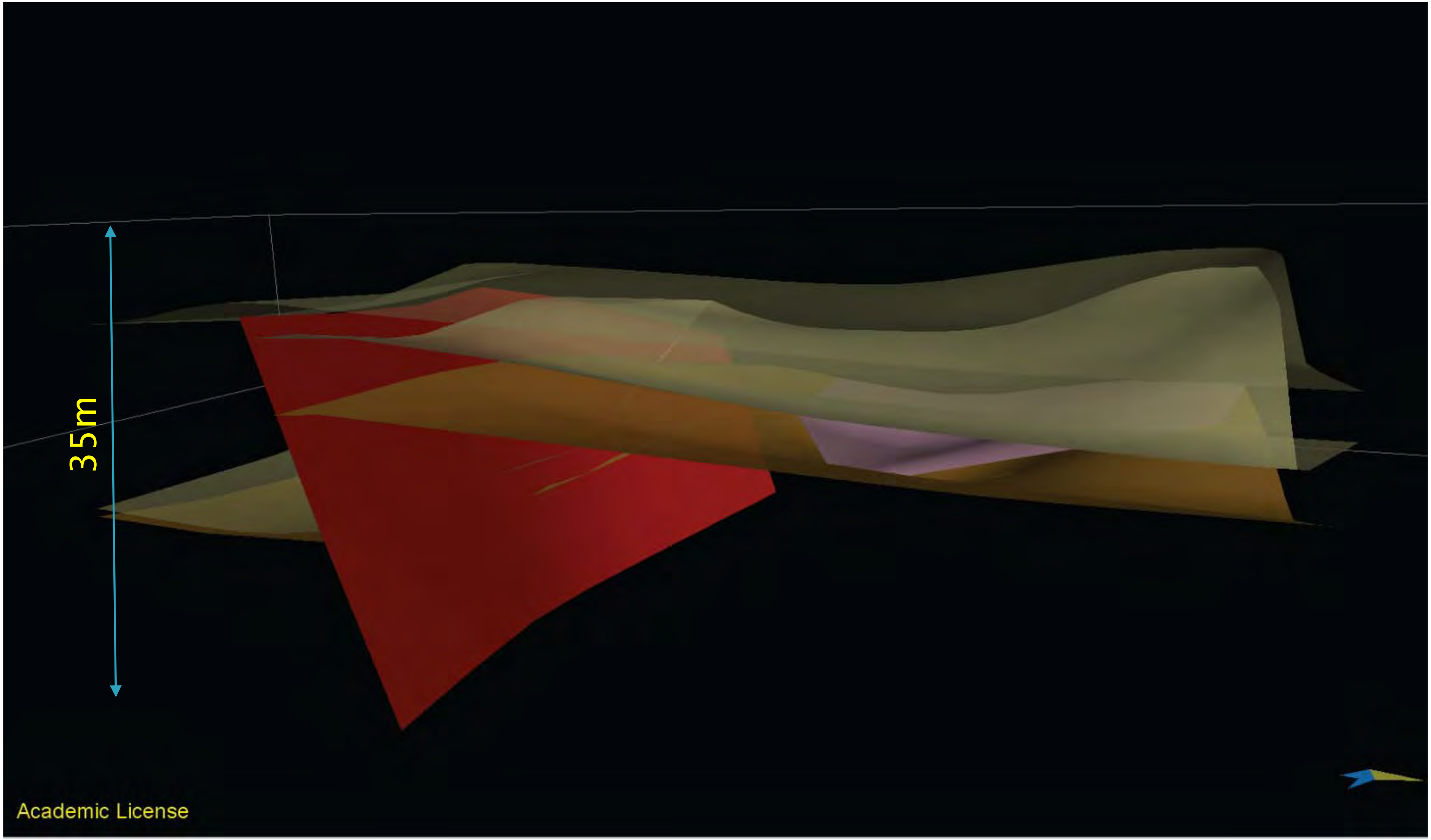




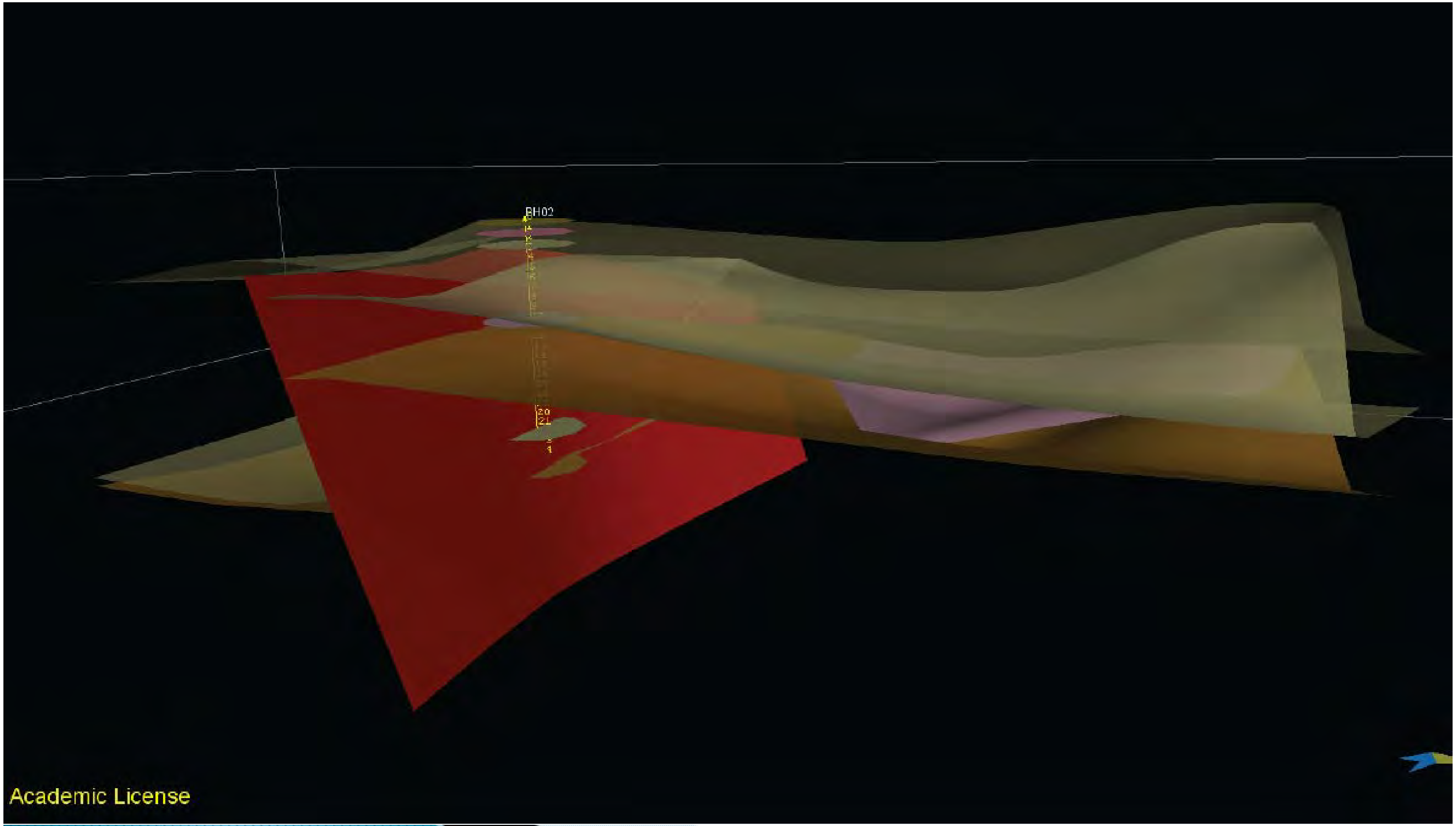
Possible model of sub-horizontal thrust-faulted wedge such as seen at UCLH

Faulting bringing Lambeth Group to near surface position, UCLH Cancer Centre

Large fault near Great Portland Street – MOVE 3D model (Richard Ghail Imperial College) showing repetition of strata, London Clay and Harwich Fm and Lambeth Group folded and faulted



Borehole recovery – repetition of layers, sand nearer to surface than anticipated



How often is faulting involved in DFH development?

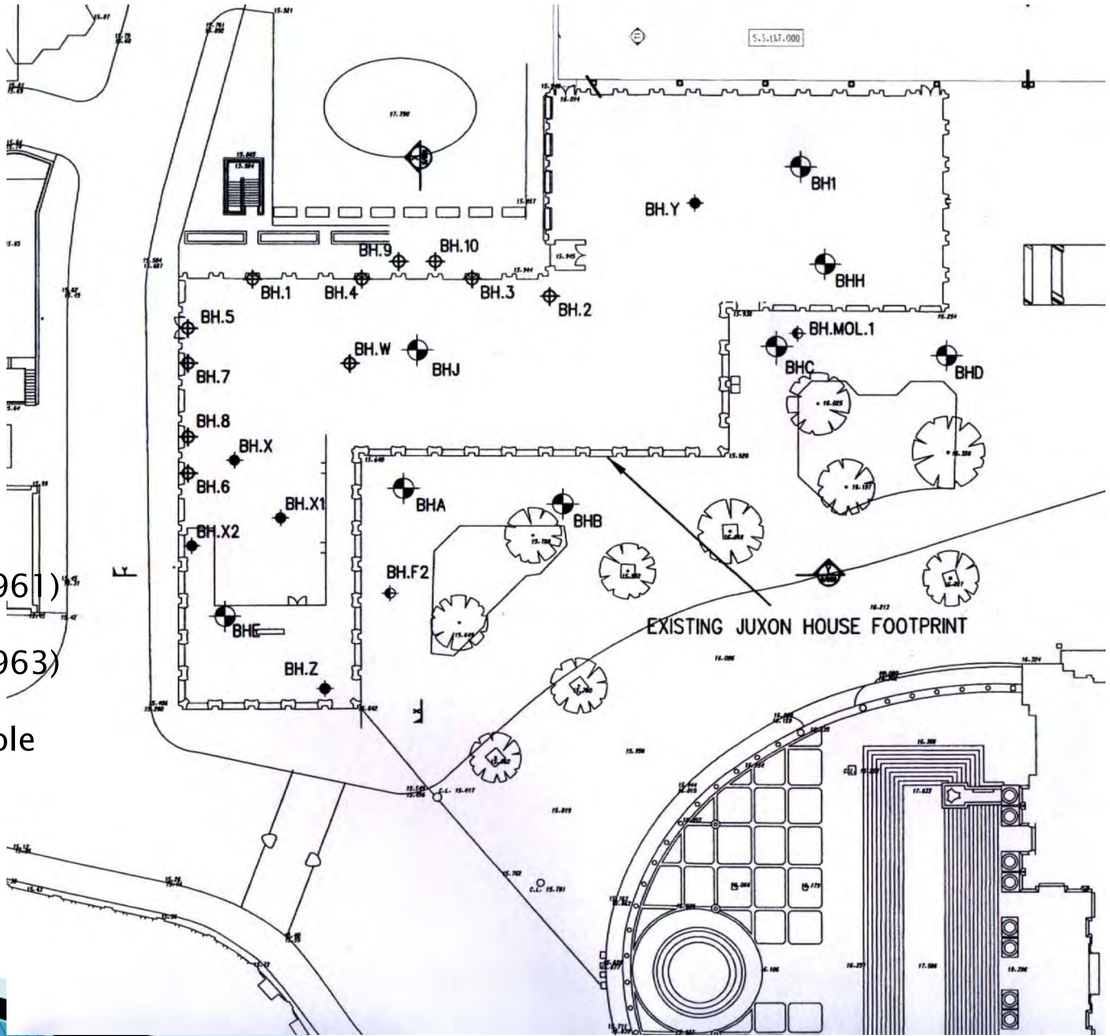
- 2 cases illustrated – one possibly, second definitely

Juxon House, St Paul's Churchyard
Designers Whitby Bird 2001

Wimpey borehole (1961)

Wimpey borehole (1963)

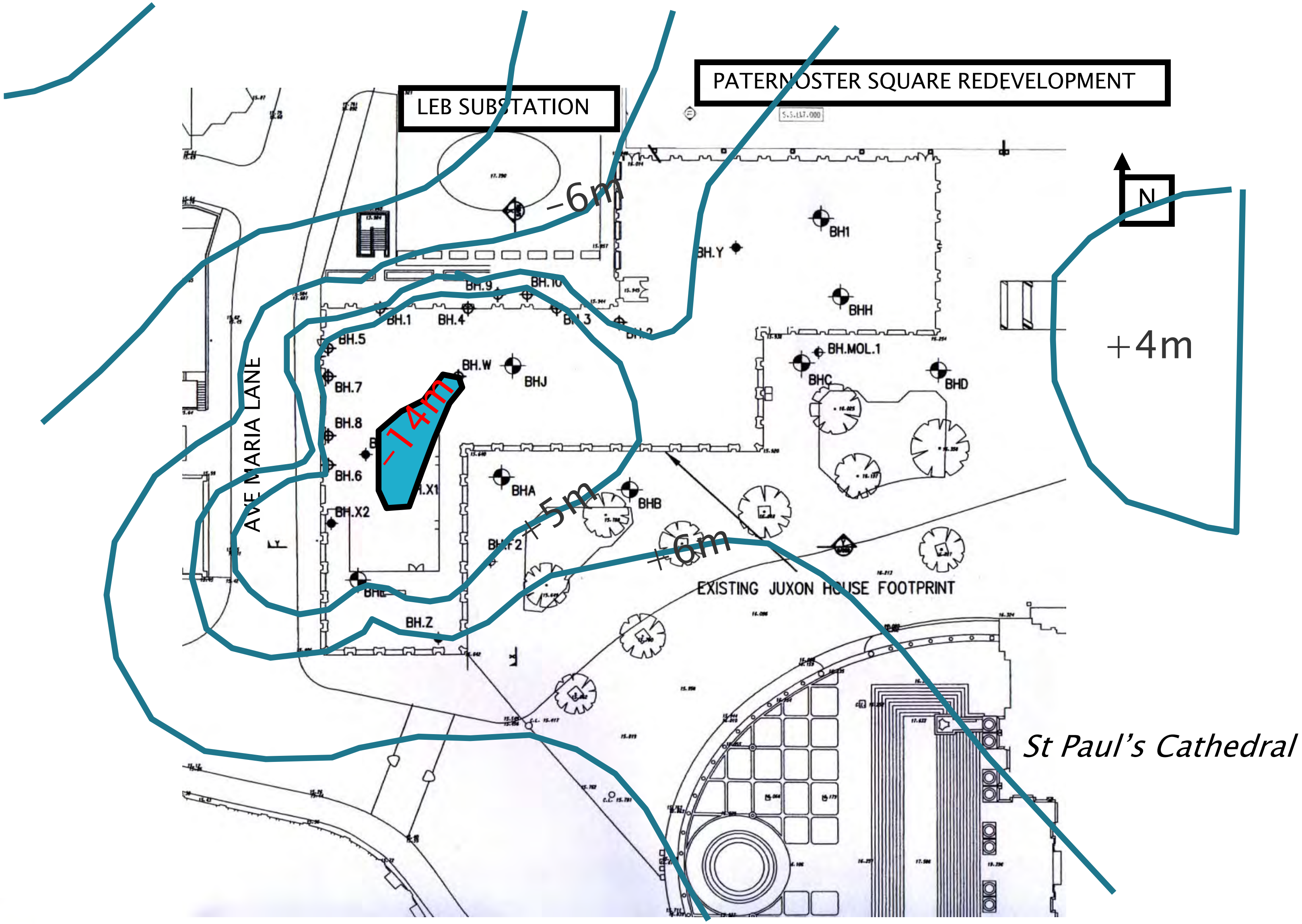
LBH Wembley borehole (2000)



Juxon House in relation to St Pauls

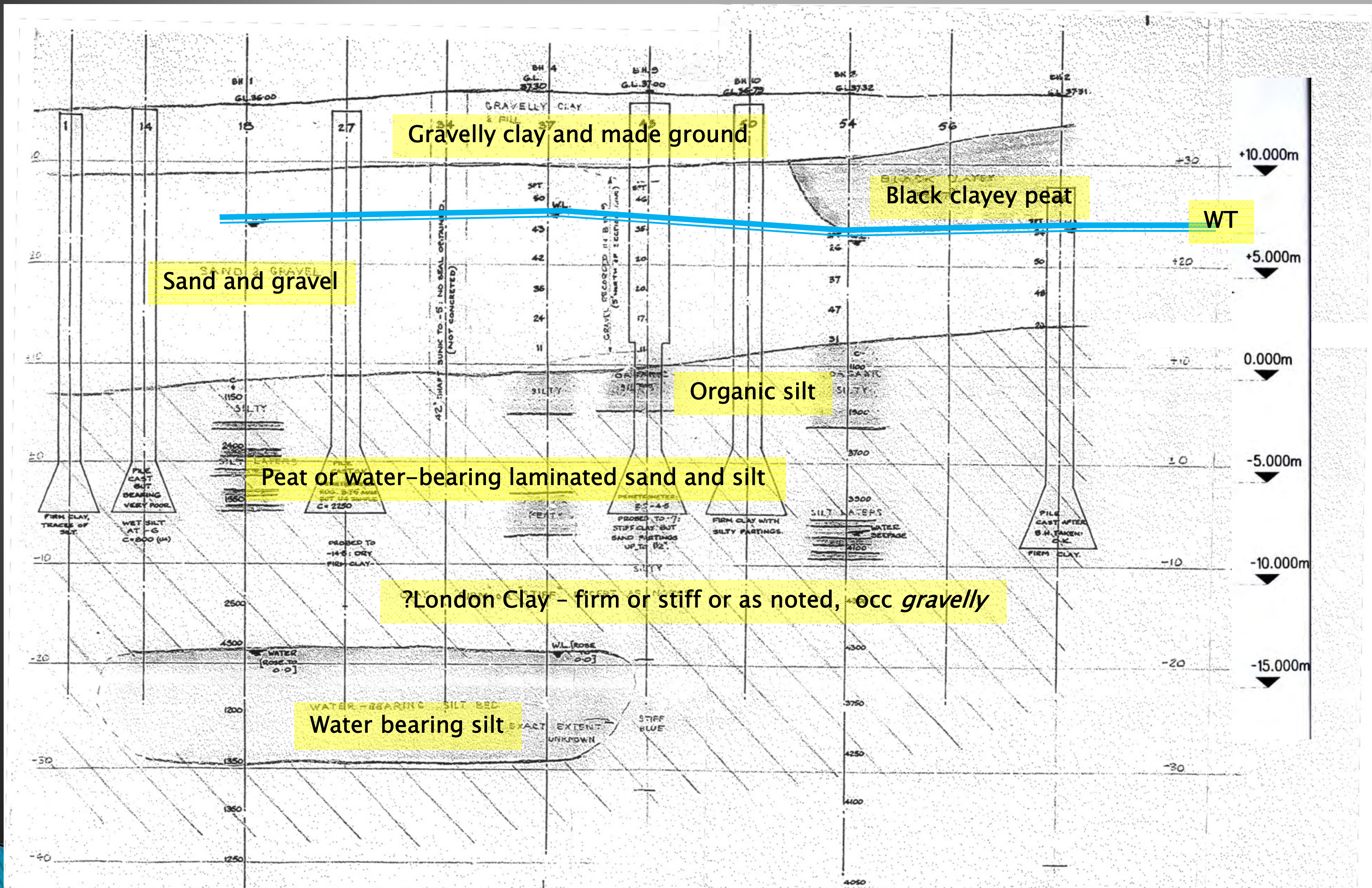
Juxon House Redevelopment involved:

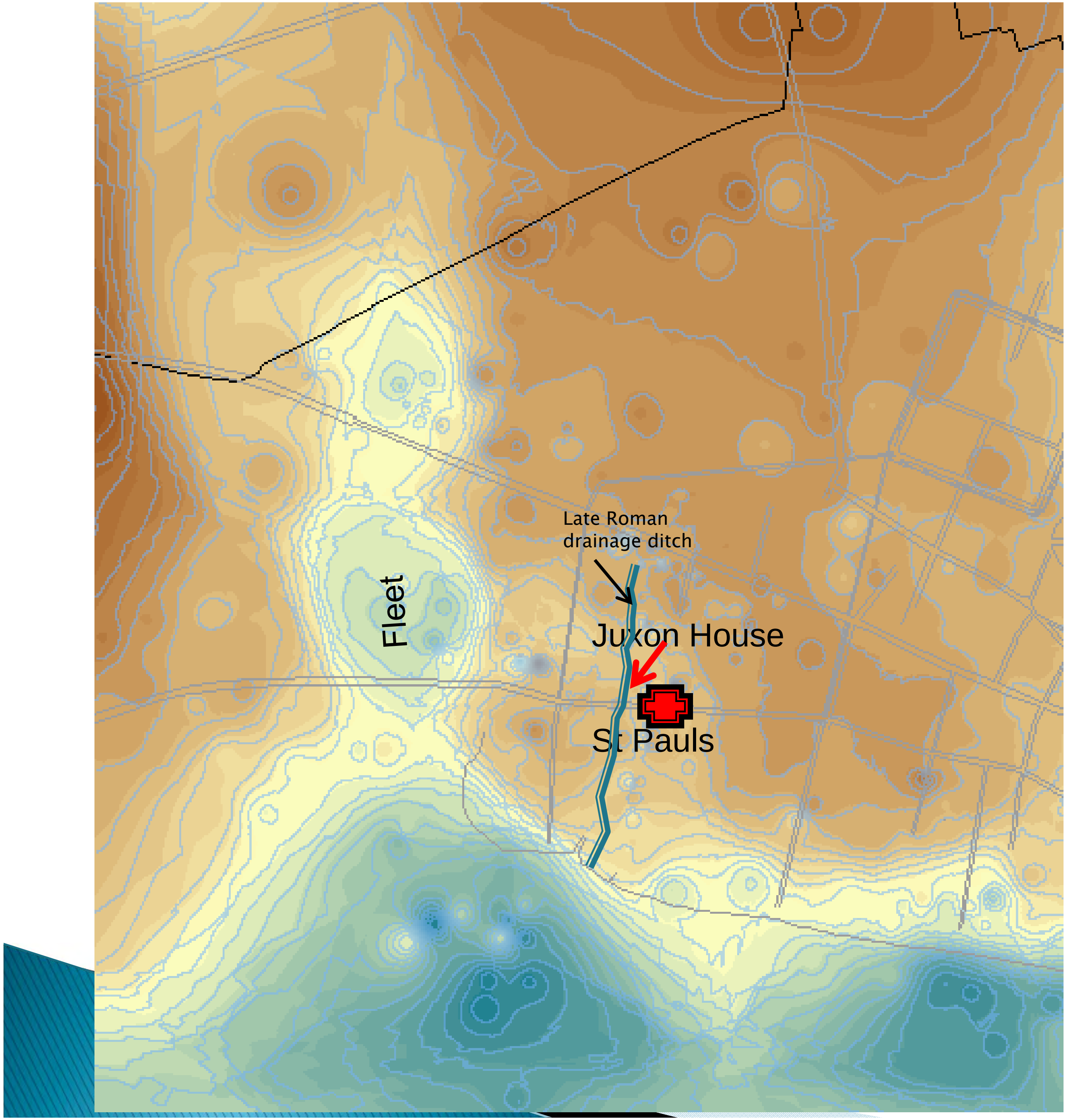
- Previous 10 storey building, founded on under-reamed and straight shafted piles
- New 8 storey building in its place (new basement levels, cores and larger area).
- Little space for new piles
- Complex ground conditions:
- *Variations in the top of the London Clay*
- Scour hollow
- Large thicknesses of disturbed London Clay under part of the site
- *Water bearing silt and fine sand layers* in London Clay
- Instability problems during the previous construction of under-reamed piles



DFH structure and site investigation boreholes contours as mOD.

Ground conditions encountered – 1960s





No obvious lost rivers but one Roman drainage ditch nearby

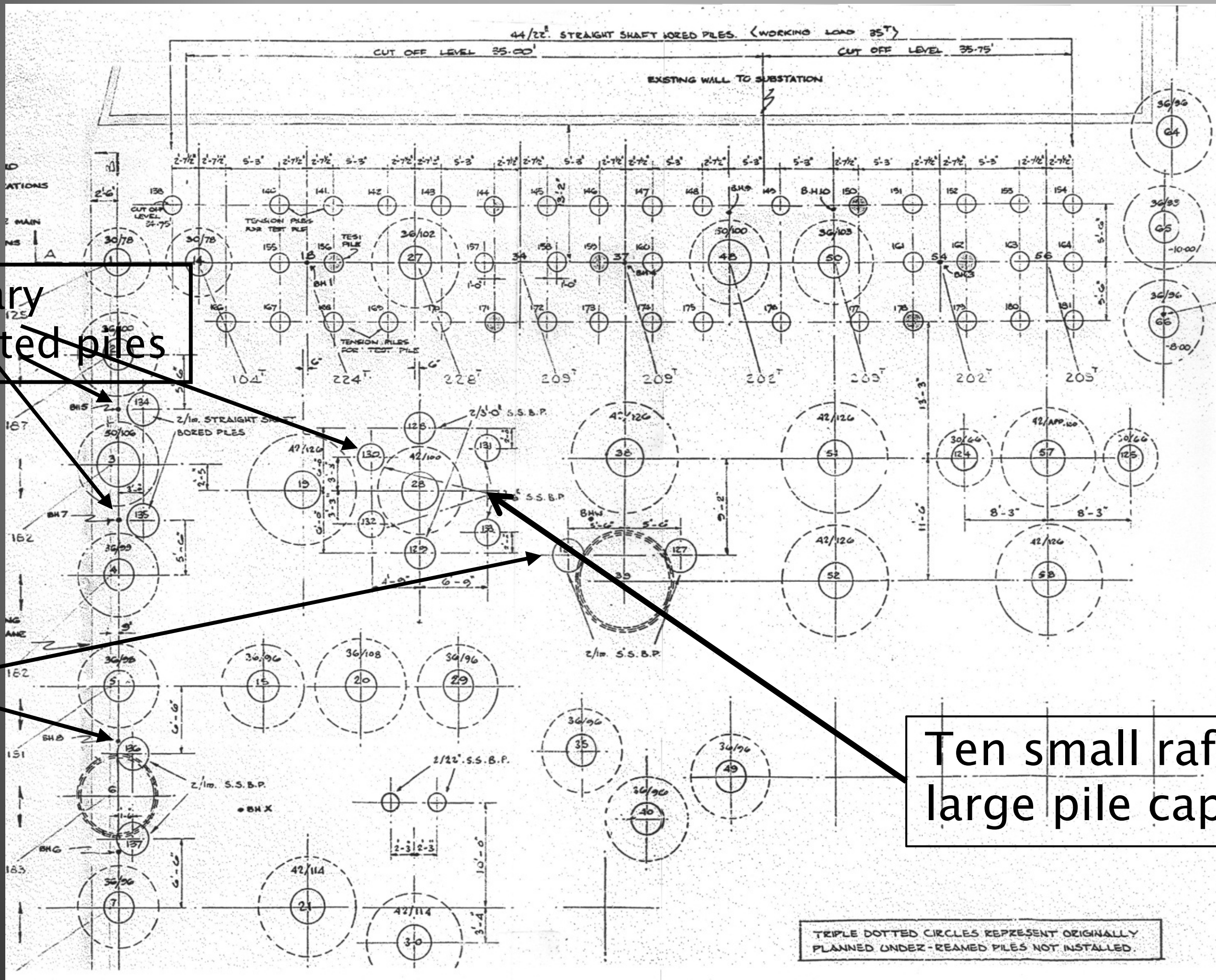
(Slide adapted from Mary Ruddy, MOLAS)

Constraints on new foundation scheme – including re-use

- Locations of existing piles, mainly under-reamed with base diameter up to 3.2m
- Additional straight sided piles = ? instability
- Archaeological remains
- Fill over relatively thin Terrace Gravel making raft solutions problematic
- One of first pile re-use projects

New piles :

- Where there were no existing piles
- To supplement existing piles where loads are higher
- Used 900mm diameter CFA piles
- Further SI undertaken and testing

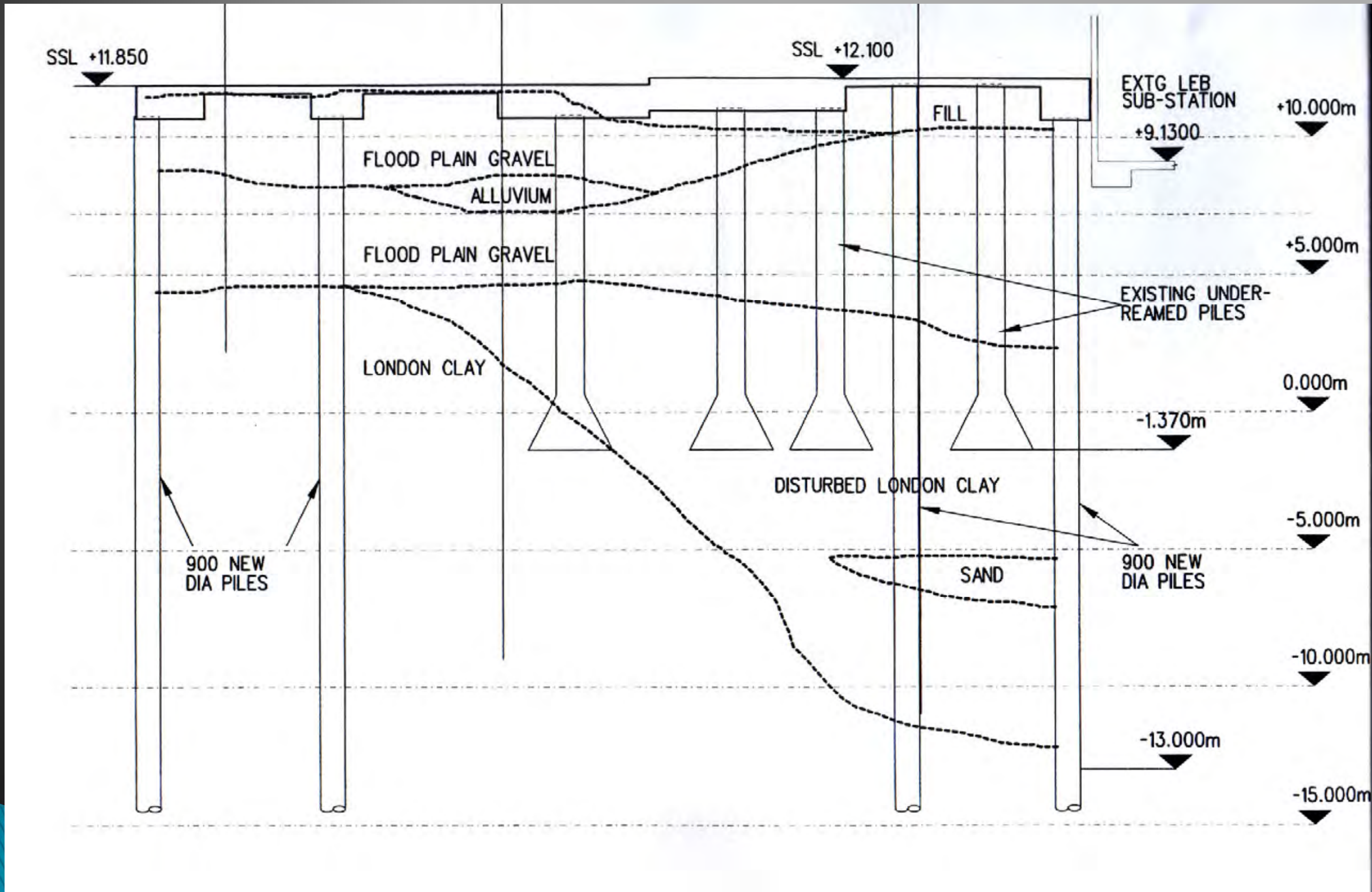


Supplementary straight shafted piles

Replacement piles

Ten small rafts (or large pile caps)

Scour hole in London Clay – cross section across DFH



Was faulting present at this site?

- Difficult to tell as most boreholes didn't penetrate London Clay
- No obvious lost rivers
- Faulting could explain poor behaviour of LC but not intermixed gravels and silt layer at
- ?-15m
- Suggests disruption of LC and erosion before infilling by later sediments.

Confidential case study, London

- Large, heavy building close to many major structures and services
- Previous very heavy building on site, short driven piles +++
- Pile raft – reuse?
- New building has high column loads around many cores and more basement levels so re-use not suitable

Site investigation

- ‘Lost’ river
- Localised throws of >10m over <30m in all deep strata down to Chalk
- Flush from depth within the London Clay flowing to ground surface
- London Clay heavily fissured, slickensided in places
- Some poor recovery and low SPT ‘N’ values with depth in London Clay
- Strike slip faulting
- Strata boundaries highly variable
- DFH associated with most extreme area of faulting

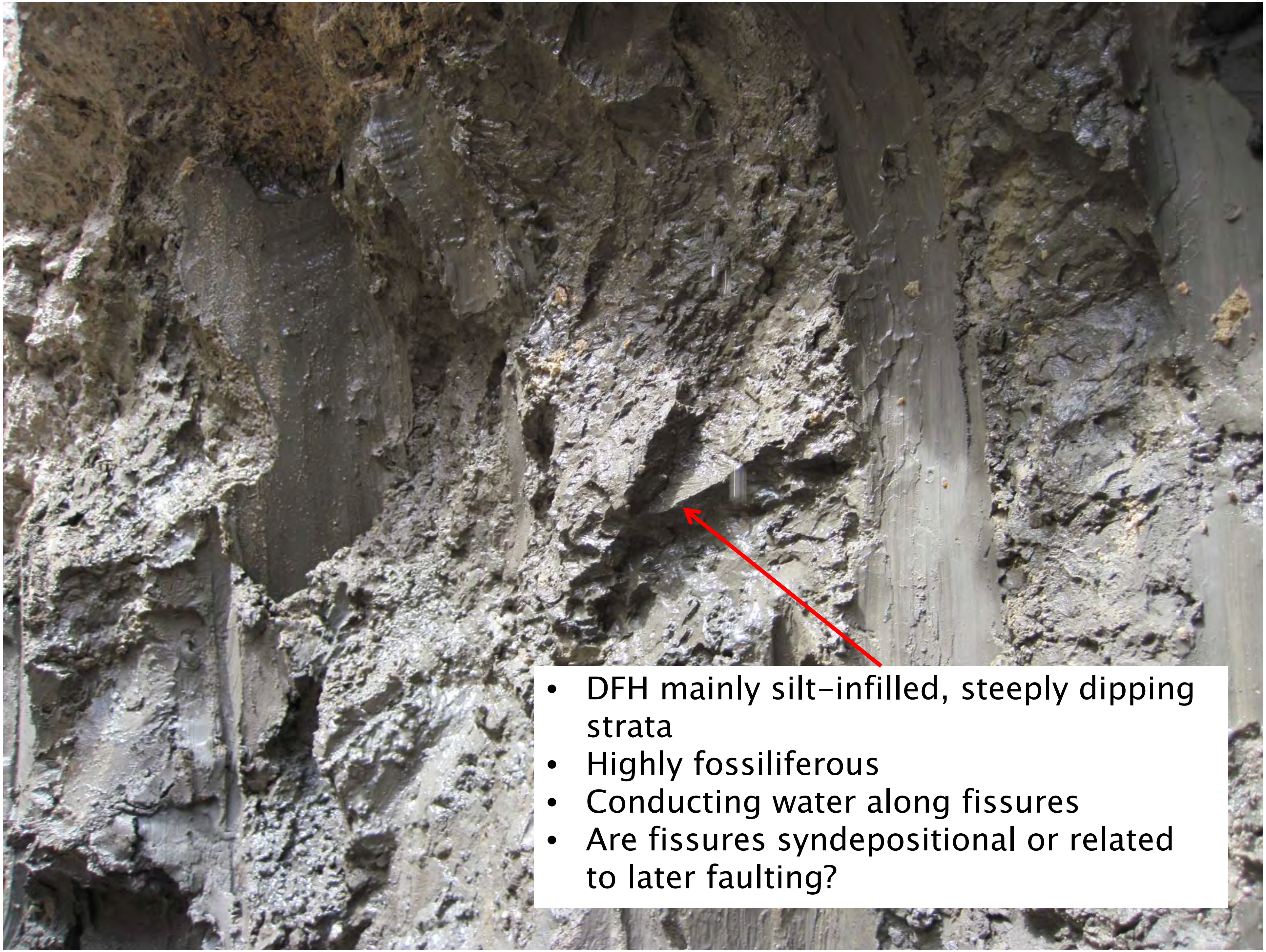
What happened next?

- Consulted SI drillers, loggers, archaeologists
- Explained importance of honesty, accuracy, reporting of unusual conditions
- Checked drilling, logging of cores
- Increased number of boreholes, piezometry
- *Good quality sampling difficult – only good core can be tested*
- Requested <u>more CP boreholes </u>in London Clay to obtain SPTs, water strike data for design

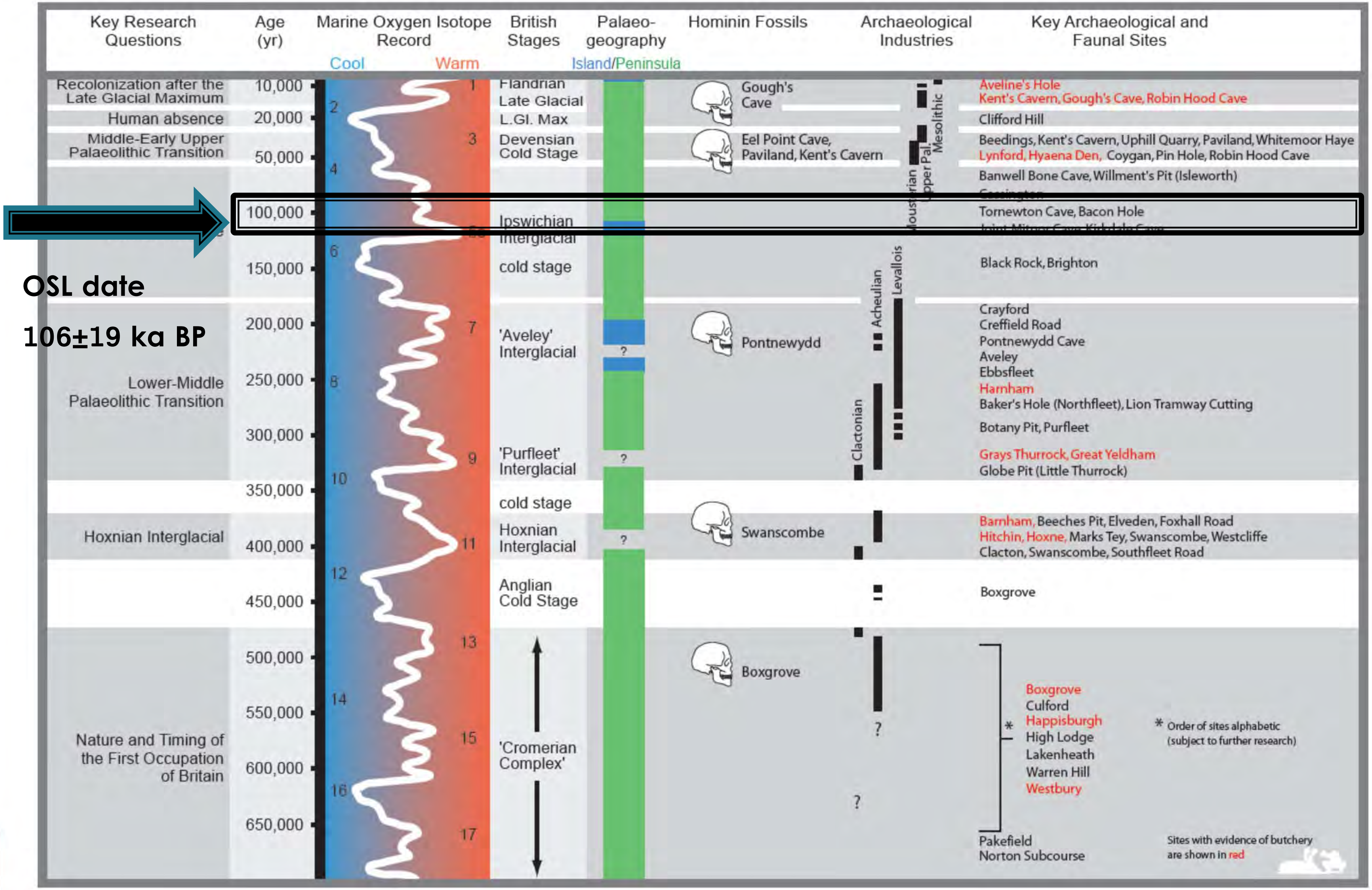
- London Clay in trial pit

The Drift Filled Hollow

- Up to 18m? deep
- Mostly silt with rare clasts of claystone, flints
- Approximately 106±19 ka BP
- At least 3 phases of infill indicated by fossils
- Two possible cold stage indicator species
- Youngest sediments indicate shallow fresh water ponding
- Steeply inclined fissuring
- Previously multiple shallow piles



- DFH mainly silt-infilled, steeply dipping strata
- Highly fossiliferous
- Conducting water along fissures
- Are fissures syndepositional or related to later faulting?

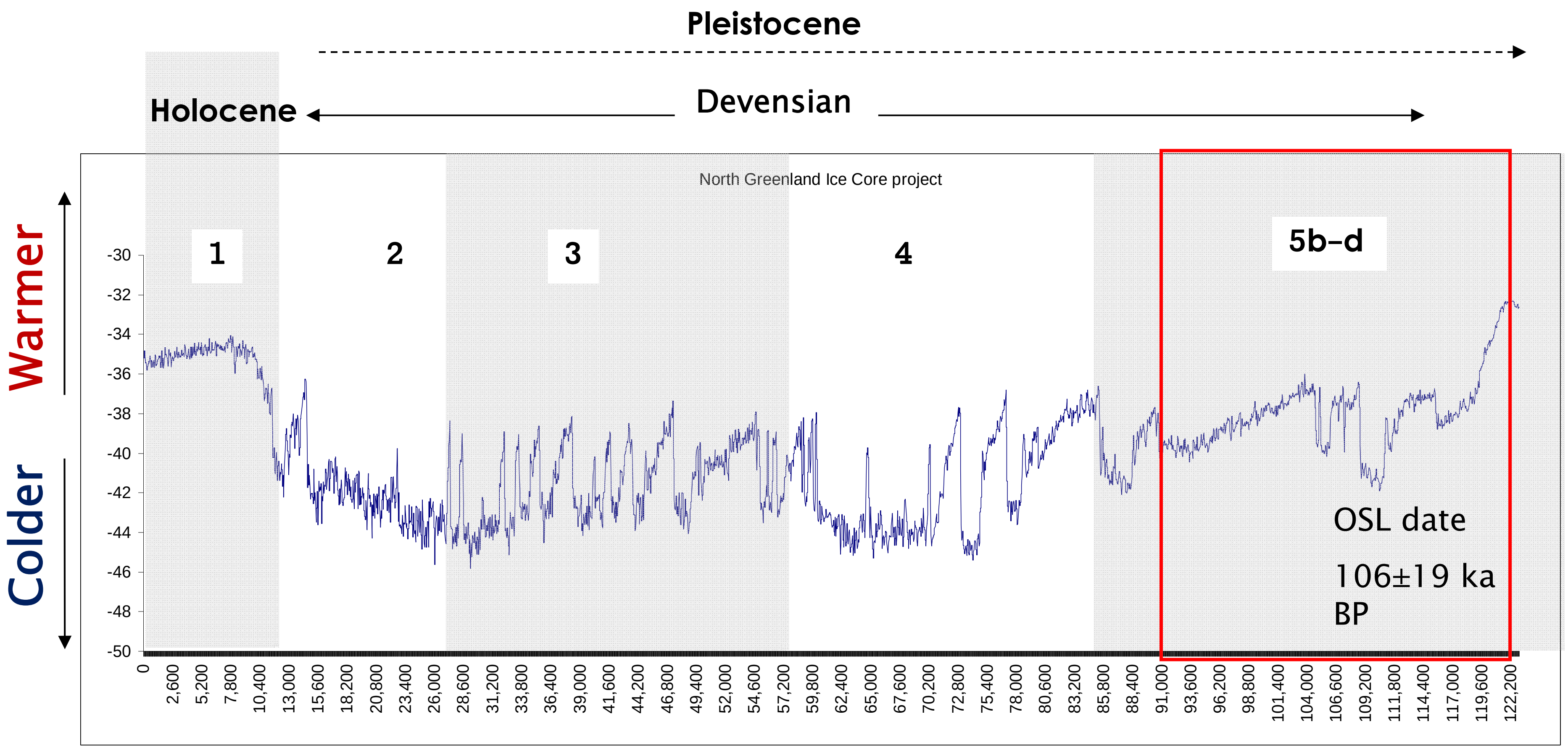


OSL date

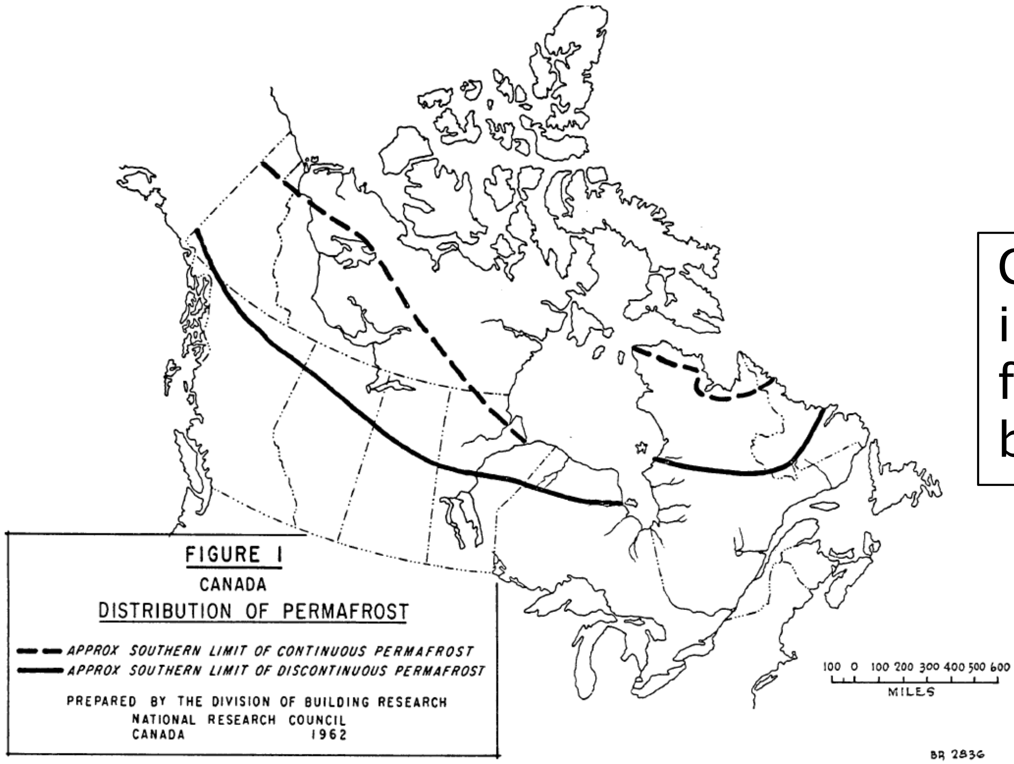
106±19 ka BP

Ancient Human Occupation of Britain Project (AHOB)

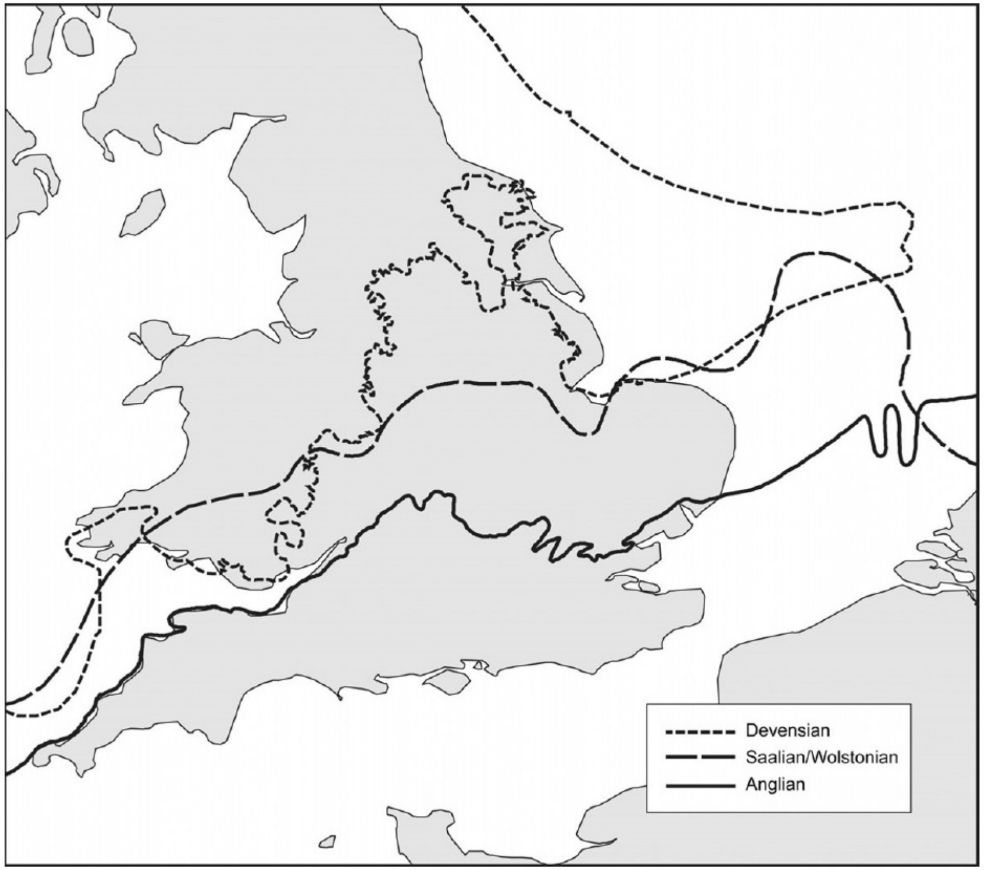
Dating of lower part of DFH infill



Data from the North Greenland Ice Core Project (NGRIP)
ftp://ftp.ncdc.noaa.gov/pub/data/paleo/icecore/greenland/summit/ngrip/isotopes/ngrip-d18o-50yr.txt
Slide from Mary Ruddy, MOLAS



Canadian Holocene ice sheet in 1960 approx 2-400 miles from continuous permafrost boundary



Devensian maximum ice sheet approx 2-400 miles from London. Was there permafrost in London?

Devensian Cold Stage scenario based on fauna in Bacon Hole, Kirkdale Caves. Could London have been like this?

Confidential Site – going forward

- *Good communication between all parties regarding issues*
- Mixture of shallow (London Clay) and deep (Thanet Sand) piles, cased &/or with bentonite when necessary
- Observational piling methodology used for most faulted/DFH area.

Conclusions: Piling and DFHs– 1

- Confluence of rivers may be predictor but not always
- Faulting *may* be associated – check!
- Faulting will have own secondary implications for piling design :- stability, level variability

Conclusions: Piling and DFHs- 2

- DFHs – may be missed!
- Bearing Capacity in scour *and beyond*
- Stability of piles in DFH?
- Depth should be clarified
- Water levels should be measured
- Extent should be investigated
- Site Investigation is *crucial* for sound design and choice of appropriate piling methods

And finally..

- Piling industry is who finds DFHs
- Is it possible to publish more case studies?
- BGS have confidential register of DFHs – tell them!