Infrared Spectroscopy in Engineering Geology

Nick Koor & Andy Gibson

Outline

- Background

Case Study 1

- Landslide Debris (Dorset)

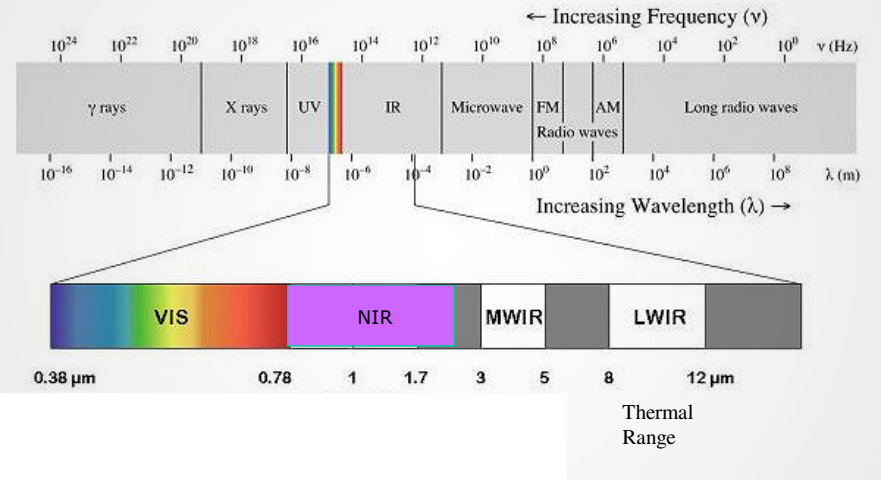
Case Study 2

- Engineering NIR Stratigraphy (Hampshire)

Case Study 3

- Weathering - London Clay (London)

NIR Spectroscopy



Spectral Logging

- Visible, NIR, SWIR Wavelengths (350-2500nm)
- Spectral resolution 1nm
- Measurement window 4-24 mm

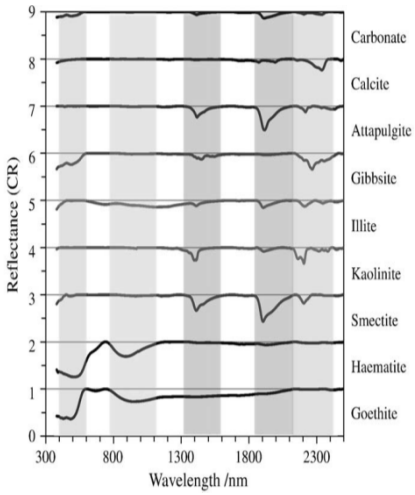
- Limited/no sample contact
- No sample prep needed
  - (lab samples can be crushed)
- Measurement time 0.05 secs

Spectral Logging

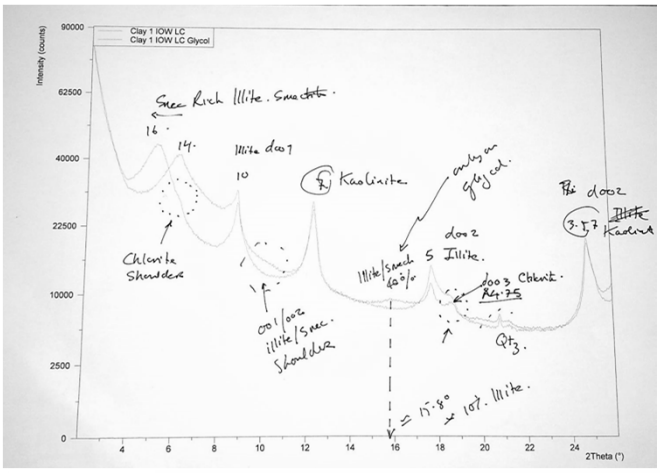
Sensitive to most minerals but especially clays

Biggest applications:

- Mining – mineral exploration
- Heritage Conservation (as non contact)
- Pharmaceuticals
- Biscuits

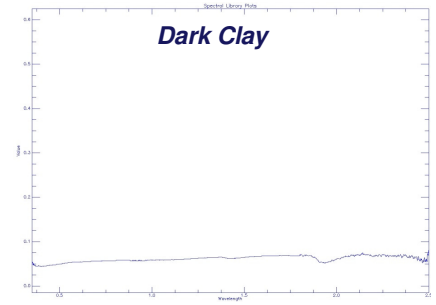


Typical XRD plot for London Clay

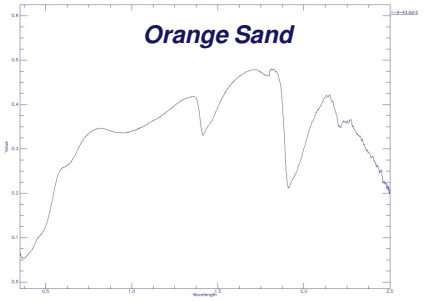


Typical Lab Spectra

- Sensitive to moisture, mineralogy, clay content, organics, plant health, particulate contaminants.....
- Relate to weathering, water movement, vegetation growth



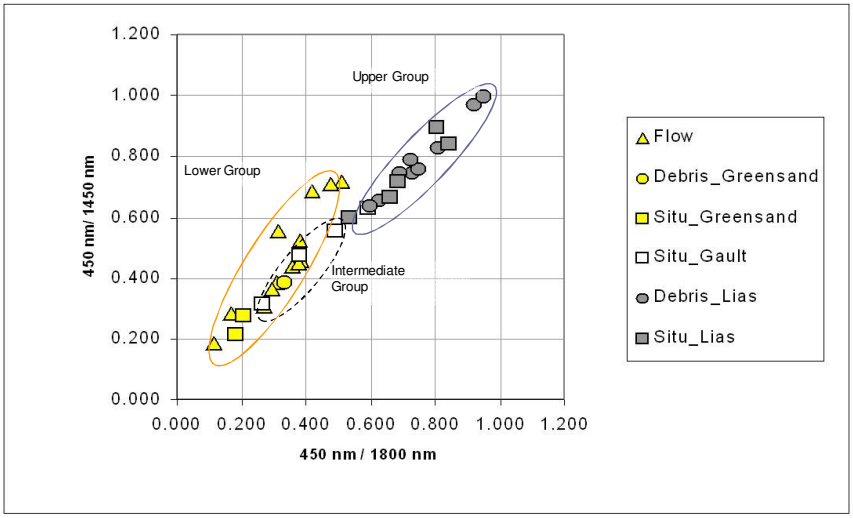
0 2500 nm



0 2500 nm

Landslide Debris

Particle Size Characterization

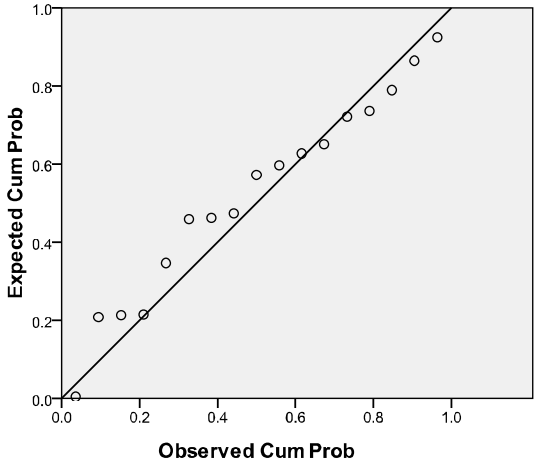


Particle Size Characterization

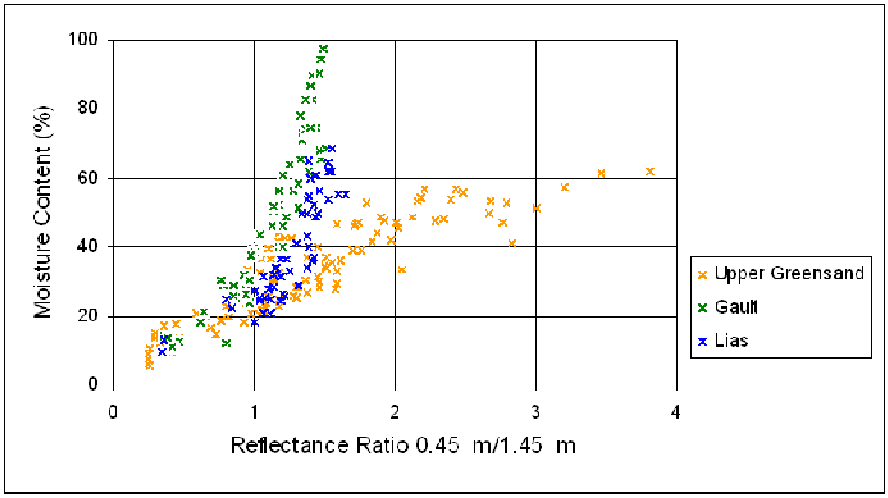
- Possible to predict article composition from 2-3 wavelengths

e.g. % clay

$=130.3-82.754*R(\lambda_{2204})$
$+937.388\ R(\lambda_{1411})$



Moisture Content



Next Steps

- Black Venn Study: debris flow mobility – does the mixing of debris flow materials relate to how mobile it is? Debris flow mechanics.
- China Bailong Corridor (Zhouqu Debris Flow – Lanzhou Uni): properties of source materials with debris flow mobility.

Current Research Projects: Engineering NIR Stratigraphy London Clay (Hampshire Basin) White Cliff Bay - Isle of Wight

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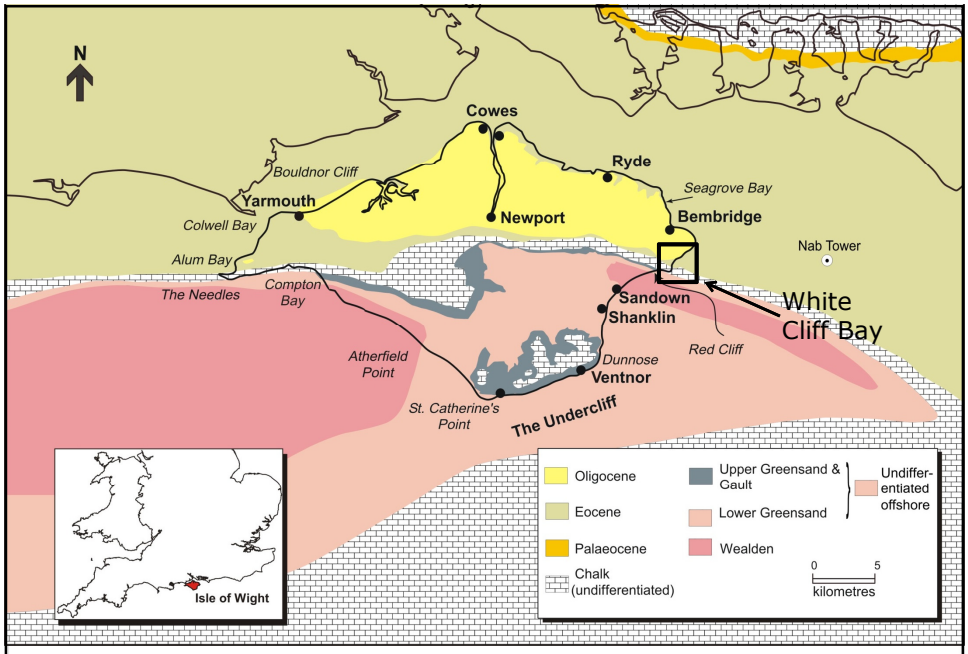

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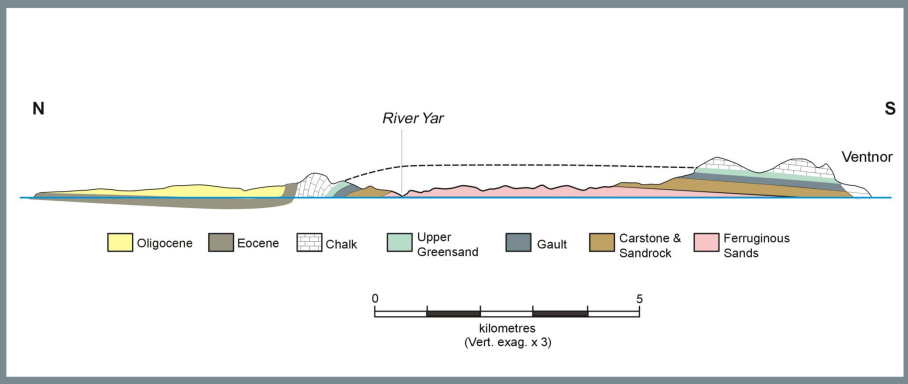

Geological section (N-S) of the Isle of Wight (after Institute of Geological Sciences, 1976)

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ALAN HOLIDAY - AERIAL PHOTOGRAPH: A VIEW ABOVE LONG LEDGE, BEMBRIDGE LOOKING SW TOWARDS SANDOWN AND BRADING. Whtecliff Bay is in the centre-left of the photograph. The Bembridge Limestone of the Solent Group can be seen descending in the cliffs until it forms the sea ledges at Bembridge. The landward edge of the ledge, in front of the grounds of the Bembridge Boarding Campus, is the location - Black Rock. In the far left are the Chalk cliffs of Culver Down. Photograph: Alan Holiday, June 2011. Alan Holiday (c) 2011.

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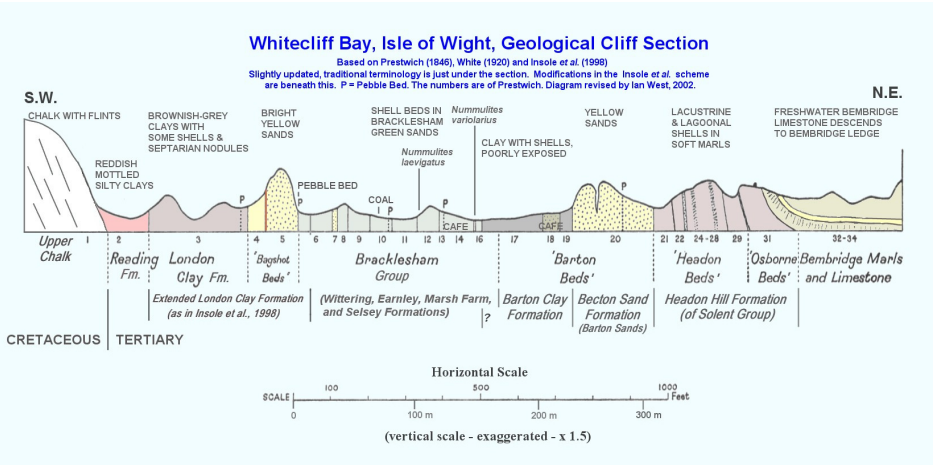
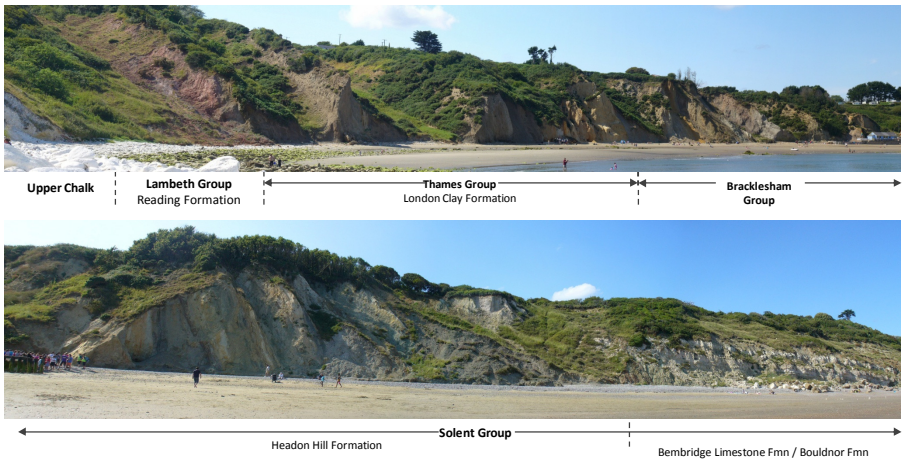
Geological Section White Cliff Bay – after Ian West



Spectral Stratigraphy of the London Clay Fmn



Sampling Whitecliff Bay SSSI

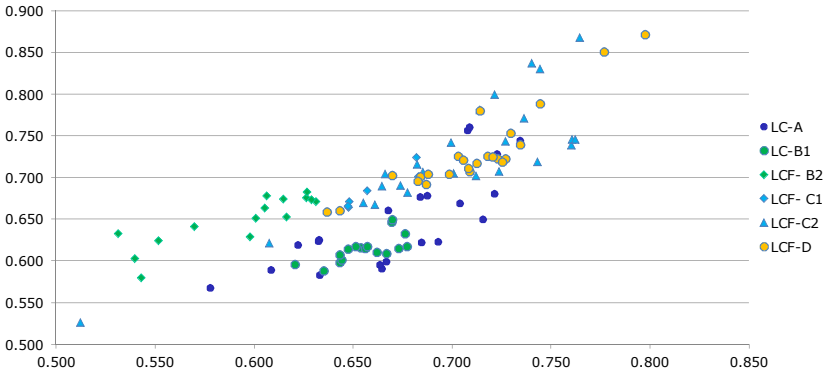
- Proof of concept study
- Sampling at 1m along cliff exposure

Spectral Testing London Clay

- Proof of concept study
- Samples tested in 'field', 'dry' and 'powdered; conditions

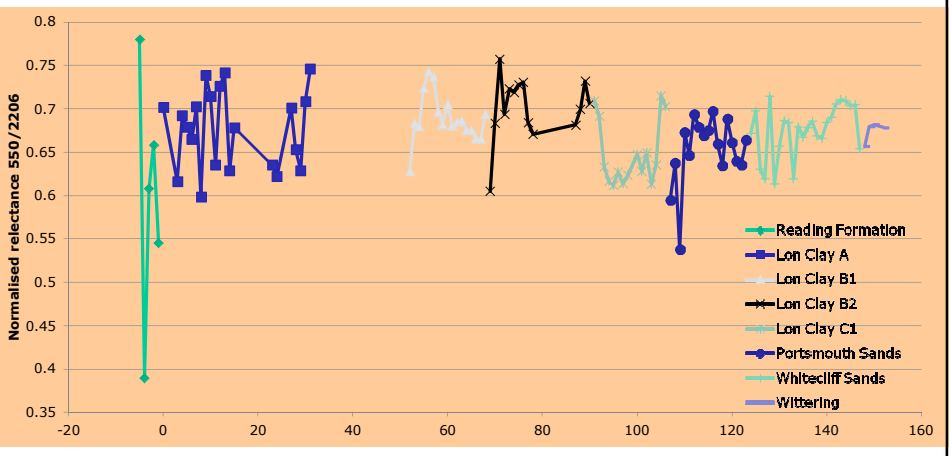
Mineralogical Analyses

- Difficult to establish exclusive mineral relationships

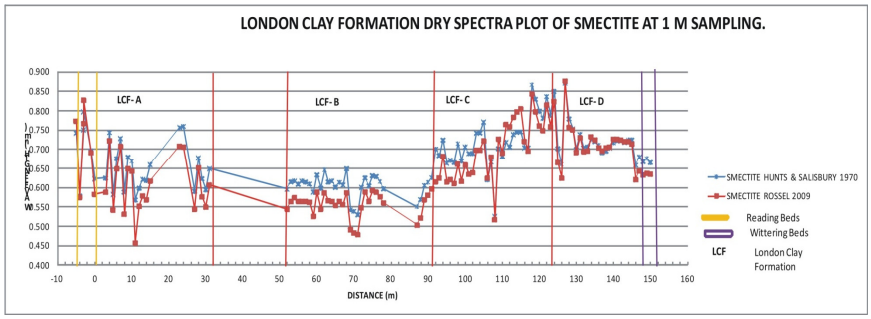


'Smectite' Log, Whitecliff Bay

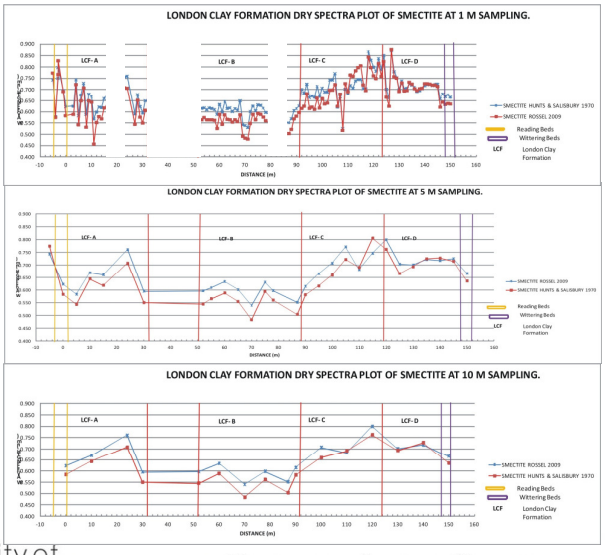
- Geological context is everything.....



'Smectite' Log, Whitecliff Bay

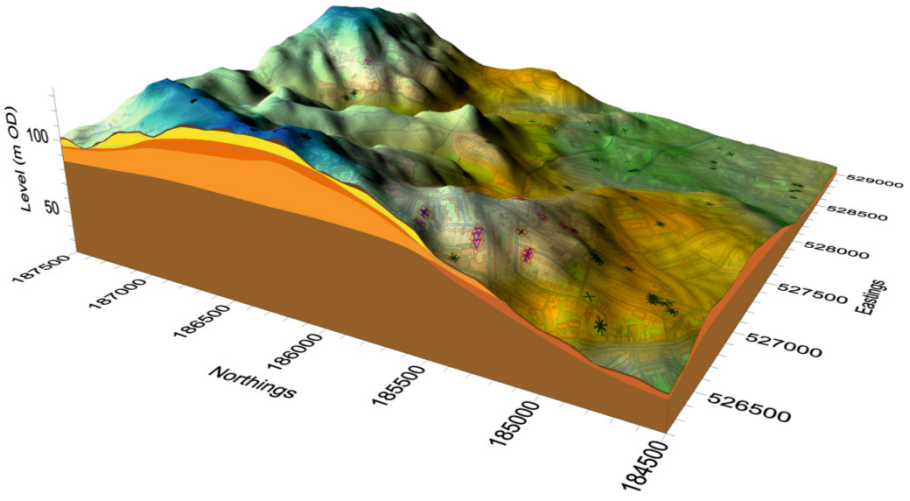


Logging Resolution?



Current Research Project: Geological controls on weathering using NIR

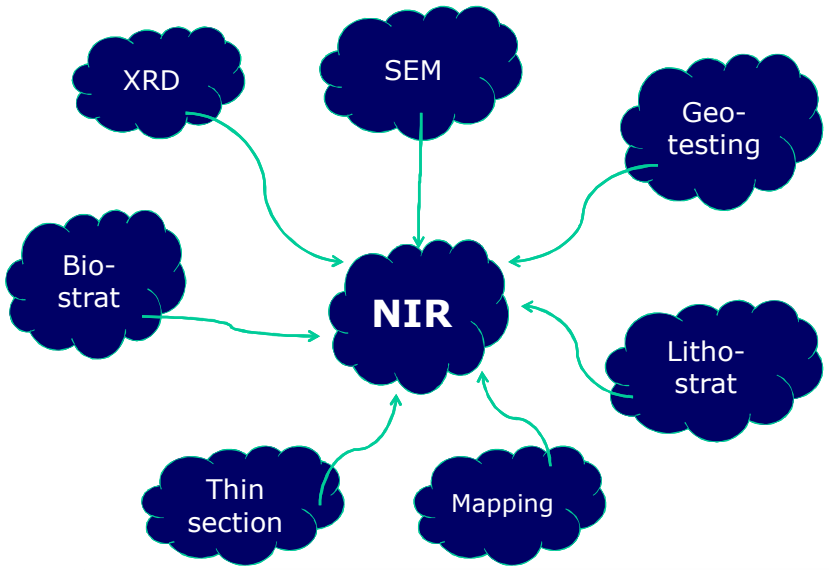
Geological Block Model of Hampstead



Geological controls on weathering using NIR

- Integrated Engineering Geological Approach
- Macro-scale (m)
- Meso-scale (mm)
- Micro-scale (µm)

Geological controls on weathering using NIR



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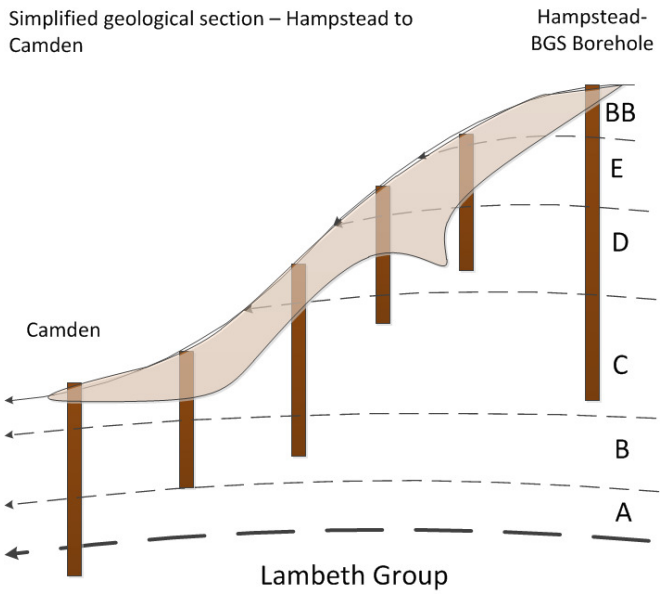
Simplified geological section – Hampstead to Camden



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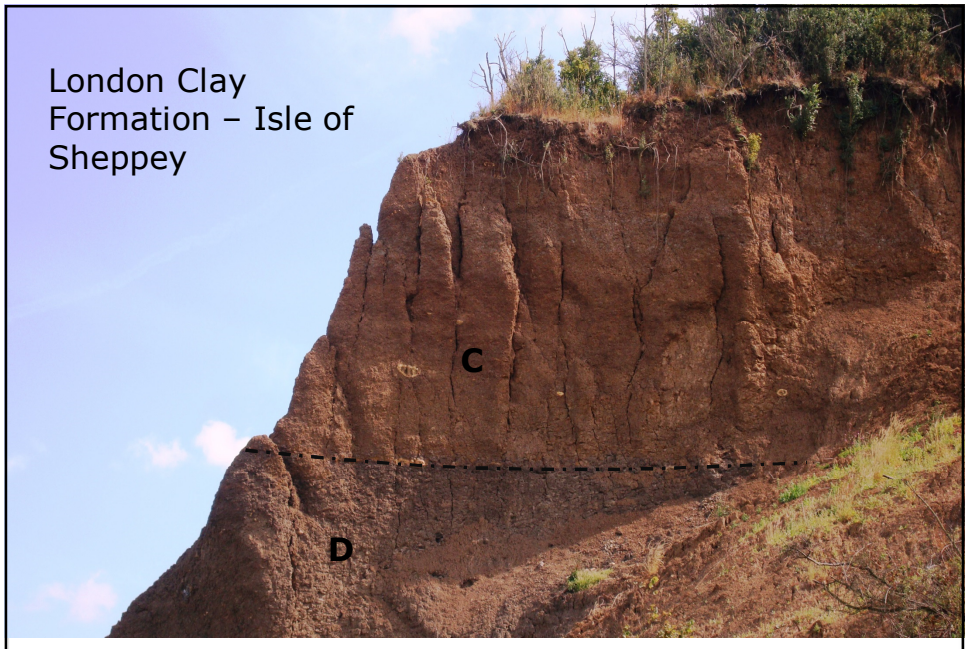

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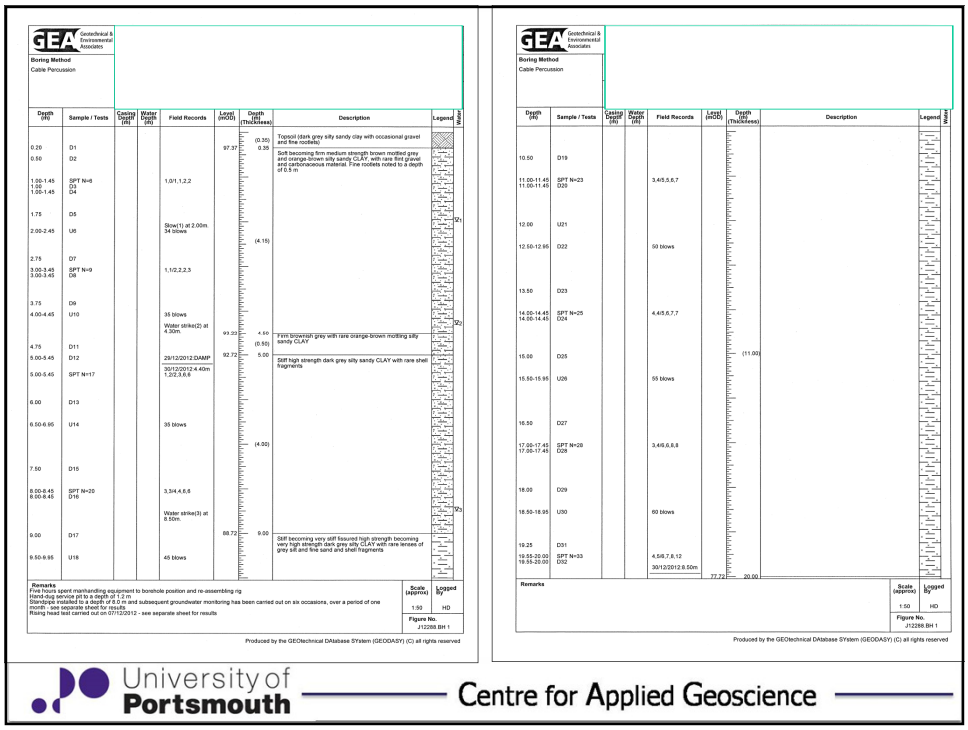
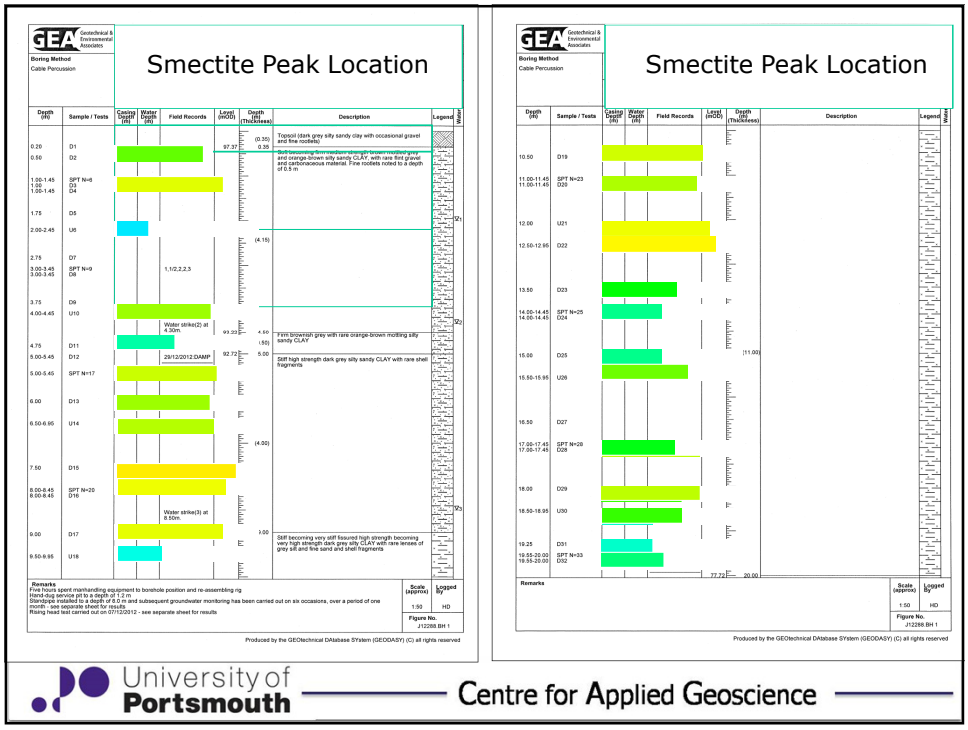

GEA
Geotechnical & Environmental Associates
Boring Method
Cable Percussion
Depth (m)
Sample / Tests
Casing Depth (m)
Water Depth (m)
Field Records
Level (mOD)
Depth (m) (Thickness)
Description
Legend
Water Strikes
0.20 D1
0.50 D2
1.00-1.45 SPT N=6
1.00 D3
1.00-1.45 D4
1.75 D5
2.00-2.45 U6
2.75 D7
3.00-3.45 SPT N=9
3.00-3.45 D8
3.75 D9
4.00-4.45 U10
4.75 D11
5.00-5.45 D12
5.00-5.45 SPT N=17
6.00 D13
6.50-6.95 U14
7.50 D15
8.00-8.45 SPT N=20
8.00-8.45 D16
9.00 D17
9.50-9.95 U18
1,0/1,1,2,2
Slow(1) at 2.00m. 34 blows
1,1/2,2,2,3
35 blows
Water strike(2) at 4.30m.
29/12/2012:DAMP
30/12/2012:4.40m 1,2/2,3,6,6
3,3/4,4,6,6
Water strike(3) at 8.50m.
45 blows
97.37
(0.35)
0.35
Topsoil (dark grey silty sandy clay with occasional gravel and fine rootlets)
Soft becoming firm medium strength brown mottled grey and orange-brown silty sandy CLAY, with rare flint gravel and carbonaceous material. Fine rootlets noted to a depth of 0.5 m
(4.15)
93.22
4.50
(0.50)
Firm brownish grey with rare orange-brown mottling silty sandy CLAY
92.72
5.00
Stiff high strength dark grey silty sandy CLAY with rare shell fragments
(4.00)
88.72
9.00
Stiff becoming very stiff fissured high strength becoming very high strength dark grey silty CLAY with rare lenses of grey silt and fine sand and shell fragments
Remarks
Five hours spent manhandling equipment to borehole position and re-assembling rig
Hand-dug service pit to a depth of 1.2 m
Standpipe installed to a depth of 8.0 m and subsequent groundwater monitoring has been carried out on six occasions, over a period of one month - see separate sheet for results
Rising head test carried out on 07/12/2012 - see separate sheet for results
Scale (approx)
1:50
Logged By
HD
Figure No.
J12288.BH 1
Produced by the GEOtechnical DAtabase SYstem (GEODASY) (C) all rights reserved
10.50 D19
11.00-11.45 SPT N=23
11.00-11.45 D20
12.00 U21
12.50-12.95 D22
13.50 D23
14.00-14.45 SPT N=25
14.00-14.45 D24
15.00 D25
15.50-15.95 U26
16.50 D27
17.00-17.45 SPT N=28
17.00-17.45 D28
18.00 D29
18.50-18.95 U30
19.25 D31
19.55-20.00 SPT N=33
19.55-20.00 D32
3,4/5,5,6,7
4,4/5,6,7,7
3,4/6,6,8,8
55 blows
60 blows
4,5/6,7,8,12
30/12/2012:8.50m
77.72
(11.00)
20.00


Smectite Peak Location
GEA
Geotechnical & Environmental Associates
Boring Method
Cable Percussion
Depth (m)
Sample / Tests
Casing Depth (m)
Water Depth (m)
Field Records
Level (mOD)
Depth (m) (Thickness)
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1.75 D5
2.00-2.45 U6
2.75 D7
3.00-3.45 SPT N=9
3.00-3.45 D8
3.75 D9
4.00-4.45 U10
4.75 D11
5.00-5.45 D12
5.00-5.45 SPT N=17
6.00 D13
6.50-6.95 U14
7.50 D15
8.00-8.45 SPT N=20
8.00-8.45 D16
9.00 D17
9.50-9.95 U18
1,0/1,1,2,2
Water strike(2) at 4.30m.
1,1/2,2,2,3
29/12/2012:DAMP
Water strike(3) at 8.50m.
97.37
(0.35)
0.35
Topsoil (dark grey silty sandy clay with occasional gravel and fine rootlets)
Soft becoming firm medium strength brown mottled grey and orange-brown silty sandy CLAY, with rare flint gravel and carbonaceous material. Fine rootlets noted to a depth of 0.5 m
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93.22
4.50
(0.50)
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5.00
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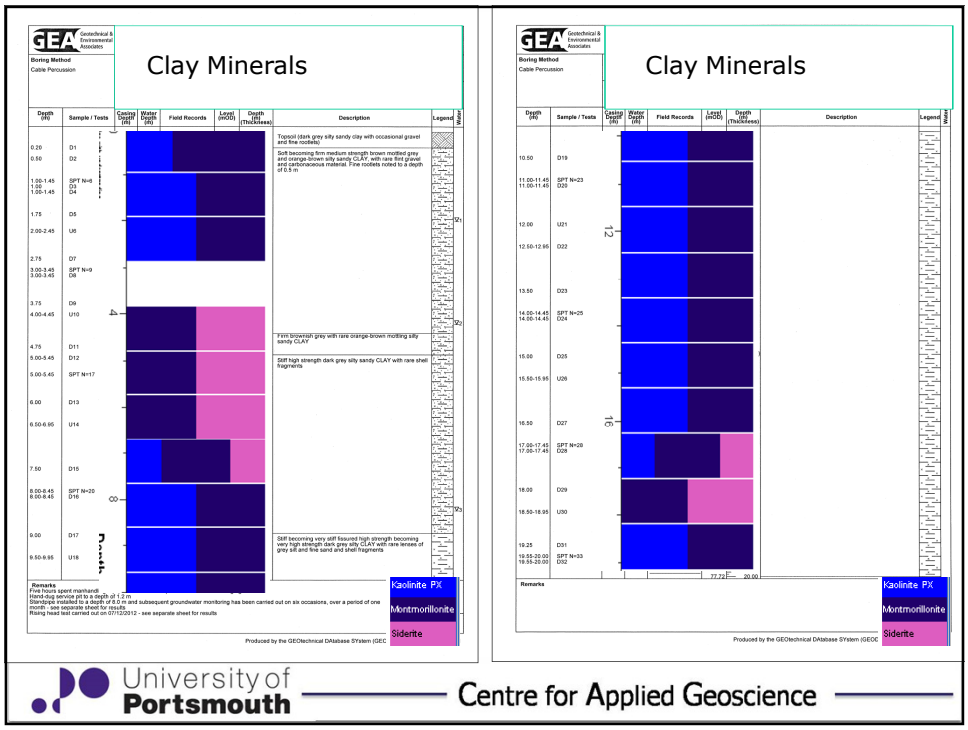
Standpipe installed to a depth of 8.0 m and subsequent groundwater monitoring has been carried out on six occasions, over a period of one month - see separate sheet for results
Rising head test carried out on 07/12/2012 - see separate sheet for results
Scale (approx)
1:50
Logged By
HD
Figure No.
J12288.BH 1
Produced by the GEOtechnical DAtabase SYstem (GEODASY) (C) all rights reserved
Smectite Peak Location
10.50 D19
11.00-11.45 SPT N=23
11.00-11.45 D20
12.00 U21
12.50-12.95 D22
13.50 D23
14.00-14.45 SPT N=25
14.00-14.45 D24
15.00 D25
15.50-15.95 U26
16.50 D27
17.00-17.45 SPT N=28
17.00-17.45 D28
18.00 D29
18.50-18.95 U30
19.25 D31
19.55-20.00 SPT N=33
19.55-20.00 D32
77.72
(11.00)
20.00


Clay Minerals
Kaolinite PX
Montmorillonite
Siderite
Clay Minerals
Kaolinite PX
Montmorillonite
Siderite
University of Portsmouth
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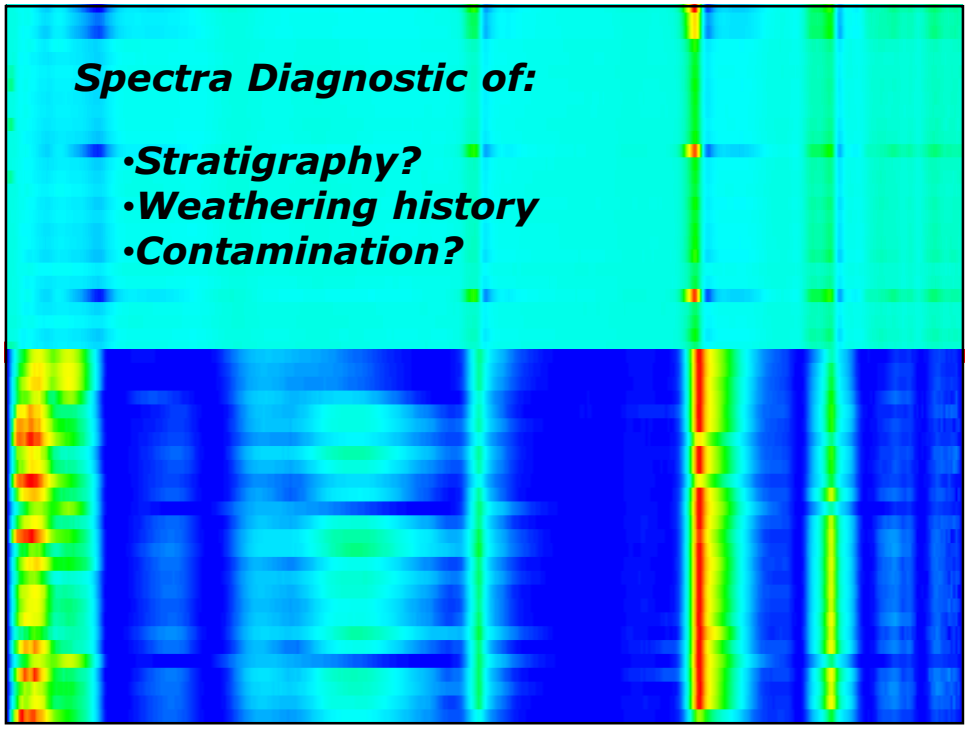
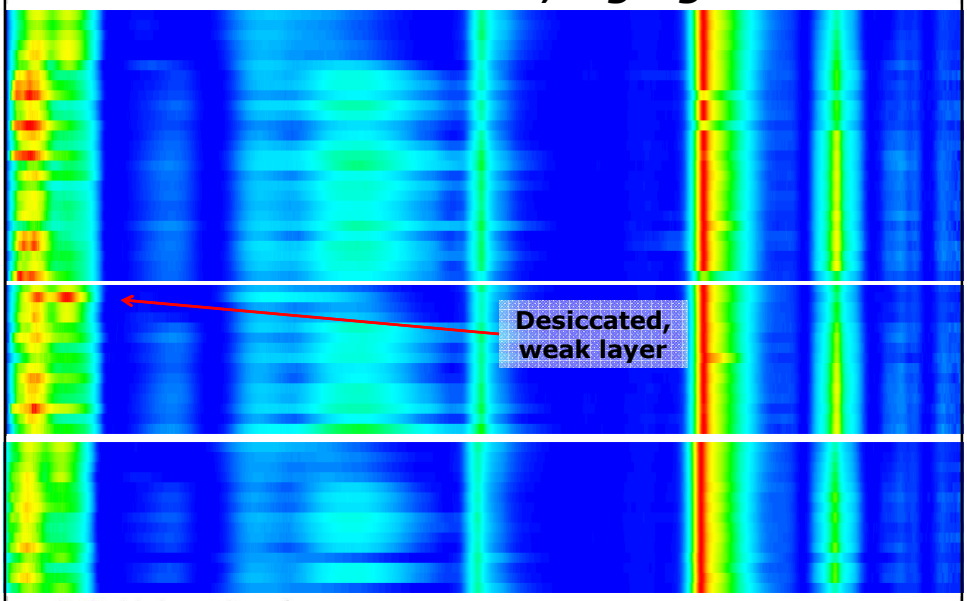

Spectra Diagnostic of:
•Stratigraphy?
•Weathering history
•Contamination?

Site 1 – Boreholes N-S; Mg-Cg-Lc



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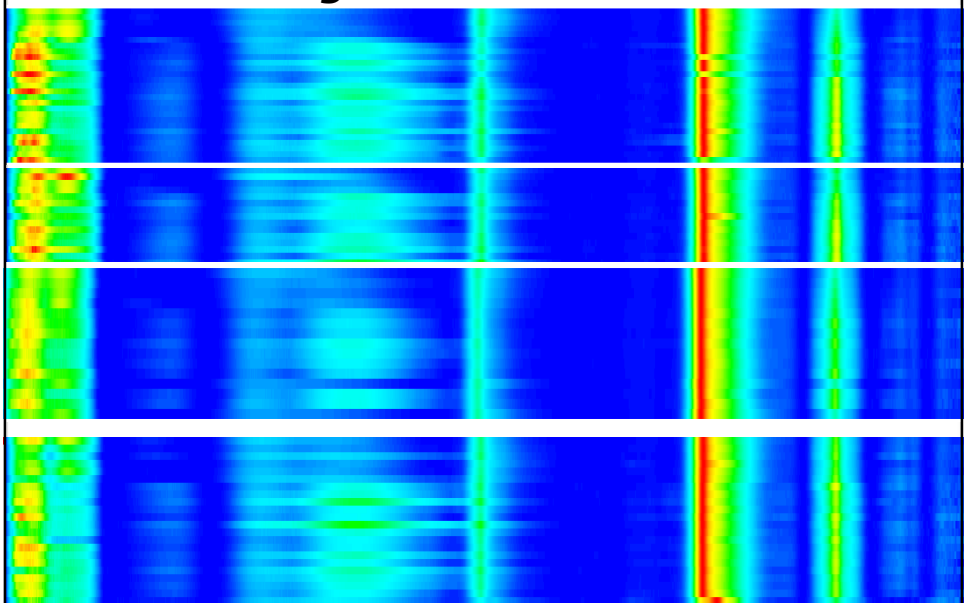
Site 1 + Neighbour



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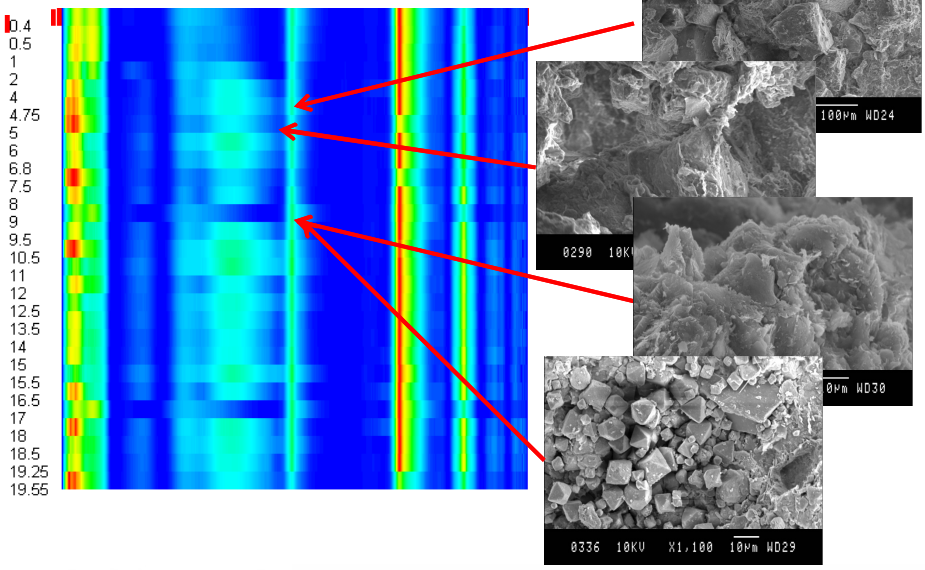
Where we are now.....



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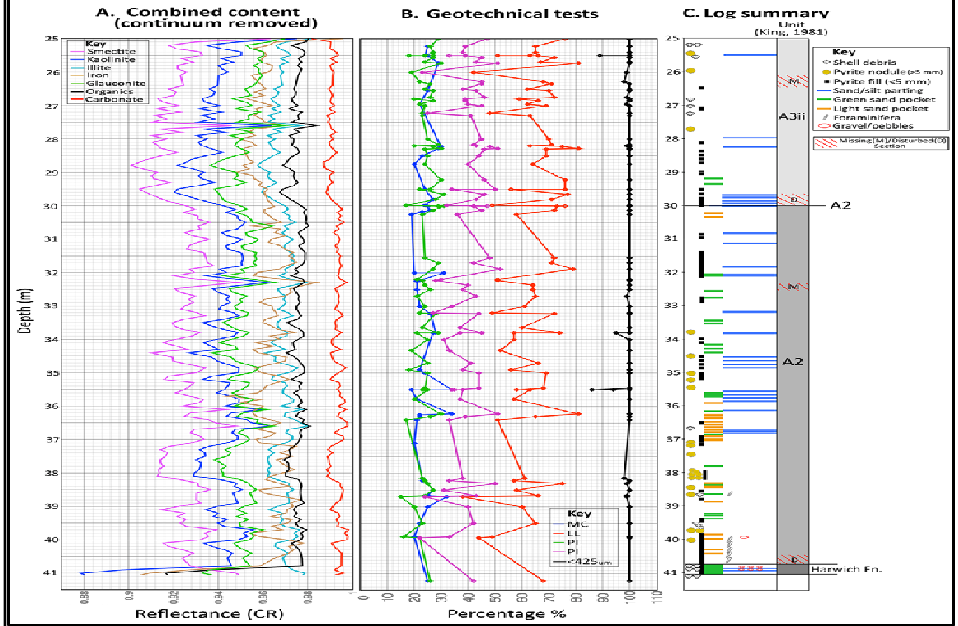
Comparison of spectral, geotechnical and stratigraphic features



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Next Steps

- Develop site/lab sensors
- Replace/add value to some existing tests.....

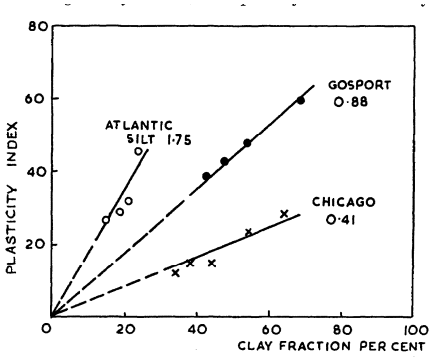

FIG. 4.—Graphs of the relation between plasticity index and per cent. clay fraction for three clays. The numbers refer to the "activity" (= plasticity index/clay fraction).

Skempton 1953

Thank you

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t: @appliedgeosci