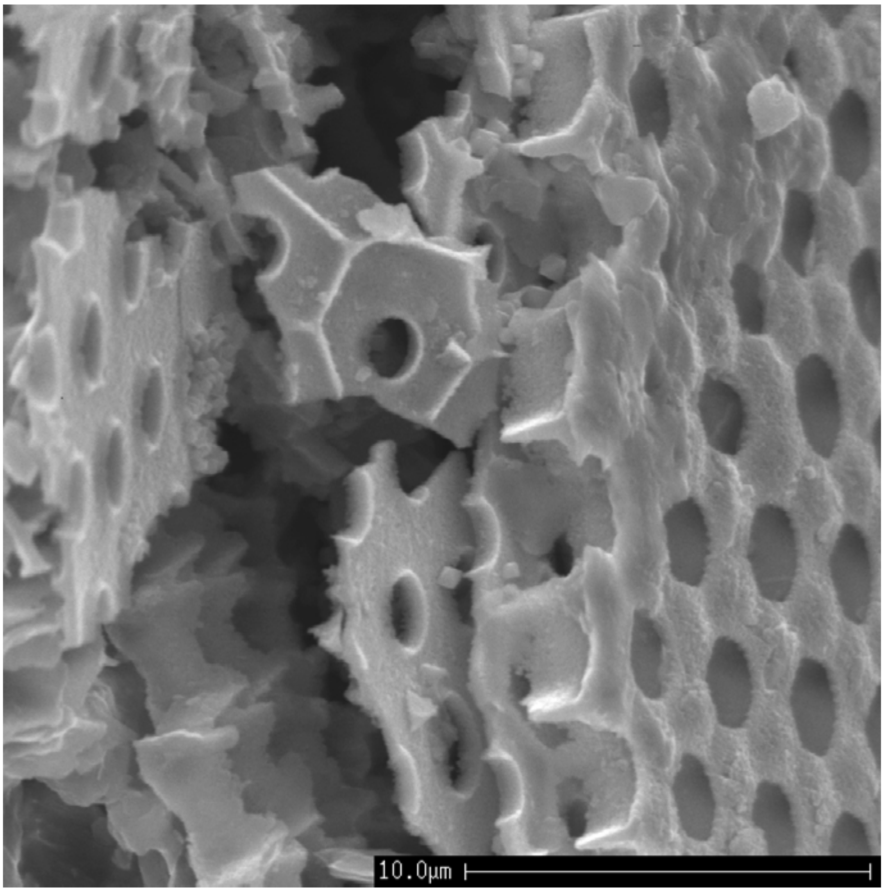
SEM Petrography of samples of the London Clay of southern England

Physical Hazards Programme

Internal Report IR/05/126



BRITISH GEOLOGICAL SURVEY

PHYSICAL HAZARDS PROGRAMME

INTERNAL REPORT IR/05/126

SEM Petrography of samples of the London Clay of southern England

J E Bouch

Keywords

London Clay, SEM, Petrography, Shrink-Swell.

Front cover

Detailed SEM image showing pyritised plant material from Hollingson Meads (Sample MPLL006).

Bibliographical reference

BOUCH, J.E.. 2006. SEM Petrography of samples of the London Clay of southern England. *British Geological Survey Internal Report*, IR/05/126. 42pp.

Keyworth, Nottingham British Geological Survey 2006

BRITISH GEOLOGICAL SURVEY

The full range of Survey publications is available from the BGS Sales Desks at Nottingham, Edinburgh and London; see contact details below or shop online at www.geologyshop.com

The London Information Office also maintains a reference collection of BGS publications including maps for consultation.

The Survey publishes an annual catalogue of its maps and other publications; this catalogue is available from any of the BGS Sales Desks.

The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as its basic research projects. It also undertakes programmes of British technical aid in geology in developing countries as arranged by the Department for International Development and other agencies.

The British Geological Survey is a component body of the Natural Environment Research Council.

British Geological Survey offices

Keyworth, Nottingham NG12 5GG
☎ 0115-936 3241 Fax 0115-936 3488
e-mail: sales@bgs.ac.uk
www.bgs.ac.uk
Shop online at: www.geologyshop.com

Murchison House, West Mains Road, Edinburgh EH9 3LA
☎ 0131-667 1000 Fax 0131-668 2683
e-mail: scotsales@bgs.ac.uk

London Information Office at the Natural History Museum (Earth Galleries), Exhibition Road, South Kensington, London SW7 2DE
☎ 020-7589 4090 Fax 020-7584 8270
☎ 020-7942 5344/45 email: bgslondon@bgs.ac.uk

Forde House, Park Five Business Centre, Harrier Way, Sowton, Exeter, Devon EX2 7HU
☎ 01392-445271 Fax 01392-445371

Geological Survey of Northern Ireland, Colby House, Stranmillis Court, Belfast, BT9 5BF
☎ 028-9038 8462 Fax 028-9038 8461

Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB
☎ 01491-838800 Fax 01491-692345

Sophia House, 28 Cathedral Road, Cardiff, CF11 9LJ
☎ 029–2066 0147 Fax 029–2066 0159

Parent Body

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1EU
☎ 01793-411500 Fax 01793-411501
www.nerc.ac.uk

Foreword

This report is the published product of a study by the British Geological Survey (BGS). It refers to work carried out as part of the Science Budget project investigating the shrink-swell properties of London Clay Formation mudstones in England, under the Physical Hazards Programme. The work provides petrographical descriptions (based on scanning electron microscope observations) of material derived from the London Clay.

Acknowledgements

This work has benefited from advice received from various members of the Shrink/Swell project team. Gren Turner is thanked for assistance in preparing the SEM stubs from occasionally difficult materials.

Contents

FIGURES

TABLES

Summary

This report summarises work undertaken in support of the Ground Movements: Shrink/Swell Project undertaken as part of the BGS Physical hazards Programme. It provides petrographical descriptions acquired using scanning electron microscopy (SEM) of a suite of samples (n = 24, from 19 sites) collected from the London Clay of the London and Hampshire Basins in southern England.

The analysis indicates that the samples from both basins display considerable variations in grain size both on a millimetric scale (mm-scale laminae of clay-rich, or silt-rich or fine-sand material), and also on a regional scale, with a broad trend to increasing grain size and decreasing clay-content from NE to SW.

The clay content of a given mudstone is likely to be an important factor in governing the shrinking and swelling capacity of the London Clay at a given site – clearly if clay is volumetrically of minor significance within the sediment, then it will have proportionally less impact on sediment volume as it shrinks/swells, irrespective of it's mineralogy. As might be anticipated, porosities, and hence permeabilities, will be higher where grain sizes are coarser, this will affect the susceptibility of the lithology at a given site to wetting/drying. It is recommended that a more quantitative assessment of sediment grain size is carried out.

X-ray microchemical analyses qualitatively confirm the results of XRD analysis (Kemp and Wagner 2006), indicating that the clays are dominated by illite and smectite species, which might be expected to undergo significant shrinking and swelling in response to wetting and drying.

1 Introduction

1.1 GEOLOGICAL BACKGROUND

The London Clay Formation occurs in two separate basins in Southern England, the London and Hampshire basins (Figure 1). The deposits in each basin are currently separated by an outcrop of underlying Cretaceous rocks, across which the London Clay was originally continuous.

The London Clay was deposited during Eocene times, when a shallow sea initially transgressed over the area now represented by the North Sea Basin, including coastal areas of Germany, Holland, Belgium and England (Davis and Elliott, 1957). During early London Clay deposition, the area of the Hampshire Basin was not transgressed, and the London Clay sea opened to the north with cool water connections. The sea then transgressed further, encompassing the Hampshire Basin and opening a connection to warmer waters from the Tethys which brought a change in marine fauna into the sea. This sea then regressed eastwards, became shallower and eventually dried out.

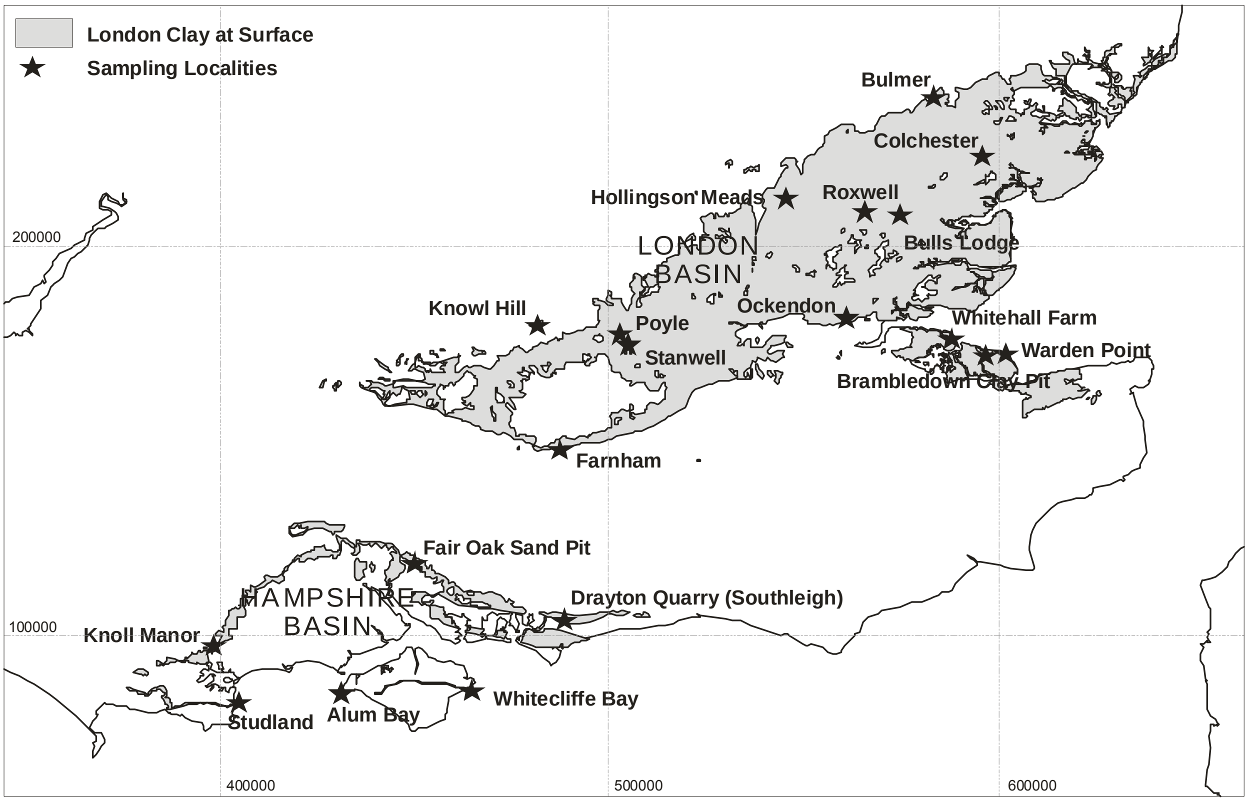


Figure 1 Location map showing the distribution of London Clay at surface, and the locations of the study sites.

On the basis of microfauna, the London Clay is separated into 5 divisions (A to E; King 1981), with an additional "Basal Bed Member". The main lithology of the Formation in the London Basin, is a stiff clay. However, there are lithological and mineralogical variations both vertically and laterally. Most notably, there is a general increase in sand content, with a corresponding decline in clay content, from east-to-west (Davis and Elliott 1957; Burnett and Fookes 1974), and the deposits in the Hampshire Basin are notably sandier than those in the London Basin.

The dominant clay minerals within the Formation are montmorillonite and illite (Gilkes 1968), although Gilkes (1968) identified two clay provinces that were sourcing clay: a western province supplying illite-kaolinite and a western province supplying montmorillonite. Furthermore, montmorillonite contents are higher in basal transgressive phases of deposition, and kaolinite contents are higher in phases with a greater continental affinity (Burnett and Fookes 1974).

Huggett and Gale (1998) provide a relatively recent account of the petrographical and diagenetic characteristics of the London Clay from the Hampshire Basin, and report extensive bioturbation and highly variable clay:sand proportions within a vertical section of the Formation. There is little variation in the relative proportions of clay minerals, and illite and smectite are the dominant clay phases present. The deposits are overprinted by minor amounts of early/shallow diagenetic phases such as pyrite, siderite, ferroan calcite, and rare kaolinite. Some faecal matter in burrows has been replaced by glauconite, and phyllosilicates are locally replaced by coarsely crystalline kaolinite. Within the London Clay concretionary calcite is also locally developed, and preserves a record of early diagenetic effects (Huggett 1994).

2 Samples and Methods

The studied samples were collected from 19 sites across the UK. The locations, stratigraphy and the general characteristics of the 25 samples are given in Table 1. Throughout this report the samples are referred to using the site name, and the Mineralogy and Petrology Laboratories "MPL" sample code of the sub-sample used for petrographical analysis. Qualitative X-ray Diffraction (XRD) analyses, surface area analysis data and XRF data for the majority of samples were reported by Kemp and Wagner (2006). Wilkinson (2004a, b, 2005) provides ages for each sample based on the microfossil assemblage, according to the scheme of King (1981).

For scanning electron microscope (SEM) analysis, approximately centimetre-sized blocks of material were excavated from the central (i.e. least likely to be disturbed) portions of the hand-specimen samples, and were air-dried. Once dry, a fresh fracture surface was prepared for each stub, with at least one fracture surface perpendicular to lamination prepared for each sample where possible. In addition to these fresh fracture surfaces, a number of samples, also had surfaces prepared by cutting with a scalpel. Whilst this preparation disturbs some details of the structural relationships between the fine particles, it has the advantage of creating a relatively flat surface upon which compositional variations, as inferred from variations in back-scattered electron intensity (BSEM), are more apparent.

The stubs were carbon-coated and analysed using a Cambridge-Leica S360 SEM fitted with an Oxford Instruments INCA system (for mineral identification by qualitative and semi-quantitative energy-dispersive X-ray analysis; EDXA).

Table 1 List of sampling locations and samples studied.

Basin	MPL Code	Location	County	Grid ref	Sample Name	**SEM**	XRD	XRF	Paleontology	*Division*
London	MPLK206	Bulmer	Essex	TL 832 382	Bulmer	**Y**	Y	Y	Y	*Upper D-E*
	MPLK615	Colchester	Essex	TL 955 226	Colchester S1	**Y**	Y	Y	Y	*A*
	MPLK616	Colchester	Essex	TL 955 226	Colchester S2	**-**	Y	-	Y	*A*
	MPLL006	Hollingson Meads	Hertfordshire	TL 453 126	Hollingson	**Y**	Y	Y	Y	*A*
	MPLL005	Roxwell	Essex	TL 657 088	Roxwell	**Y**	Y	-	Y	*B-C*
	MPLK614	Bulls Lodge	Essex	TL 747 085	Bulls Lodge	**Y**	Y	Y	Y	*A*
	MPLK612	Ockenden	Essex	TQ 614 820	Ockenden S1	**Y**	Y	Y	Y	*A*
	MPLK613	Ockenden	Essex	TQ 614 820	Ockenden S2	**Y**	Y	-	Y	*A*
	MPLK205	Knowl Hill	Berkshire	SU 816 795	Knowl Hill	**Y**	Y	Y	Y	*B-C*
	MPLK618	Poyle	Surry	TQ 028 766	Poyle	**Y**	Y	Y	Y	--
	MPLK207	Whitehall Farm	Kent	TQ 882 762	Grain Quarry S1	**Y**	Y	-	Y	*B-C*
	MPLK208	Whitehall Farm	Kent	TQ 882 762	Grain Quarry S2	**Y**	Y	Y	Y	*B-C*
	MPLK619	Stanwell	Surry	TQ 049 746	Stanwell	**Y**	Y	Y	Y	*B1*
	MPLK209	Warden Point	Kent	TR 020 724	Warden Point	**Y**	Y	-	Y	*B-C*
	MPLK210	Brambledown	Kent	TQ 967 715	Brambledown	**Y**	Y	Y	Y	*B1*
	MPLK617	Farnham	Surry	SU 877 475	Farnham	**Y**	Y	Y	Y	--
Hampshire	MPLK211	Fair Oak Sand Pit	Hampshire	SU 504 183	Fair Oak Sand Pit	**Y**	Y	Y	Y	--
	MPLK212	Southleigh (Drayton Quarry)	West Sussex	SU 886 043	Southleigh	**Y**	Y	-	Y	*C*
	MPLK217	Knoll Manor	Dorset	SY 977 730	Knoll Manor S1	**Y**	Y	Y	Y	--
	MPLK218	Knoll Manor	Dorset	SY 977 730	Knoll Manor S2	**Y**	Y	Y	Y	--
	MPLK213	Whitecliff Bay	Isle of White	SZ 643 580	Whitecliff Bay S1	**Y**	Y	-	Y	*A*
	MPLK214	Whitecliff Bay	Isle of White	SZ 643 580	Whitecliff Bay S2	**Y**	Y	-	Y	*A*
	MPLK215	Alum Bay	Isle of White	SZ 307 530	Alum Bay S1	**Y**	Y	Y	Y	*A*
	MPLK216	Alum Bay	Isle of White	SZ 307 530	Alum Bay S2	**Y**	Y	Y	Y	*A*
	MPLK219	Studland	Dorset	SZ 043 240	Studland	**Y**	Y	Y	Y	--

3 Results

Descriptions of individual samples, including representative photomicrographs are given in Appendix 1. The following sections, and Table 2 summarise the key petrographical characteristics of the samples from each basin. However, given the previously identified heterogeneity in the London Clay Formation, which is confirmed by these new observations, the sample set available here does not have sufficient coverage to provide a thorough assessment of any systematic lateral/vertical variations through the formation.

Table 2 Qualitative descriptions of clay, silt and sand contents of samples studied.

Basin	MPL Code	Sample Name	*Division*	Overall Character (Qualitative)	Clay Content (% visual estimate)	Maximum Grain Size (µm visual estimate)
London	MPLK206	Bulmer	*Upper D-E*	silty	70	60
	MPLK615	Colchester S1	*A*	silty	70	80
	MPLK616	Colchester S2	*A*	*No SEM Sample*	--	--
	MPLL006	Hollingson	*A*	silty, with sandy lamina	variable	120
	MPLL005	Roxwell	*B-C*	muddy	100	-
	MPLK614	Bulls Lodge	*A*	muddy	100	-
	MPLK612	Ockenden S1	*A*	muddy	100	-
	MPLK613	Ockenden S2	*A*	silty-sandy	70	100
	MPLK205	Knowl Hill	*B-C*	muddy	100	-
	MPLK618	Poyle	--	heterogeneous silty-muddy	90	50
	MPLK207	Grain Quarry S1	*B-C*	?weathered, silty	80	60
	MPLK208	Grain Quarry S2	*B-C*	muddy	100	-
	MPLK619	Stanwell	*B1*	muddy	100	-
	MPLK209	Warden Point	*B-C*	muddy	100	-
	MPLK210	Brambledown	*B1*	muddy	100	-
	MPLK617	Farnham	--	muddy	100	-
Hampshire	MPLK211	Fair Oak Sand Pit	--	sandy	60	150
	MPLK212	Southleigh	*C*	sandy	50	100
	MPLK217	Knoll Manor S1	--	coarse sandy	20	500
	MPLK218	Knoll Manor S2	--	silty	60	60
	MPLK213	Whitecliff Bay S1	*A*	silty	50	100
	MPLK214	Whitecliff Bay S2	*A*	silty	80	60
	MPLK215	Alum Bay S1	*A*	silty	50	100
	MPLK216	Alum Bay S2	*A*	silty	70	100
	MPLK219	Studland	--	?weathered, silty	70	60

3.1 LONDON BASIN

As might be expected, the samples display considerable variation in prevailing grain size – with some samples being mud-dominated, silt/sand-poor mudstones (e.g. MPLL005 Roxwell; Figure 2), whereas others are silt and/or sand-rich (e.g. MPLL006 Hollingson meads; Figure 3). Grain size also commonly varies on a fine scale, with individual laminae or domains of mud-rich and silt/sand-rich material occurring within the same SEM stub. The amount of silt/sand present within a given layer would be anticipated to have a significant impact upon the shrink-swell capacity of the formation at that location. Table 2 provides a crude, qualitative assessment of whether an individual sample is generally muddy, silty or sandy in character, and an estimation as to its clay content and maximum grain size. However, it is suggested that more quantitative measurements of grain size are made, to enable closer interpretation of the results of the engineering tests currently being conducted (Freeborough and Jones 2006; Nelder and Jones 2004).

Within the **mudstone samples**, fabrics range from massive to well laminated, however in all cases individual particles are relatively tightly packed and porosities are relatively low (Figure 2). EDXA of the clays was not particularly diagnostic, with most samples returning a K, Fe, ±Mg-bearing clay possibly indicative of illite, illite-smectite or smectite. Kaolinite was also detected, but this was rare relative to the supposed illite/smectite. These qualitative observations are consistent with the results of XRD analysis (Kemp and Wagner 2006). The majority of the clay had a ragged platy appearance indicative of a detrital origin, however, minor amounts of fibrous outgrowths were locally noted suggesting incipient neomorphism of the clay.

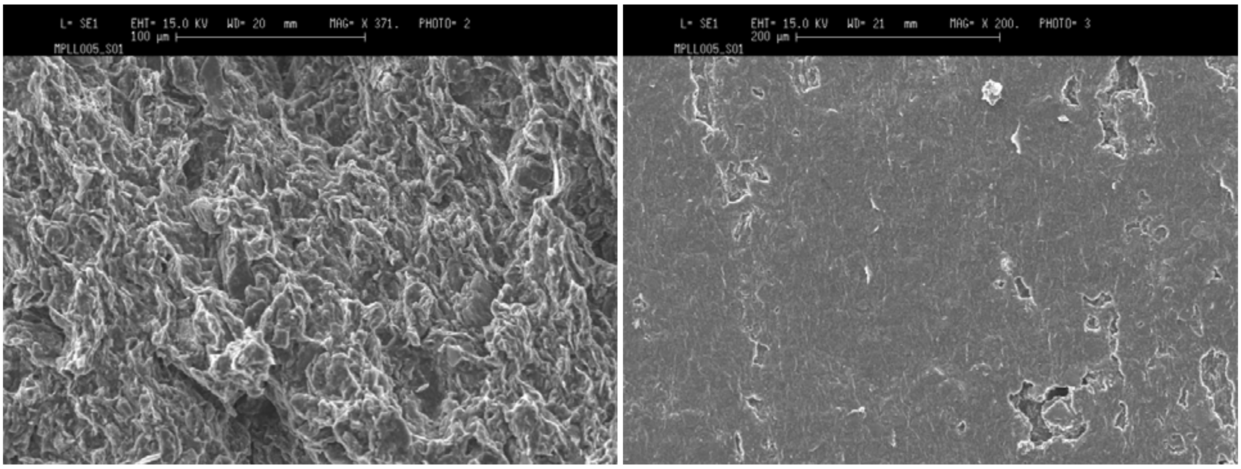


Figure 2 SEM images of fresh fracture surface (left) and cut surface (right) of a muddy sample from the London Basin. The prevailing grain size is seen to be very low, and the cut surface has a smooth appearance, with only small amounts of porosity visible. (Sample MPLL005 Roxwell).

Within the **silty and sandy samples** the granular material is dominated by quartz with subordinate feldspar and micas. The amount of interstitial/matrix clay is typically high (usually making up in excess of 70% of the sample), however some particularly coarse-grained, clay-poor laminae contain appreciable porosity (Figure 3). EDXA suggests that this clay is of the same composition as that seen in the muddier samples. Grain size variations within a single sample, occur either between laminations or between more irregular domains that possibly represent bioturbation (although this can't be proved on the scale of the samples used for SEM stubs).

Other detrital components observed include rare shelly debris (sample MPLK619 Stanwell), and micas.

Diagenetic Overprinting. The majority of samples displayed only minor evidence for diagenetic overprinting. As noted above, minor amounts of authigenic clay were locally observed. Patches of pyrite were commonly observed, and in some cases these were clearly replacive of organic material (Figure 4), but clusters of micron-scale octahedral and framboids are more common, and locally occur along channel or burrow-like features (e.g. sample MPLK205 Knowl Hill).

Post-sampling effects. A large number of samples of both muddy and silty/sandy samples contain well-developed gypsum/anhydrite which is almost certainly developed in response to drying out of the samples and oxidation of pyrite. In addition, both samples from Ockenden (MPLK612 and MPLK613) contain bacterial material on their surfaces (Figure 4).

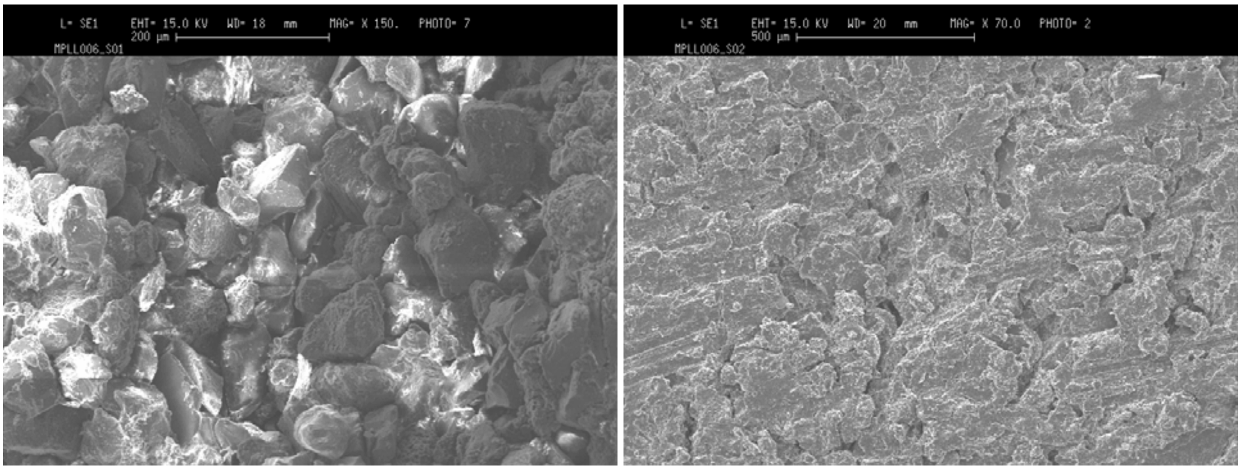


Figure 3 SEM images of fresh fracture surface (left) and cut surface (right) of a sandy sample from the London Basin. The fresh fracture surface image is from a particularly coarse-grained and clay-poor lamina. Significant intergranular porosity is evident. In the image of the cut surface, the coarser-grained nature of the material is readily apparent, with the cut surface being irregular, extensively striated by silt/sand grains dragged across the surface during cutting, and exposing significant amounts of intergranular porosity. (Sample MPLL006, Hollingson Meads)

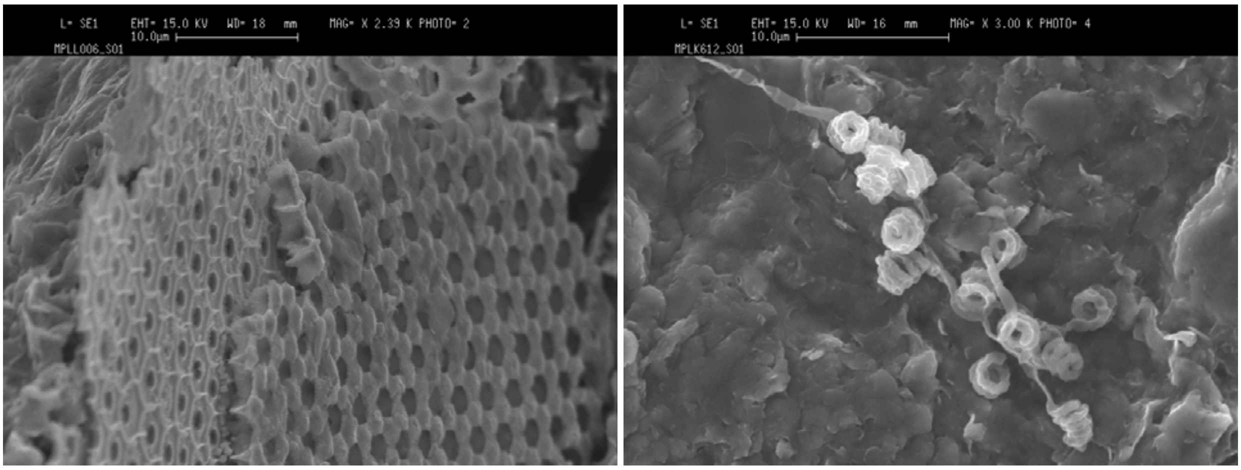


Figure 4 SEM image of pyritised plant material (left) and filaments and spiral bacteria (right). (Samples: Left - MPLL006 Hollingson Meads, right – MPLK612 Ockenden).

3.2 HAMPSHIRE BASIN

Although a similar overall range in grain size is observed in the samples from both basins, the samples from the Hampshire Basin are in general coarser-grained, siltier/sandier and less clay-rich than those from the London (Table 2 and Figure 5). This reflects the general E-W coarsening trend previously established (Davis and Elliott 1957, Burnett and Fookes 1974).

The silt and sand particles are dominated by quartz with subordinate feldspar. Interstitial clay abundances range from very low to very high: some sandy laminae are grain-supported others are matrix supported (e.g. within sample MPLK212 Southleigh). EDXA of the clay indicates similarly Fe, K, ±Mg bearing compositions consistent with illite, illite-smectite or smectite.

One sample (MPLK219 Studland) is relatively unusual in that it is made up of rounded aggregates of clay and silt-grade grains typically of between 100-300 µm diameter. This sample also has an unusual clay mineralogy overwhelmingly dominated by a mixed kaolinite-smectite species (Kemp and Wagner 2006). This is further substantiated by EDXA observations made during SEM analysis, which indicates a composition consistent with that of kaolinite.

A similarly light degree of **diagenetic overprinting** to that seen in the London Basin is observed with minor amounts of authigenic clay developed as fine crenulations on detrital substrates. Pyrite is widespread, typically as framboids and octahedra, but also replacing bioclastic material (e.g. sample MPLK214 Whitecliff bay). In addition, minor amounts of micro-rhombic dolomite have formed within the clay matrices (e.g. sample MPLK614 Whitecliff Bay), feldspars are locally lightly corroded (e.g. sample MPLK216 Alum bay), and biotite is locally altered to Fe-oxides (Figure 6).

As seen in the London Basin, **post-sampling effects** have caused the formation of locally significant gypsum/anhydrite on sample surface (Figure 6), and one sample (MPLK212 Southleigh) contains clusters of bacterial filaments.

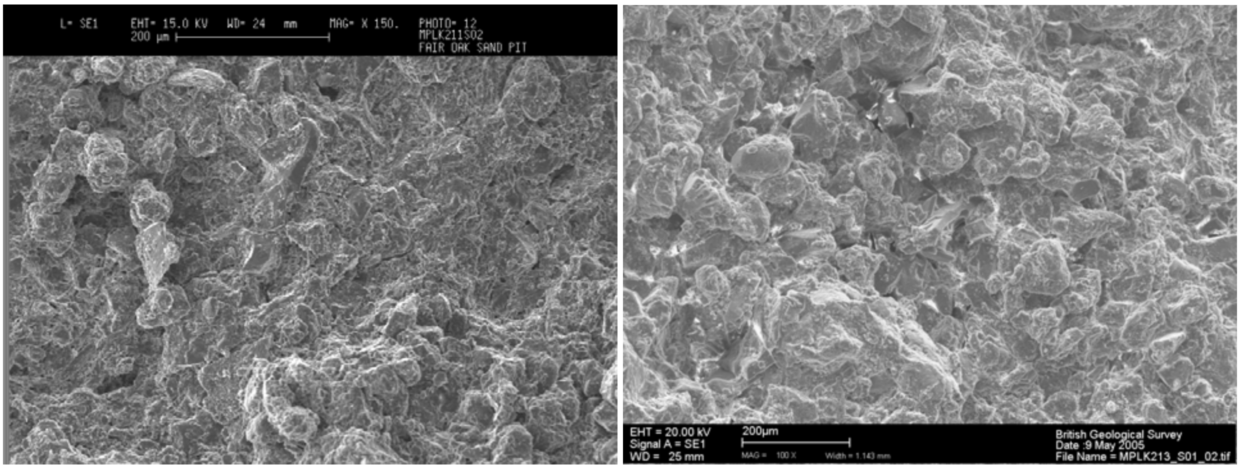


Figure 5 Representative SEM photomicrographs of silty mudstones from the Hampshire Basin. (Samples: Left – MPLK211 Fair Oak Sand Pit, right – MPLK213 Whitecliff Bay.)

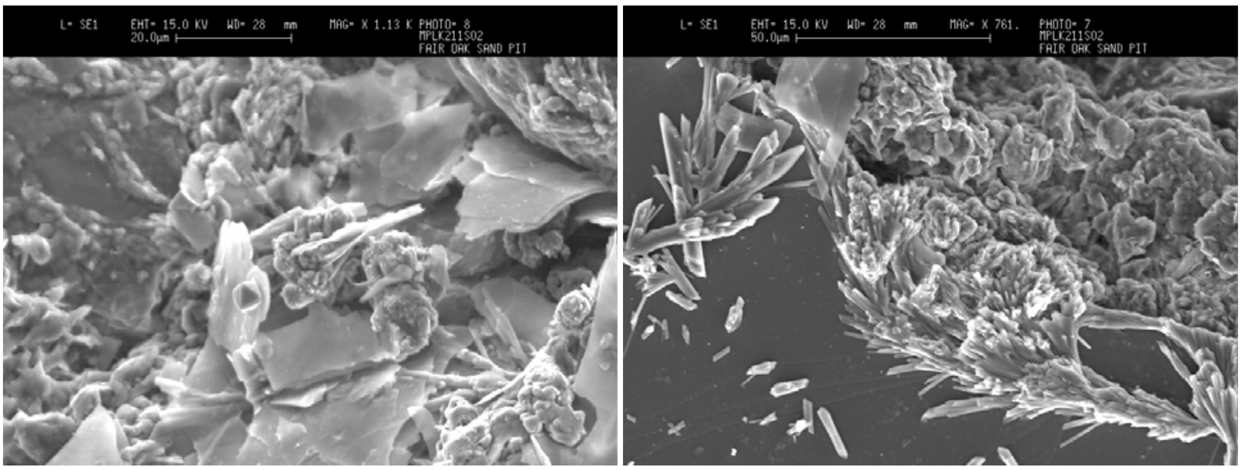


Figure 6 Left - Altered biotite flake, with development of irregular aggregates of Fe-oxide crystals (centre of image). Minor octahedral pyrite is also present. Right – Authigenic blades of gypsum/anhydrite developed on the exposed surface of a detrital grain. (Sample MPLK211 Fair Oak Sand Pit).

4 Discussion and Conclusions

SEM observations of samples from the London Clay in the London and Hampshire Basins have confirmed the previously reported general trend of increasing sand content and decreasing clay content from east-to-west. Within the London Basin, the selected samples are a mixture of mudstones and variably silty and sandy mudstones. In the Hampshire Basin, the samples are typically coarser grained, being variably silty and sandy mudstones, and clay contents are correspondingly lower (Figure 7).

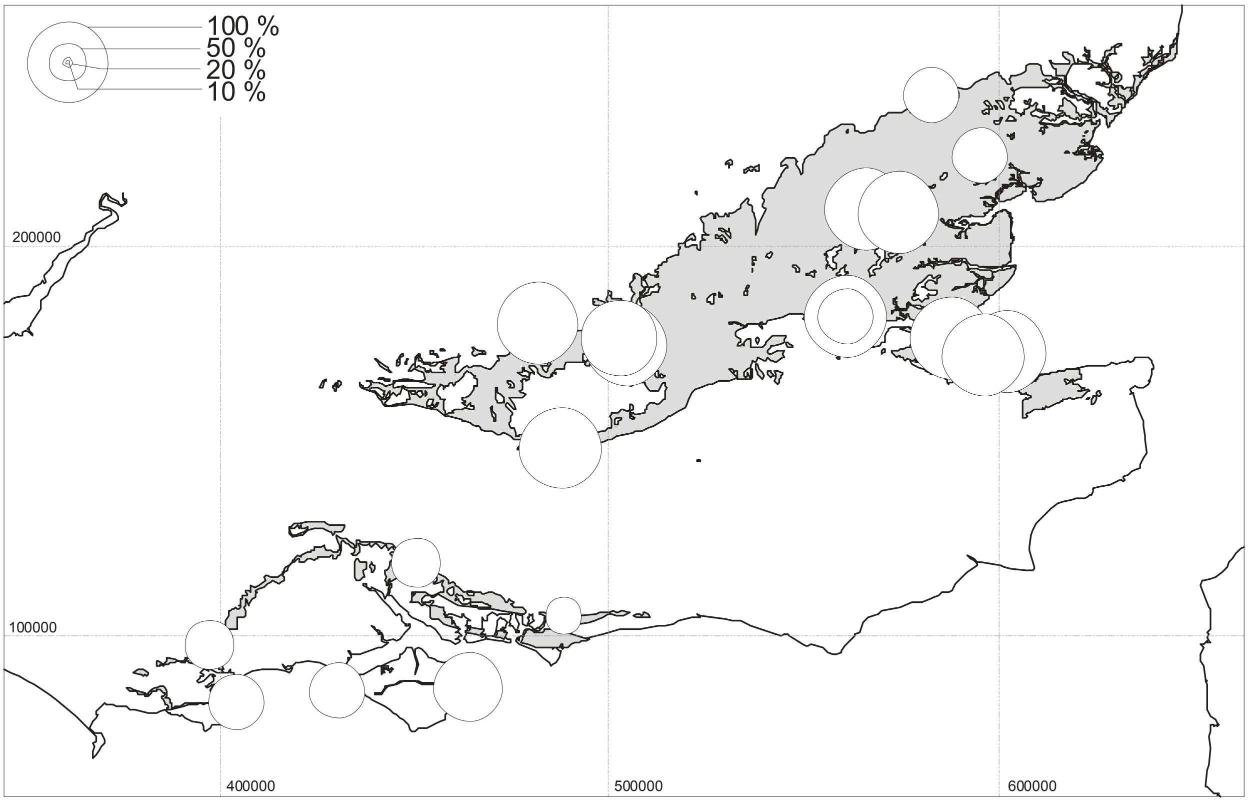
In addition to this general increase in silt/sand content, there is also a general increase in the maximum grain size encountered (Figure 7) from east-to-west. However, beyond these general observations, there are insufficient samples to undertake a detailed investigation of vertical and lateral variations in texture across the area formerly covered by the London Clay sea. Fine scale grain size variations occur on the mm- and cm-scale, and are typically related to lamination, but are also locally caused by probable bioturbation.

The sand content, and correspondingly the clay content of a given mudstone is likely to be an important factor in governing the shrinking and swelling capacity of the London Clay at a given site – obviously if clay is volumetrically of minor significance within the sediment, then it will have proportionally less impact on sediment volume as it shrinks/swells. Furthermore, grain size is also seen to influence porosity and by extension permeabilities of the sediments. It is recommended that a more quantitative assessment of sediment grain size is carried out.

EDXA observations qualitatively confirm the results of XRD analysis (Kemp and Wagner 2006), indicating that the clays are dominated by illite and smectite species, which might be expected to undergo significant shrinking and swelling in response to wetting and drying. The sediments have relatively light diagenetic overprints, with widespread development of pyrite, volumetrically insignificant dolomitisation within the matrix clays, and minor amounts of feldspar and mica dissolution/alteration.

Sample MPLK219 Studland, is slightly anomalous, in terms of both its texture, which comprises 100-300μm diameter aggregates of clay and silt particles, and its mineralogy, being characterised by a mixed kaolinite-smectite species.

A



B

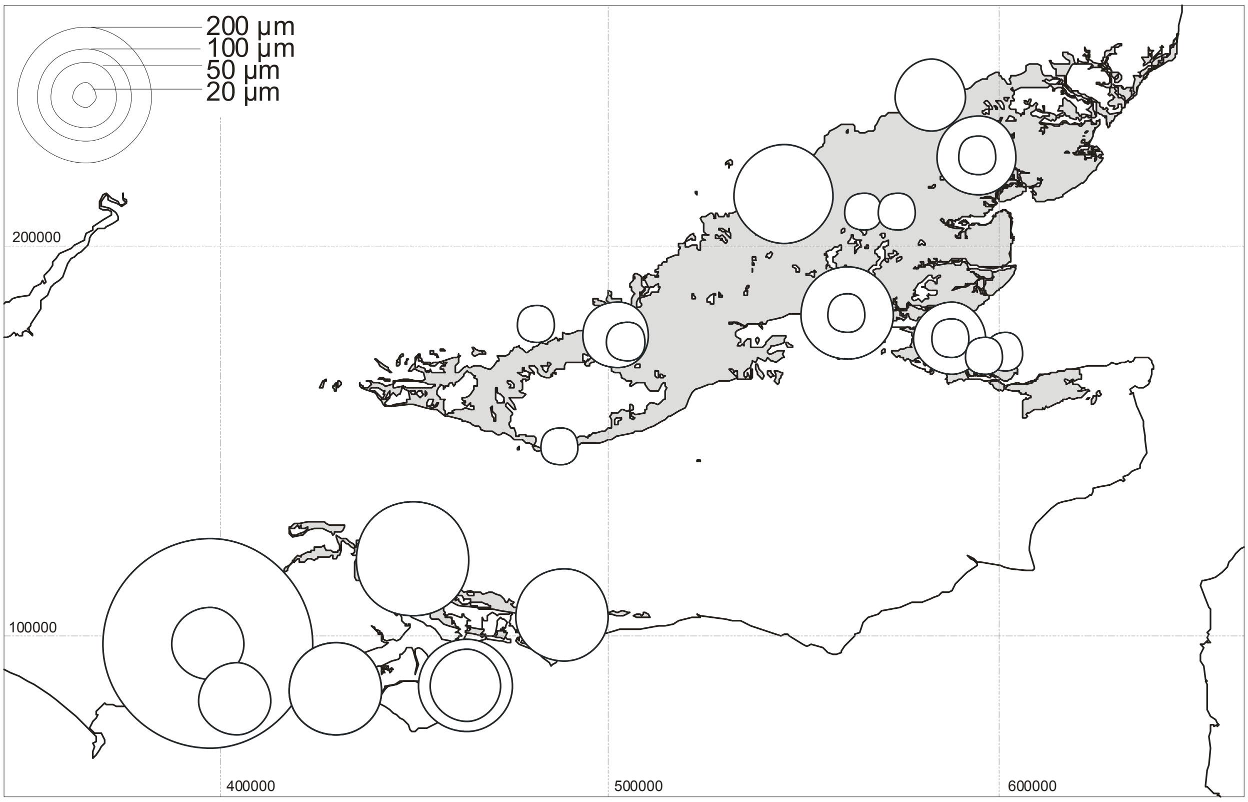


Figure 7 Maps showing variations in clay content (A) and grain size (B). Top – the diameter of each bubble corresponds to estimated clay content as a percentage of whole rock. Bottom - the area of each bubble corresponds to the maximum grain size (microns).

References

Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

BURNETT, A.D., and FOOKES, P.G., 1974, A regional engineering geological study of the London Clay in the London and Hampshire basins: *The Quarterly Journal of Engineering Geology, v. 7, p. 257-295*.

DAVIS, A.G., and ELLIOTT, G.F., 1957, The palaeogeography of the London Clay sea [with discussion]: *Proceedings of the Geologists' Association, v. Part 4: London, United Kingdom, Geologists' Association*.

FREEBOROUGH, K. A. and JONES, L. D., 2006. Determination of the shrinking & swelling properties of the London Clay Formation. *British Geological Survey Internal Report*, IR/06/058.

GILKES, R.J., 1968, Clay mineral provinces in the Tertiary sediments of the Hampshire Basin: *Clay Minerals, v. 7, p. 351-361*.

HUGGETT, J.M., 1994, Diagenesis of mudrocks and concretions from the London Clay Formation in the London Basin, *in Bain, D.C., Hall, P.L., Shaw, H.F., and Spears, D.A., eds., Issue devoted to papers read at a conference on Diagenesis, overpressure and reservoir quality: Clay Minerals: London, United Kingdom, Mineralogical Society, p. 693-707*.

HUGGETT, J.M., and GALE, A.S., 1998, Petrography and diagenesis of the Thames Group at Whitecliff Bay, Isle of Wight, UK: *Proceedings of the Geologists' Association, v. 109, p. 99-113*.

KEMP.J. and WAGNER, D.. 2005. The mineralogy, geochemistry and surface area of mudrocks from the London Clay Formation of southern England. British Geological Survey Internal Report, IR/06/060.

KING, C. 1981 The stratigraphy of the of the London Clay and associated deposits. Backhuys, Rotterdam.

NELDER, L.M. and JONES, L.D. 2005. Determination of the shrinkage and swelling properties of the London Clay: oedometer consolidation testing. *British Geological Survey Report*, IR/04/138. 42pp

WILKINSON, I P. 2004a. Microfossils from a Suite of samples from the London Clay Formation. *British Geological Survey Internal Report, IR/04/165. 4pp.*

WILKINSON, I P. 2004b. Microfossils from a suite of samples of London Clay from southern and south-eastern England. *British Geological Survey Internal Report, IR/04/093. 5pp.*

WILKINSON I P. 2005. Microfossils from two samples of London Clay from the Harlow District (50K sheet 240). *British Geological Survey Internal Report, IR/05/083. 2pp.*

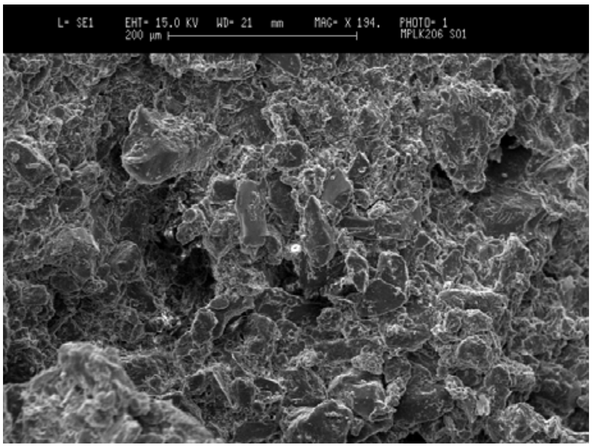
Appendix 1 SEM Sample Descriptions

This section contains descriptions of all the samples studied, grouped according to basin, and ordered from North to South.

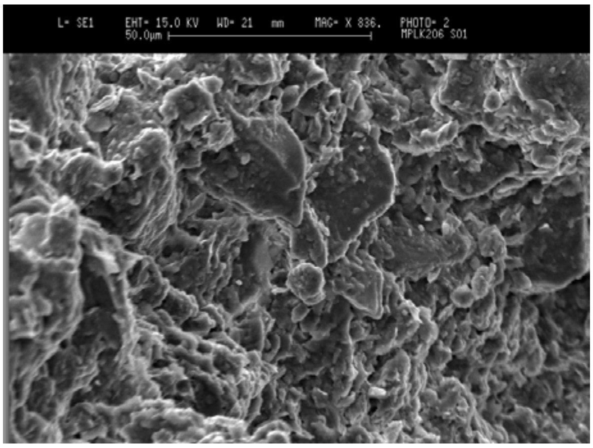
LONDON BASIN

Site:	**Bulmer**	Sample ID:	**Bulmer**
Basin:	**London**	Division:	**Upper D-E**
MPL Sample Code(s):	**MPLK206_S01**	Preparation:	**Air dried, fresh fracture surface**

Description:
A green-orange mottled, silty mudstone with ferruginous nodules up to c. 1mm diameter.



General view, showing the relatively silty nature of this sample, which contains numerous irregular grains of c.20-60 μm diameter.

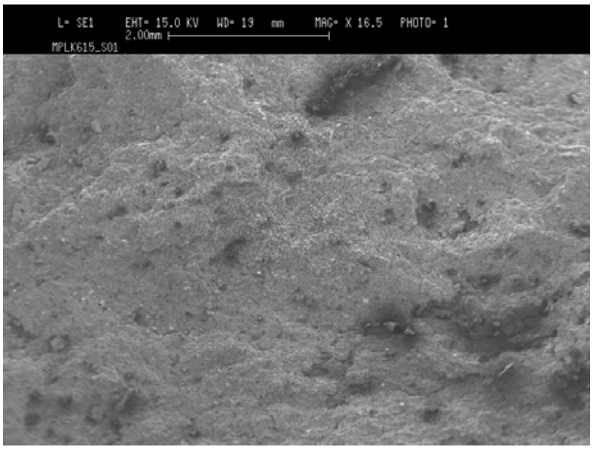


Detail showing the relatively massive fabric of this sample.

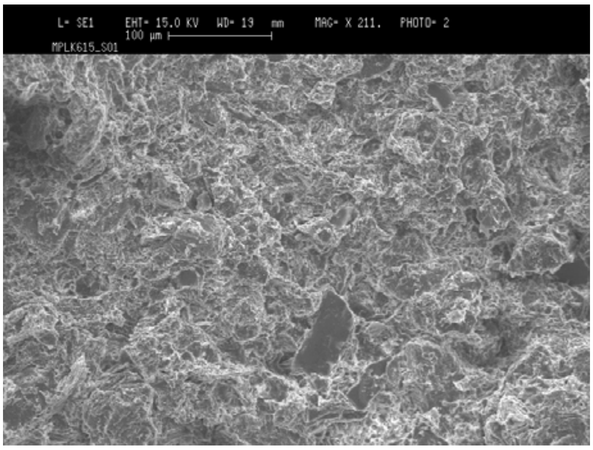
Site:	**Colchester**	Sample ID:	**Colchester S1**
Basin:	**London**	Division:	**A**
MPL Sample Code(s):	**MPLK615_S01**	Preparation:	**Air dried, fresh fracture surface**

Description:

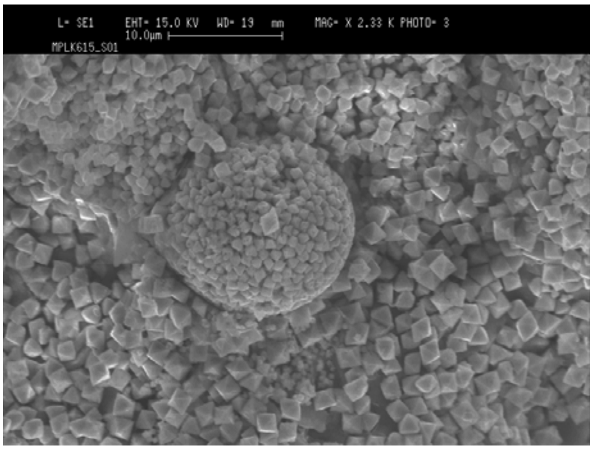
A massive mudstone with relatively abundant silt-grade material. In detail fresh fracture surfaces of this sample develop a "lumpy" texture, with clays occurring in distinct clumps of randomly oriented particles. EDXA indicates a similar clay chemistry to that seen elsewhere. Small patches of framboidal and octahedral pyrite are disseminated throughout.



Low magnification image showing the massive nature of this sample



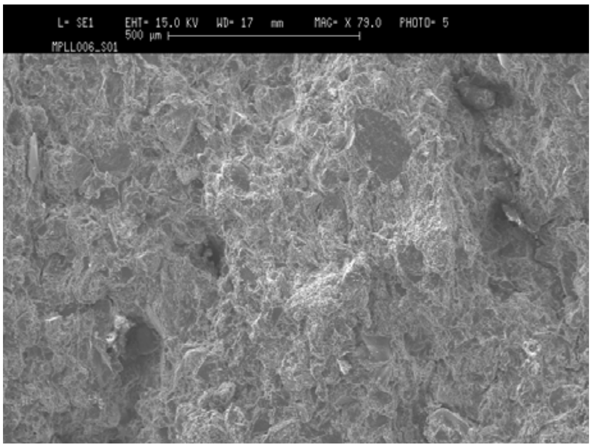
Higher magnification image showing presence of abundant silt-grade material.



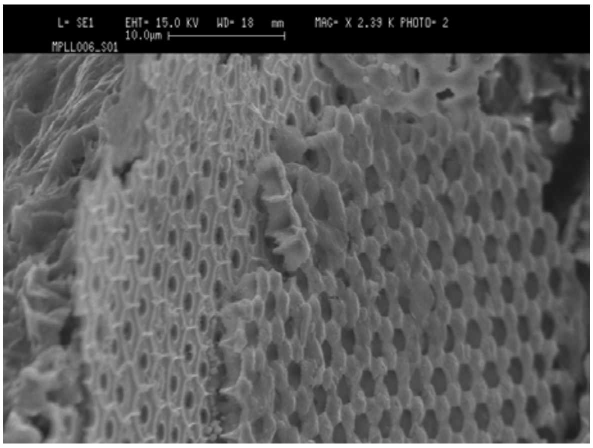
Detail of framboidal and octahedral pyrite.

Site:	**Hollingson Meads**	Sample ID:	**Hollingson Meads**
Basin:	**London**	Division:	**A**
MPL Sample Code(s):	**MPLL006_S01**	Preparation:	**Air dried, fresh fracture surface**
	MPLL006_S02		**Air dried, cut surface**

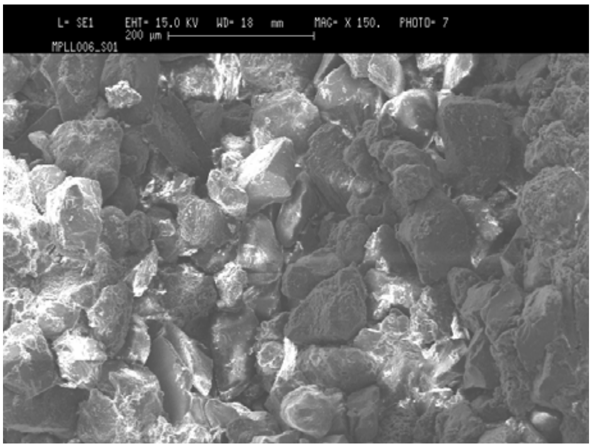
Description:
A siltstone with a faintly laminated fabric, which is expressed in terms of the relative proportion of clay and silt/very-fine-sand grade material. Some lamina contain only very minor amounts of clay, whereas others contain near-pervasive pore-filling clay. Pyritised plant material is abundant throughout. The interstitial clay has a relatively lumpy appearance, and has Si:Al:Mg:K peak ratios of c. 15:10:1:1. Some potential authigenic outgrowths from clay particles protrude into open space.



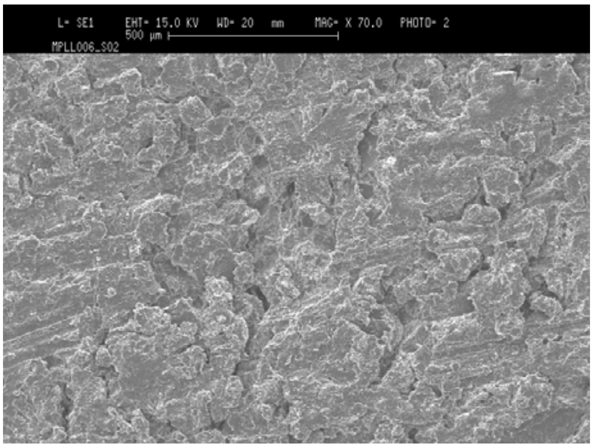
Low magnification image showing the faintly laminated (oriented N-S in this image) nature of this sample. This image is of a relatively clay rich lamina.



Detail showing pyritised plant matter with fossilised cellular structure.



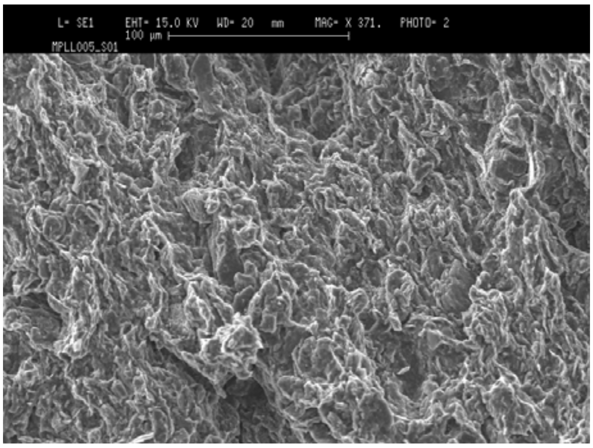
Low magnification image of a sandy lamina, with a very low clay content. The friable nature of the lamina (due to it's low clay content) causes it to charge under the electron beam giving relatively poor image quality.



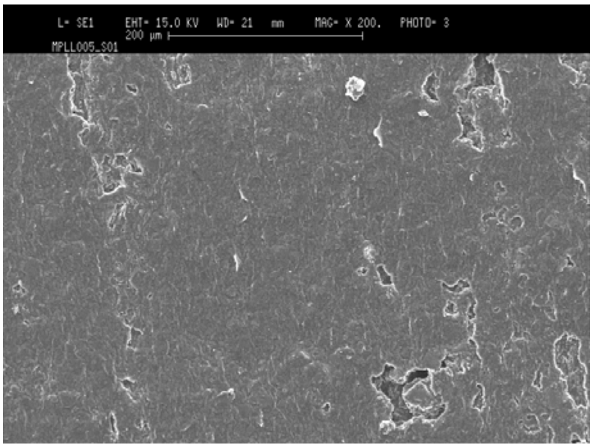
Low magnification image of the cut surface of MPLL006_S02, showing the granular and relatively porous nature of this sample.

Site:	**Roxwell**	Sample ID:	**Roxwell**
Basin:	**London**	Division:	**B-C**
MPL Sample Code(s):	**MPLL005_S01**	Preparation:	**Air dried, fresh fracture/ cut surface**

Description:
A silt-poor mudstone, with a laminated fabric. EDXA indicates a variable clay chemistry with a possible mixture of kaolinite (sub equal Al:Si peak ratios) and a K-Fe-Ca-bearing clay as described elsewhere.



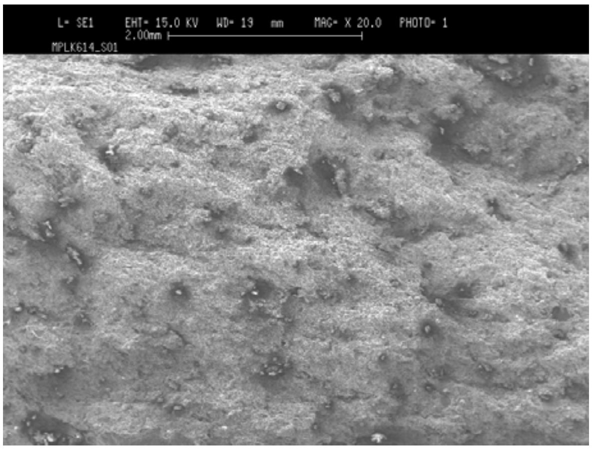
General view showing the laminated fabric, and tightly packed nature of the clay in this sample.



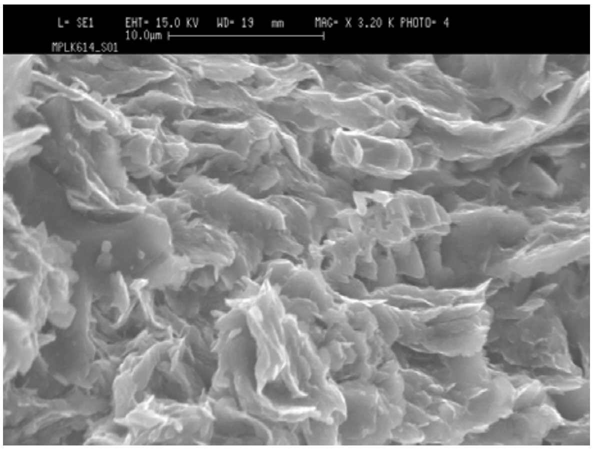
Low magnification image of the cut surface, showing smooth appearance, with tightly packed clay particles and relatively low interparticle porosity.

Site:	**Bulls Lodge**	Sample ID:	**Bulls Lodge**
Basin:	**London**	Division:	**A**
MPL Sample Code(s):	**MPLK614_S01**	Preparation:	**Air dried, fresh fracture surface**

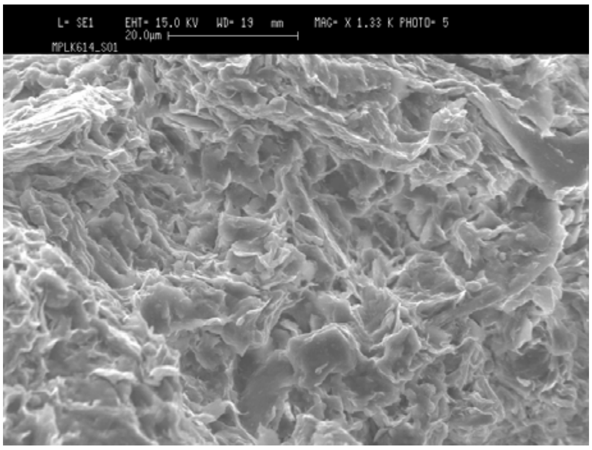
Description:
A faintly laminated, but otherwise homogeneous mudstone containing flat-lying, very fine flakes of clay (typically <5 µm diameter). EDXA indicates peak ratios of Si:SI:K:Fe ~ 5:5:1:1 – possibly indicative of a smectitic or illitic-smectitic composition. Small patches (<50 µm diameter) of more webby clay are also present, and these are of similar composition to the clay elsewhere in the sample. Minor amounts of silt-grade material are evenly dispersed throughout the sample.



Low magnification image showing a faintly laminated mudstone.



Detail showing the close packing of the clay particles, but also the development of minor authigenic wispy outgrowths.



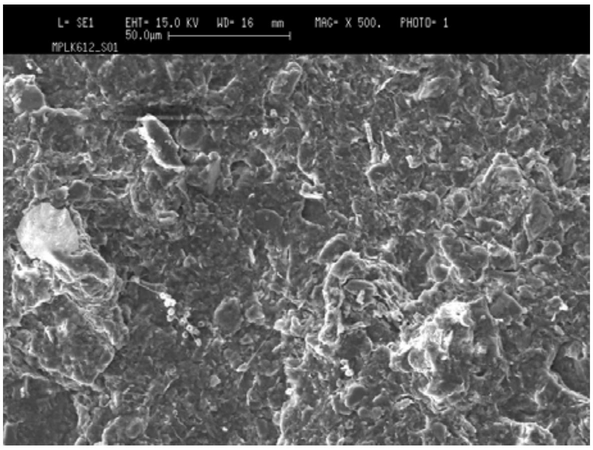
Detail showing the close packing of the clay particles.

Site:	**Ockenden**	Sample ID:	**Ockenden S1**
Basin:	**London**	Division:	**A**
MPL Sample Code(s):	**MPLK612_S01**	Preparation:	**Air dried, fresh fracture surface**
	MPLK612_S02		**Air dried, fresh fracture surface**
	MPLK612_S03		**Air dried, cut surface**

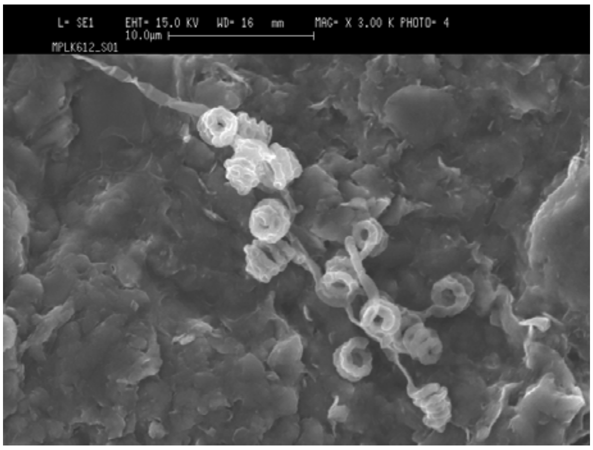
Description:

A mudstone dominated by densely-packed fine clay particles, with relatively minor amounts of silt and very-fine sand grade quartz and feldspar. EDXA indicates a K:Al:Si dominated composition for the clay (peak ratios ~ 1:5:5).

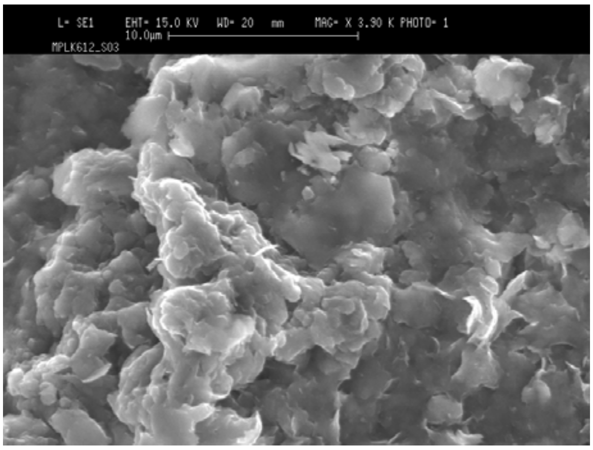
Stub MPLK612_S01 contains abundant micron-scale organic material, which occurs as a mixture of filamentous material (strands a few µm long), and spirals of thicker filaments (typically a couple of µm in diameter). These probably represent bacteria growing on the sample surface post-sampling. A root channel through the corner of this sample is filled by relatively coarsely crystalline gypsum/anhydrite. Stub MPLK612_S02 is extensively cemented by gypsum/anhydrite and contains a mm-diameter root channel that is largely replaced by finely crystalline pyrite framboids and octahedra (typically c. 5-10 µm diameter).



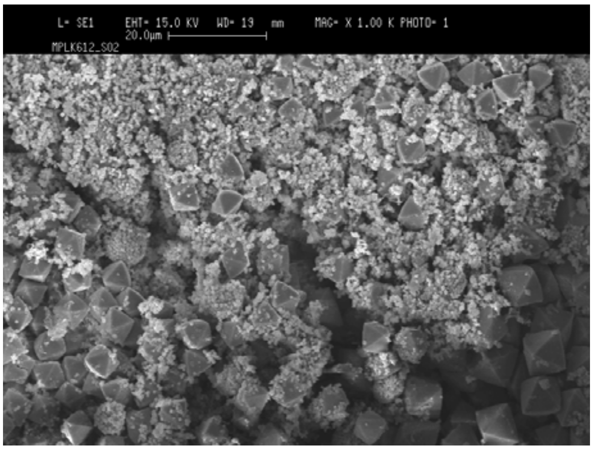
Low magnification image showing the massive, tightly packed nature of this sample.



Detailed image showing spiral arrangement of probable bacterial cells which are widespread in this sample.



Detail showing tightly packed, fine clay particles.

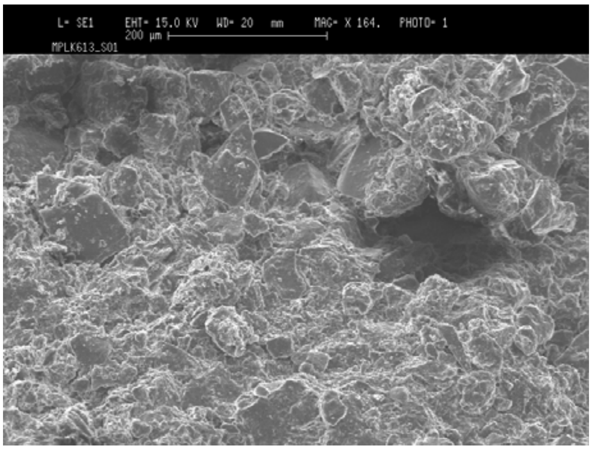


Pyrite framboids and octahedral.

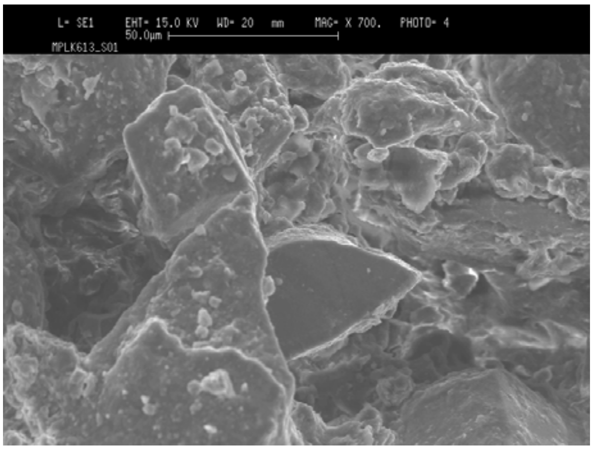
Site:	**Ockenden**	Sample ID:	**Ockenden S2**
Basin:	**London**	Division:	**A**
MPL Sample Code(s):	**MPLK613_S01**	Preparation:	**Air dried, fresh fracture surface**

Description:

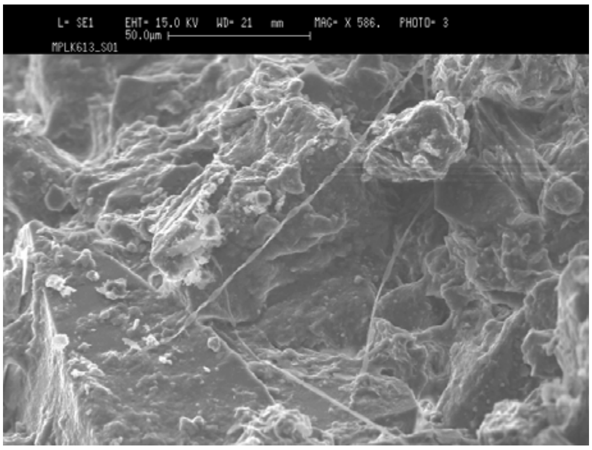
This sample is notably less densely-packed, and more heterogeneous with a more significant sand-grade component than the other Ockenden sample (MPLK612_S01). The sand-grade grains are usually moderately well-rounded. Sand grade grains are not evenly distributed over the sample, and there are distinct domains between which the prevailing grain size varies between silt (<63 µm) and very fine-sand (65-125 µm). Detrital grains are typically coated with thin coatings of clay, which also forms local bridges between grains. EDXA of this clay indicates variable composition, with some kaolinite (sub-equal Si:Al peak ratio), and some K-Ca+/-Fe-bearing clay (?smectite or illite-smectite?). Root fibres or bacterial filaments are present in small amounts.



Low magnification image showing the relatively sand-rich nature of this sample.



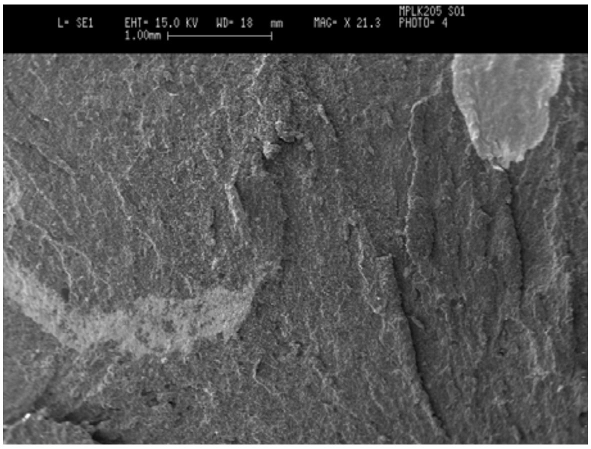
Detail showing sand particles with intergranular porosity.



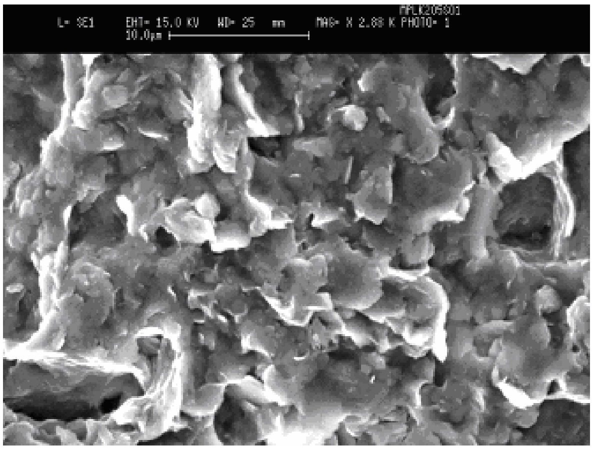
Root fibres occur throughout the sample.

Site: **Knowl Hill** Sample ID: **Knowl Hill**
County: **London** Division: **B-C**
MPL Sample Code(s): **MPLK205_S01** Preparation: **Air dried, fresh fracture/ cut surface**

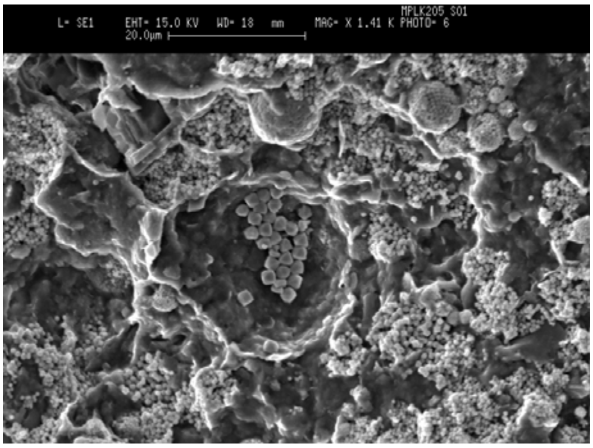
Description:
A grey, dense mudstone. In detail this is massive, clay-rich and poorly porous with tightly packed clay particles. Minor silt-grade grains of feldspar are locally present. This sample has the same general clay chemistry as noted in other samples (see below).



General view, showing dense, fine-grained mudstone. The bright “blob” at the top of the image marks the samples top. The bright area in the bottom left is pyritised organic material.



Detail showing densely packed, fine clay particles with crenulated appearance and incipiently-developed outgrowths.



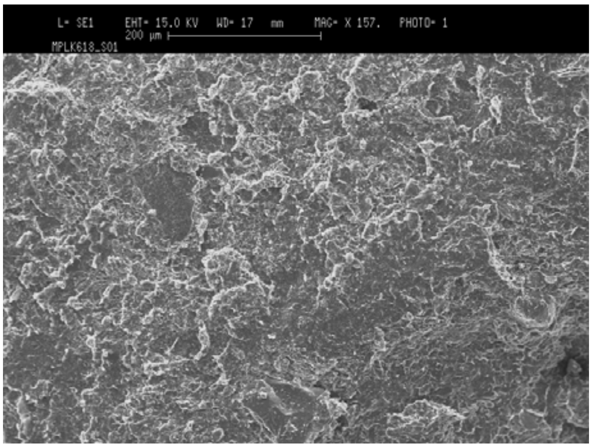
Detail showing pyrite framboids and octahedral replacing organic matter.

Site:	**Poyle**	Sample ID:	**Poyle**
Basin:	**London**	Division:	**???**
MPL Sample Code(s):	**MPLK618_S01**	Preparation:	**Air dried, fresh fracture surface**

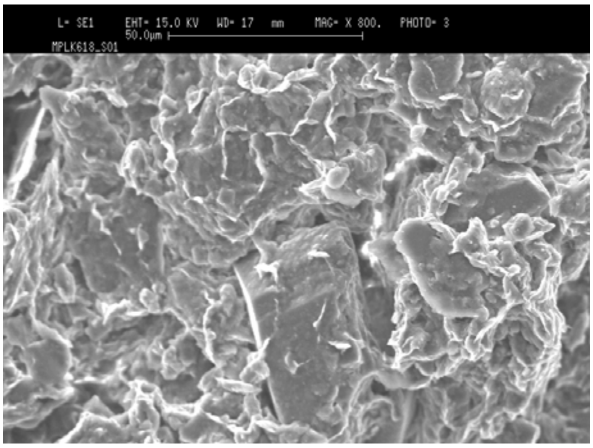
Description:

A heterogeneous sample, dominated by clay-rich domains with minor silt-rich domains. Within the clayey domains particles are typically < 5 µm diameter, have a preferred orientation and are usually quite tightly packed. Individual clay particles commonly have irregular, ragged margins with the development of minor wispy authigenic outgrowths. EDXA indicates variable clay compositions with variable Fe, Mg, K and Ca contents. Minor authigenic dolomite is observed.

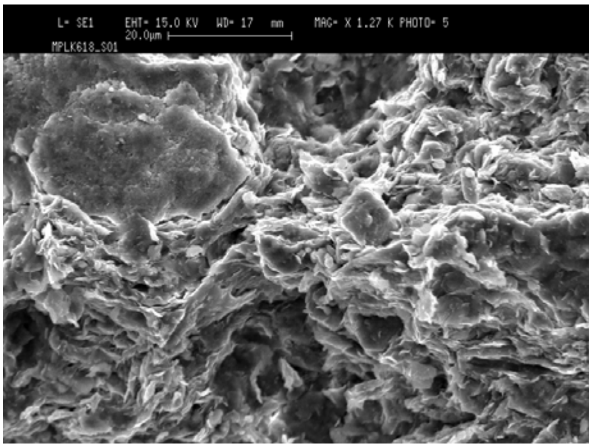
Within the silty domains, scattered grains of quartz and feldspar (typically 30-80 µm diameter sit in a matrix of clays of similar character to those described above.



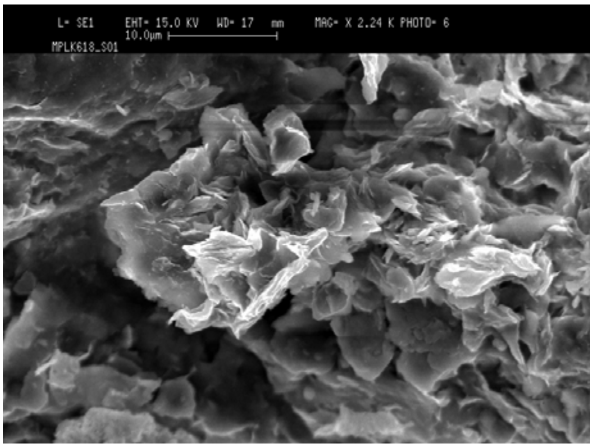
General view showing a slightly silty mudstone.



Feldspar grain with incipiently developed authigenic clay on its surface.



Tightly packed, faintly laminated clay particles, and small rhomb of authigenic dolomite (just of centre of image).



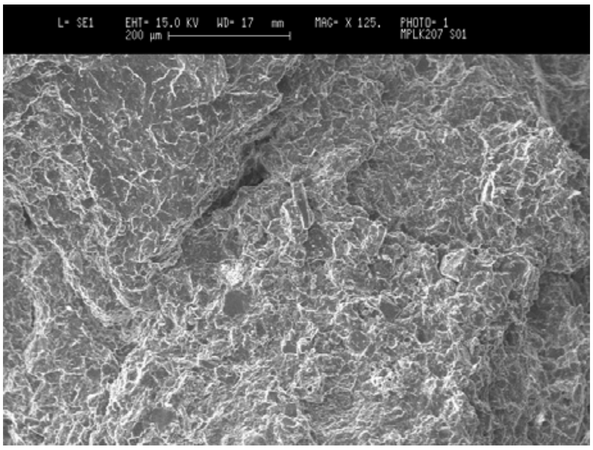
Tightly packed clay particles with minor possible outgrowths.

Site:	**Whitehall Farm**	Sample ID:	**Grain Quarry S1**
Basin:	**London**	Division:	**B-C**
MPL Sample Code(s):	**MPLK207_S01**	Preparation:	**Air dried, fresh fracture/ cut surface**

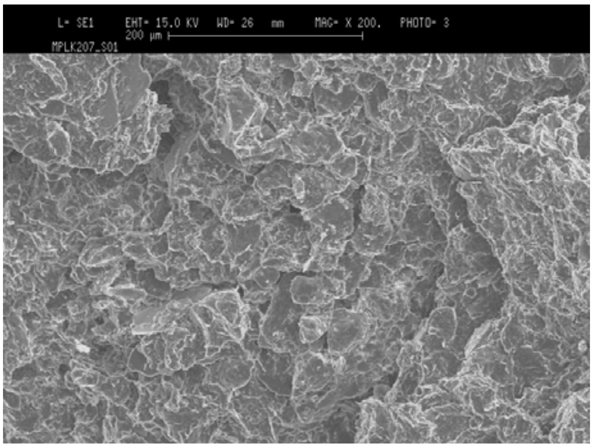
Description:

A relatively heterogeneous mudstone, which is in places comprises 1 mm diameter, rounded peds (possibly related to weathering?), and in others is massive. There are also differences in fabric at a fine scale, with some domains comprising silt-grade particles (<63 μm diameter), with rounded outlines which appear to have clayey-coatings, and could represent either silt-grade clastic material, or amalgamated/flocculated clay particles. Elsewhere, the sample comprises more massive, tightly packed clay grade material.

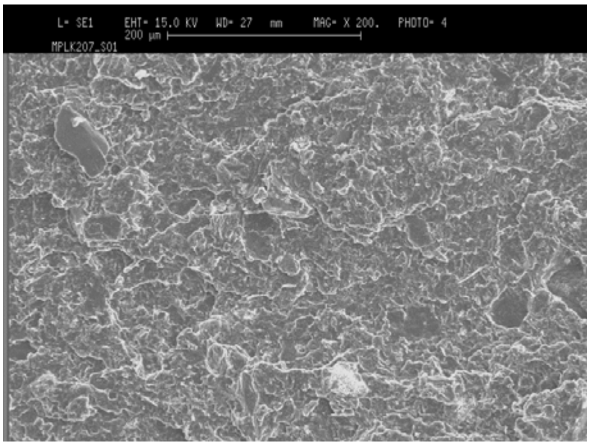
EDXA is generally un-diagnostic, with all the tested clays indicating the following (approximate) peak ratios: Si:Al:Mg:K:Fe 10:5:1:1:1.



General view showing mm-scale, rounded ped-like structure.



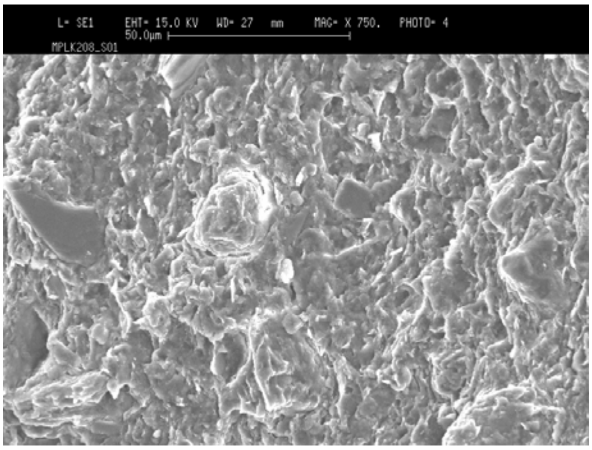
Detail showing silt-grade particles in mudstone.



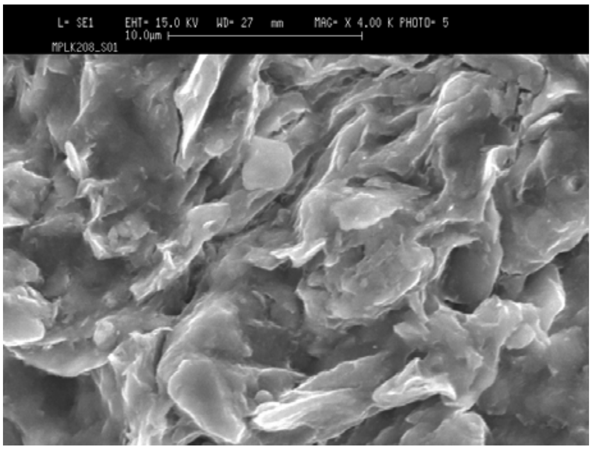
Detail of more massive part of sample with tightly packed clay particles.

Site:	**Whitehall Farm**	Sample ID:	**Grain Quarry S2**
Basin:	**London**	Division:	**B-C**
MPL Sample Code(s):	**MPLK208_S01**	Preparation:	**Air dried, fresh fracture surface**
	MPLK208_S02		**Air dried, cut surface**

Description:
A brown, plastic, massive mudstone, which fractures into 2-5 mm diameter lumps with angular margins. The SEM stub made using a cut surface confirms the hand-specimen observation indicating a massive mudstone with no evidence for lamination. The fresh fracture surface is similarly featureless, with the sample fracturing along irregular surfaces of no-apparent preferred orientation. In detail the sample is seen to comprise relatively tightly packed clay particles of < 10 μm diameter which display preferred orientations on a local scale (spanning << 1mm), but on the larger scale are effectively randomly oriented. EDXA is un-diagnostic as seen in the other sample from this site (MPLK207), with similar peak ratios observed: Si:Al:Mg:K:Fe:Ca 10:6:1:1:1:1.



Detail showing clay particles end-on.

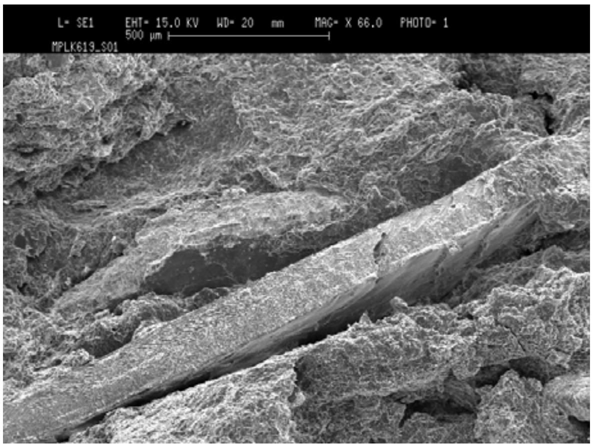


Detail showing flat-lying clay flakes.

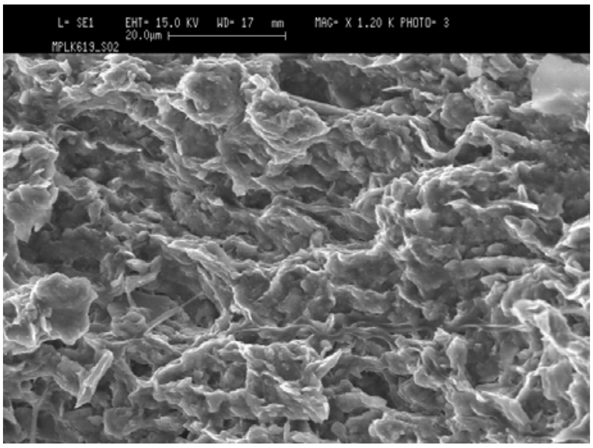
Site:	**Stanwell**	Sample ID:	**Stanwell**
Basin:	**London**	Division:	**B1**
MPL Sample Code(s):	**MPLK619_S01**	Preparation:	**Air dried, fresh fracture surface**
	MPLK619_S02		**Air dried, fresh fracture surface**
	MPLK619_S03		**Air dried, cut surface**

Description:

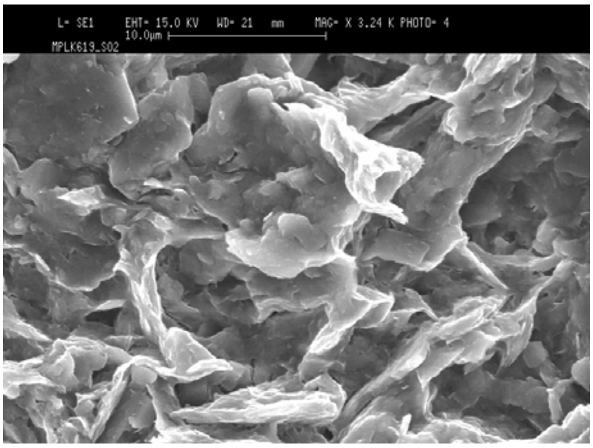
A slightly silty, mudstone, with floating silt-grade grains of quartz and feldspar, in a matrix of only locally oriented clay particles. Individual clay particles are less well-defined in this sample relative to the sample from the adjacent sampling location at Poyle (sample MPLK618). Minor rhombic dolomite is noted. The clay has a similar, variable chemistry to that described in the sample from Poyle (MPLK618). Fine root fibres occur throughout the sample.



Low magnification image showing a shell fragment within the mudstone matrix.



Detailed image showing the relatively amorphous and “lumpy” nature of the clays within this sample.



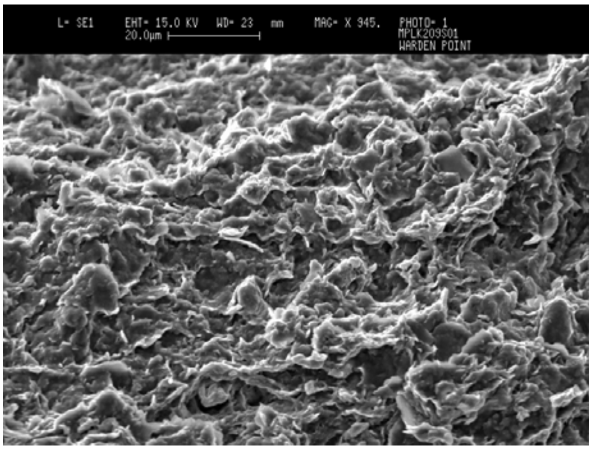
Detail showing more platy clay particles.

Site:	**Warden Point**	Sample ID:	**Warden Point**
Basin:	**London**	Division:	**B-C**
MPL Sample Code(s):	**MPLK209_S01**	Preparation:	**Air dried, fresh fracture/ cut surface**

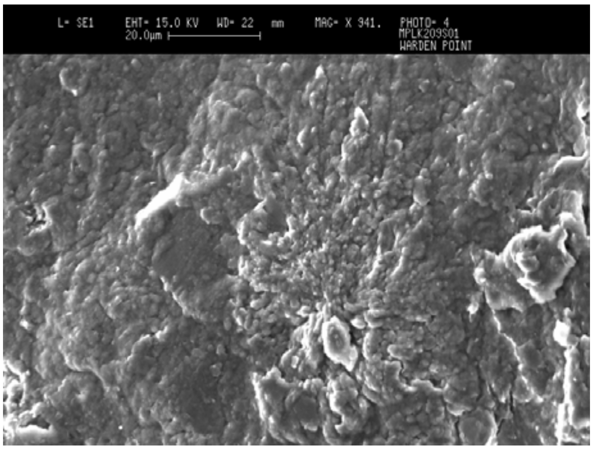
Description:

A green-grey, massive mudstone. On standing between sample preparation and analysis, this sample has suffered from oxidative effects with the development of patches of anhydrite/gypsum on fracture surfaces, causing blistering and localised disruption of the fabric. This is most probably related to oxidation of pyrite.

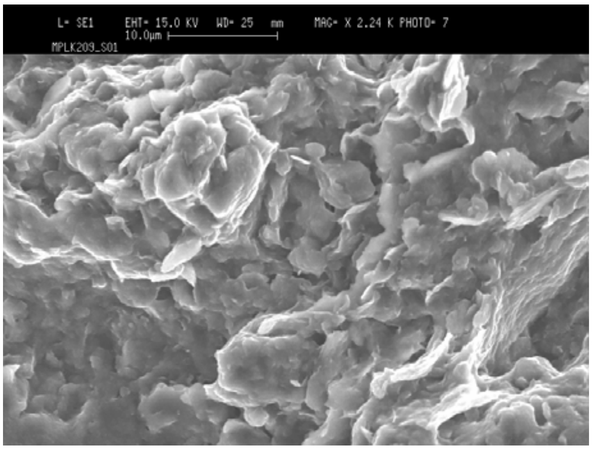
In detail the mudstone is dominated by fine-grained clay flakes (<<10 µm), with very miner silt-grade quartz grains. The fabric is relatively massive and individual clay flakes are variably packed, in dome domains being tight, and other relatively loosely packed. EDXA indicates a range of clay types present including some kaolinite (Al:Si peak ratios ~1:1), plus the same un-diagnostic Al:Si:Fe:K:Mg-bearing clay described in samples MPLK207 and MPLK208. Minor euhedral pyrite is developed in clusters.



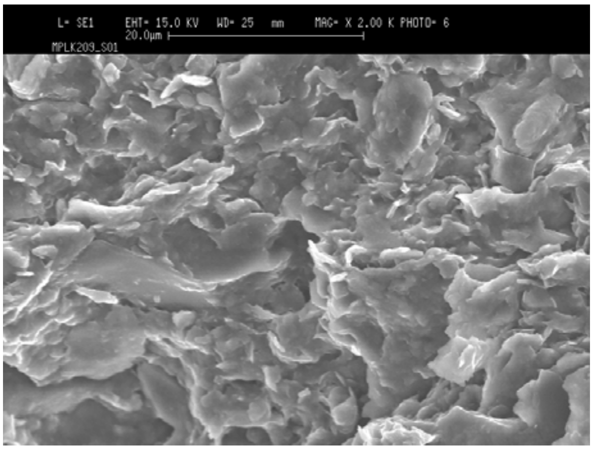
General view showing the laminated, clay-rich, poorly porous, nature of this sample.



Anhydrite/gypsum developed just below the sample surface causing blistering and disruption of the fabric.



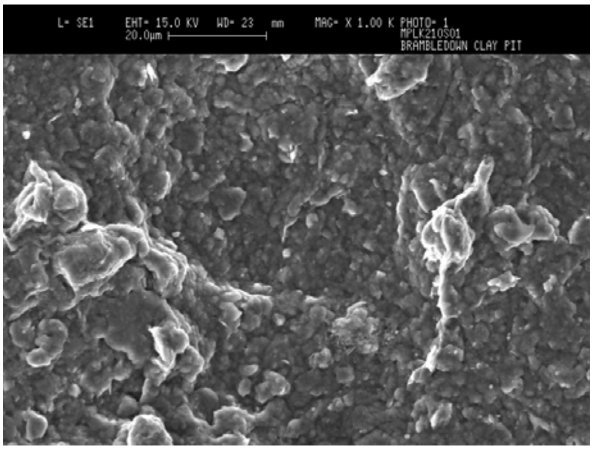
Detail of individual clay particles, showing close-packing, and low interparticle porosity.



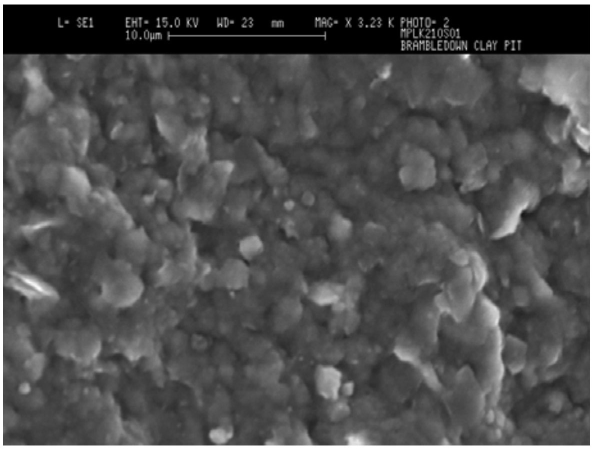
Detail of individual clay particles, showing close-packing, and low interparticle porosity.

Site:	**Brambledown**	Sample ID:	**Brambledown**
Basin:	**London**	Division:	**B1**
MPL Sample Code(s):	**MPLK210_S01**	Preparation:	**Air dried, fresh fracture/ cut surface**

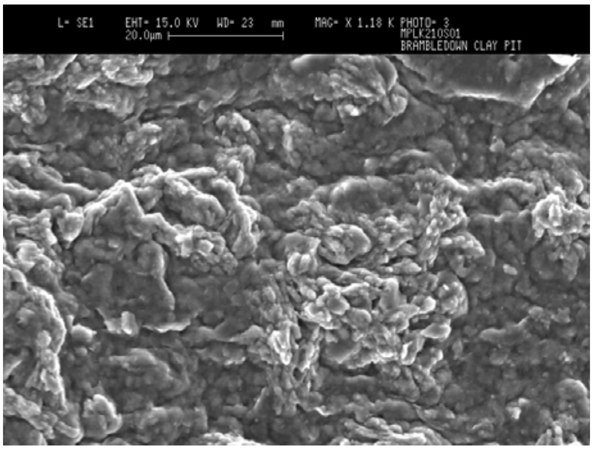
Description:
A massive, hard, grey mudstone. In detail, the massive fabric is confirmed, with closely packed, fine-clay particles with little interparticle porosity. EDXA indicates a mixture of kaolinite (sub-equal Al:Si peak ratios) and the same un-diagnostic Al:Si:Fe:K:Mg-bearing clay described in samples MPLK207 and MPLK208.



General view showing densely-packed, fine-grained clay particles.



Detail showing the very fine-grained nature of the clay.

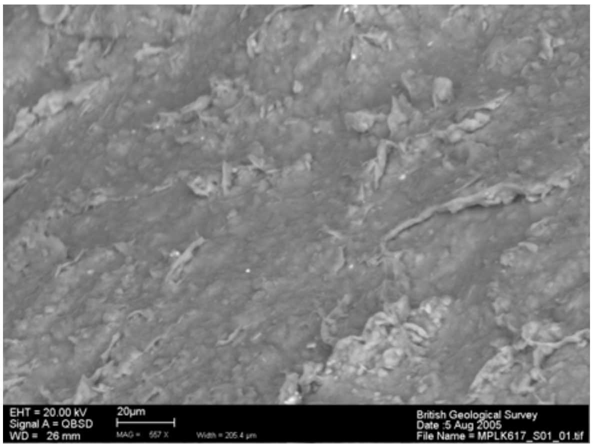


Detail showing some blistering of the sample surface due to the development of gypsum/anhydrite within the sample.

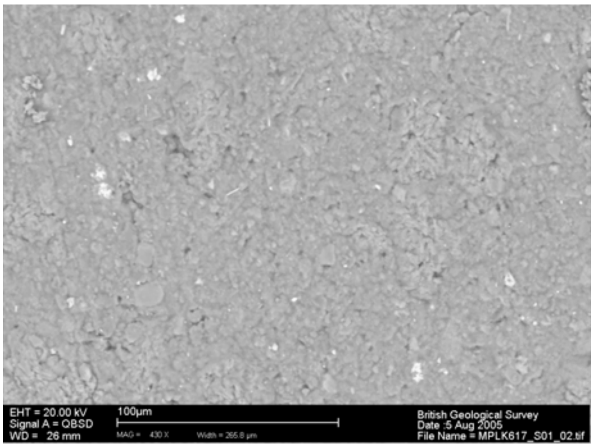
Site:	**Farnham**	Sample ID:	**Farnham**
Basin:	**London**	Division:	**???**
MPL Sample Code(s):	**MPLK617_S01**	Preparation:	**Air dried, fresh fracture/ cut surface**

Description:
A massive, dense mudstone. EDXA indicates a clay of comparable composition to that seen elsewhere with Al:Si:K:Fe peak ratios of c. 20:15:1:0.5.

Note: due to problems with the sample charging, these images were captured in variable pressure mode, using a different detector to the images associated with these descriptions. This accounts for the different appearance of these images.



Low magnification image showing the tightly-packed, fine-grained nature of this sample.



Low magnification image of the cut surface showing a smooth appearance, fine-grained particles and an absence of porosity.

HAMPSHIRE BASIN

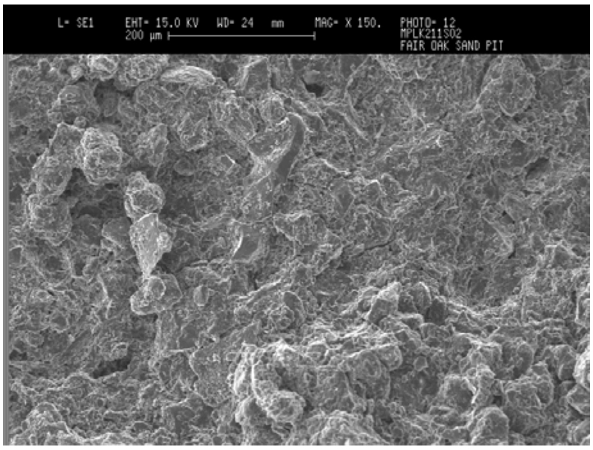
Site:	**Fair Oak Sand Pit**	Sample ID:	**Fair Oak Sand Pit**
Basin:	**Hampshire**	Division:	**???**
MPL Sample Code(s):	**MPLK211_S01**	Preparation:	**Air dried, fresh fracture surface**
	MPLK211_S02		**Air dried, fresh fracture surface**
	MPLK211_S03		**Air dried, fresh fracture surface**

Description:

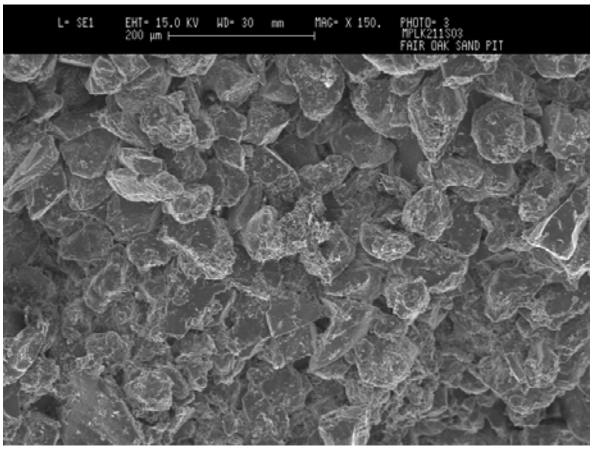
The stubs of this sample reveal a very-fine grained sandstone with abundant well-rounded grains of typically 50-120 µm diameter. Detrital feldspar is abundant and commonly corroded. Clay contents are highly variable with a number of clean (clay-poor) lenses, and other clay-rich domains. Within the clay-poor lenses, such as that sampled by MPLK211_S03, the sand grains are relatively loosely packed/poorly consolidated and friable and minor clay occurs adhered to grain surfaces.

Sample MPLK211_S01 includes a sand-filled tube-like structure, which is of similar character to the clean lenses described above. In the clay-rich domains the clays have similar compositions to those described above in sample MPLK207.

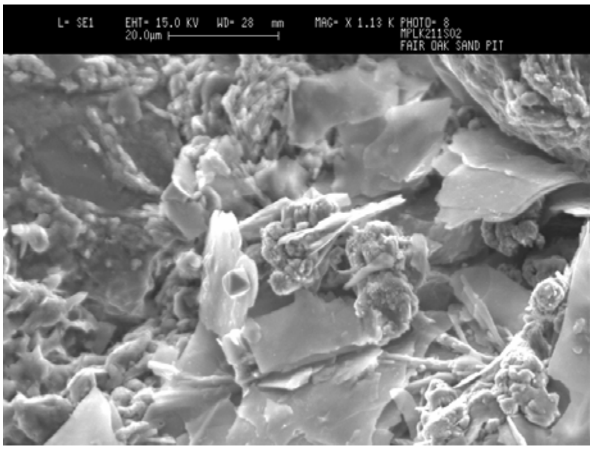
This sample also contains significant amounts of gypsum/anhydrite developed on it's surface as a result of drying out and oxidation of the samples.



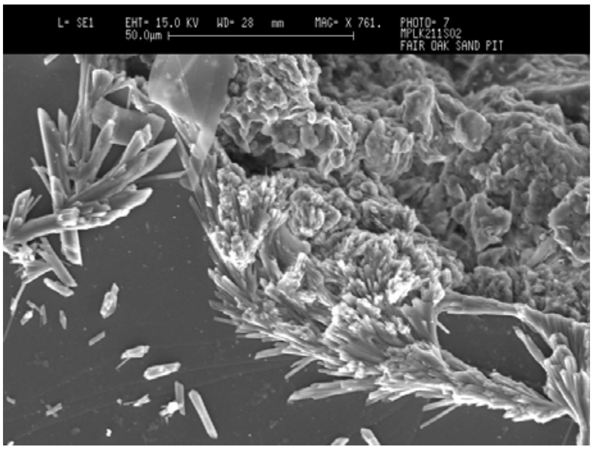
Detail of relatively clay-rich part of the sample.



Detail of relatively clay-poor / sandy part of the sample



Detailed image showing altered biotite, with the development of Fe-oxides.



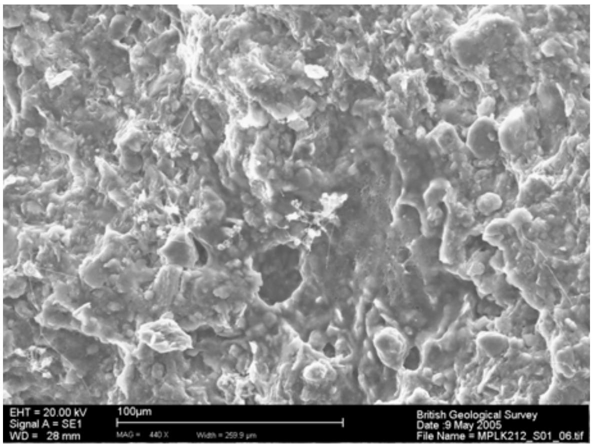
Fine-grained gypsum/anhydrite developed on the exposed surface of a grain.

Site:	**Southleigh**	Sample ID:	**Southleigh**
Basin:	**Hampshire**	Division:	**C**
MPL Sample Code(s):	**MPLK212_S01**	Preparation:	**Air dried, fresh fracture surface**
	MPLK212_S02		**Air dried, cut surface**

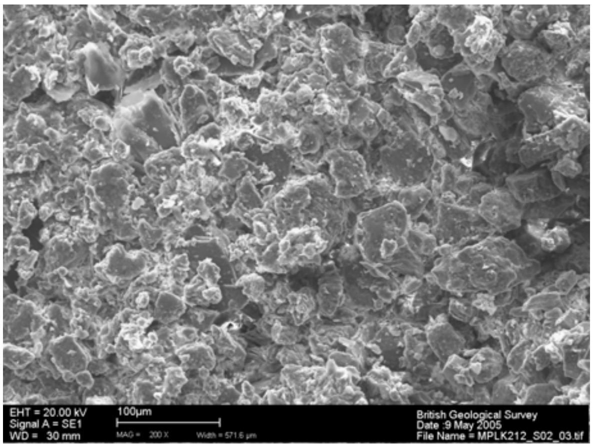
Description:
A dense, hard, grey mudstone with minor sandy lenses up to 1mm thick. Within the muddy domains which dominates the sample, individual particles occur over a considerable size range (up to > 10 μm), and rare silt grade material is also present. The muddy domains appear relatively massive/structureless with closely packed particles. EDXA is non-definitive, indicating a dominance of clays yielding peak ratios of approximately Si:Al:K:Fe:Mg 10:5:1:1:1. The sample surface is locally covered with filamentous material which may represent bacterial filaments although this is inconclusive.

In detail the sandy lenses contain silt and very-fine sand grade grains (30-70 μm diameter) of quartz and K-feldspar. These grains are typically sub-angular, although the feldspars may have minor authigenic overgrowths. Although there are clay-poor domains within the sandy lenses, clays are typically still abundant forming discontinuous grain coats and irregular pore-fillings, locally associated with very fine-grained authigenic pyrite. Traces of rhombic authigenic dolomite are also locally evident.

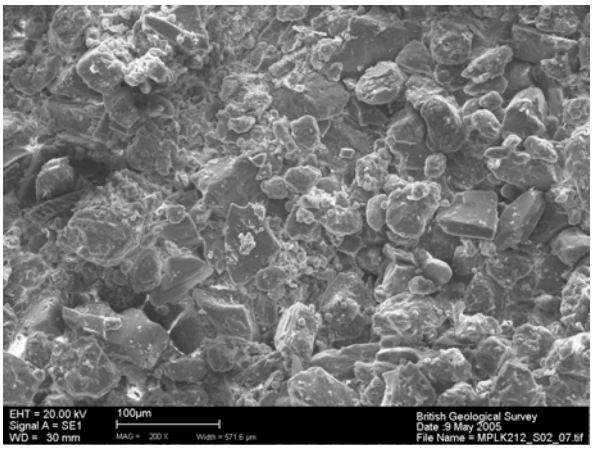
The cut surface of the sample is locally blistered/disrupted by the development of gypsum/anhydrite in response to oxidation of pyrite within the sample.



Low magnification image of relatively clay-rich domain. the fibrous patch near the centre of the image is probably bacterial in origin.



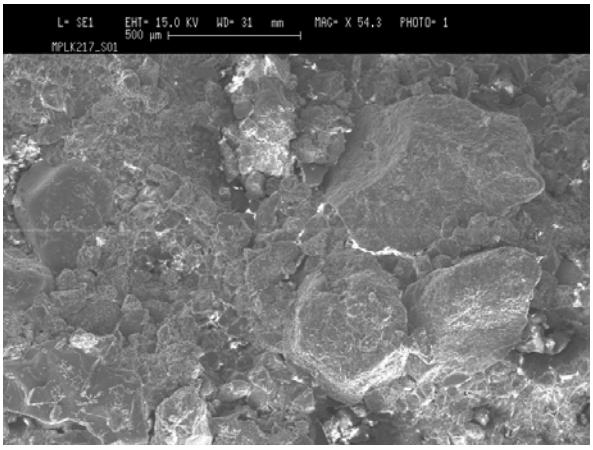
Low magnification image of relatively sand-rich lens.



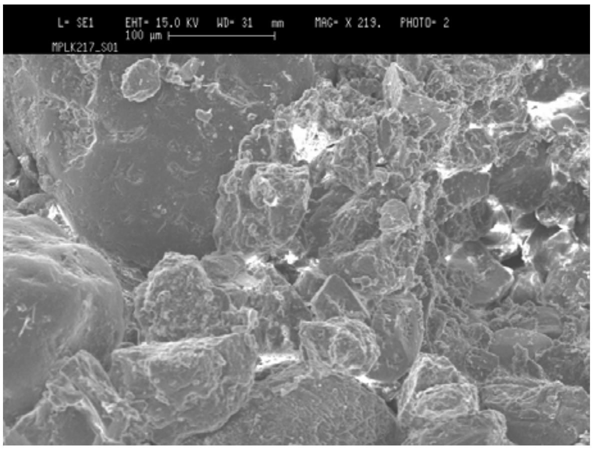
Low magnification image of relatively sand-rich lens.

Site:	**Knoll Manor**	Sample ID:	**Knoll Manor S1**
Basin:	**Hampshire**	Division:	**???**
MPL Sample Code(s):	**MPLK217_S01**	Preparation:	**Air dried, fresh fracture surface.**
	MPLK217_S02		**Air dried, fresh fracture surface.**

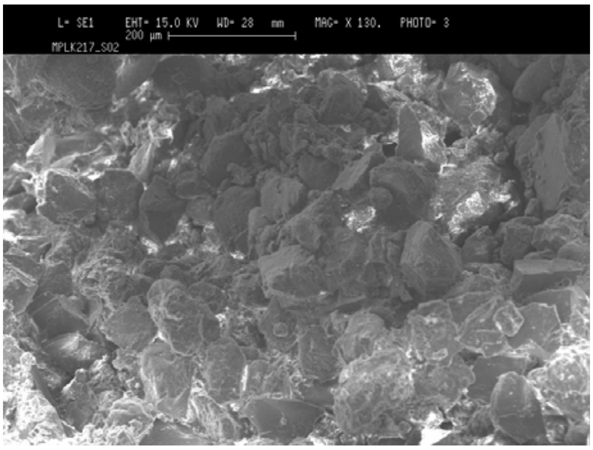
Description:
A poorly-consolidated (causing the sample to charge-up under the electron beam), poorly-sorted fine to medium-grained laminated sandstone. The dominant grain size is c. 100 µm diameter, but rare grains in excess of 500 µm are also present. The sample also has a relatively low clay content and correspondingly high porosity. Diagenetic overprinting appears to be slight, although possible incipient quartz overgrowths are locally observed. Minor anhydrite/gypsum precipitation related to drying out and oxidation of the sample is also observed.



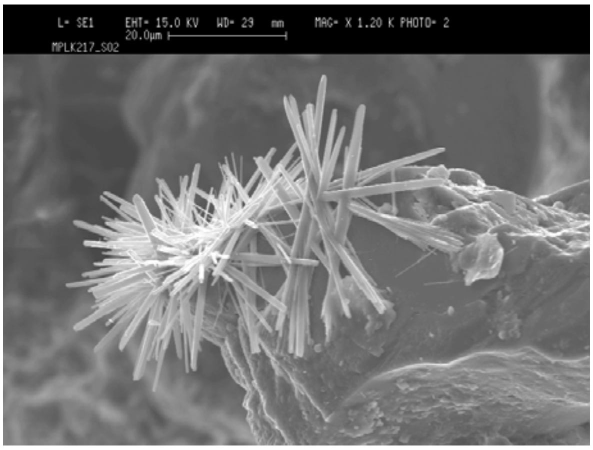
General view of this poorly-sorted sandstone, showing the wide range in particle size.



High volumes of porosity are present between the grains.



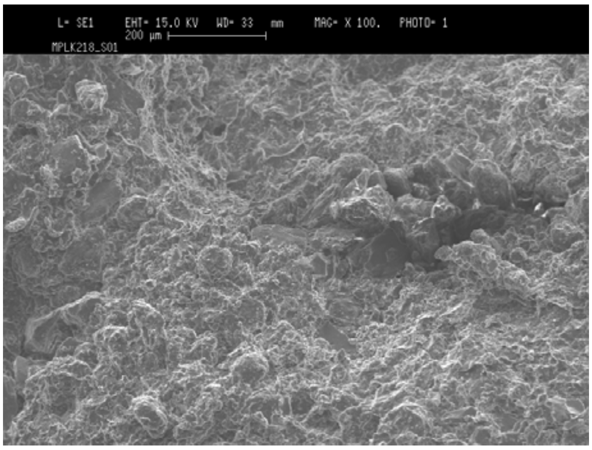
Detail showing a relatively fine-grained lamina, which is charging under the electron beam.



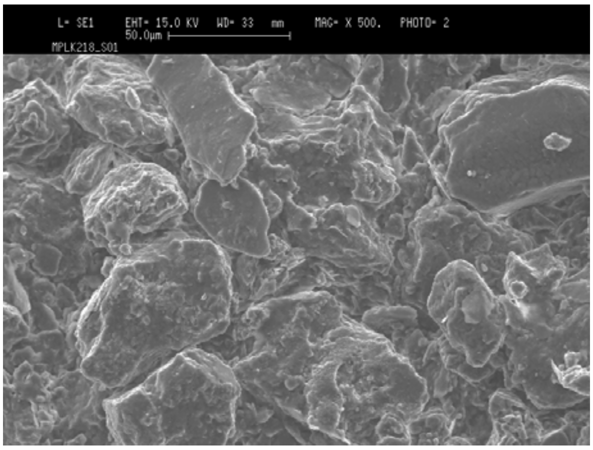
Gypsum/anhydrite developed on the surface of quartz grain.

Site:	**Knoll Manor**	Sample ID:	**Knoll Manor S2**
Basin:	**Hampshire**	Division:	**???**
MPL Sample Code(s):	**MPLK218_S01**	Preparation:	**Air dried, fresh fracture surface**
	MPLK218_S02		**Air dried, cut surface**

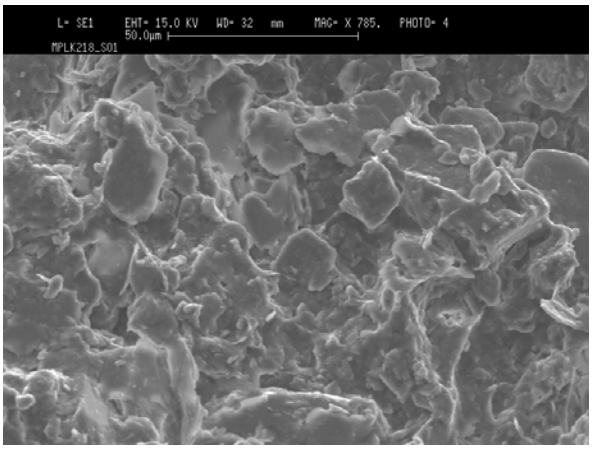
Description:
A massive, mudstone with a high content of silt and very-fine sand-grade grains. The proportions of clay, silt and sand vary over the sample with some sandy, relatively clean domains and other more clay rich ones.



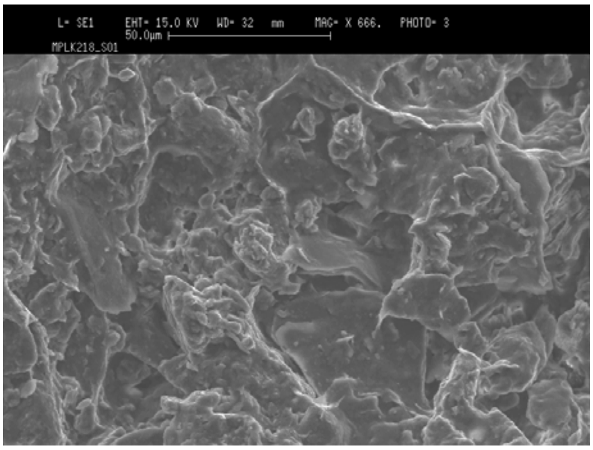
General view of this silty mudstone.



Detail of a relatively sand-rich domain within the mudstone.



Detail of a silt-rich domain.



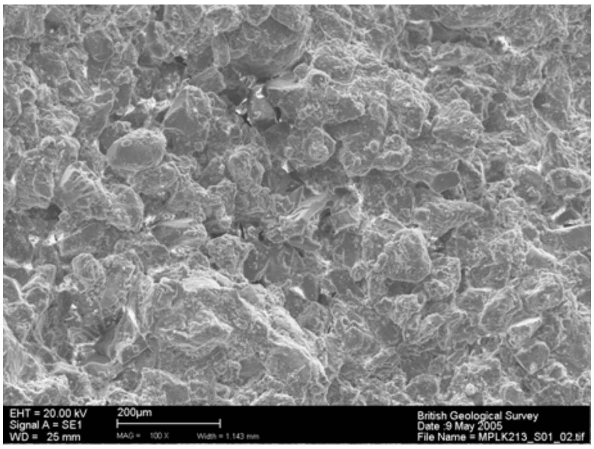
Detail of a silt-rich domain.

Site:	**Whitecliff Bay**	Sample ID:	**Whitecliff Bay S1**
Basin:	**Hampshire**	Division:	**A**
MPL Sample Code(s):	**MPLK213_S01**	Preparation:	**Air dried, fresh fracture surface.**

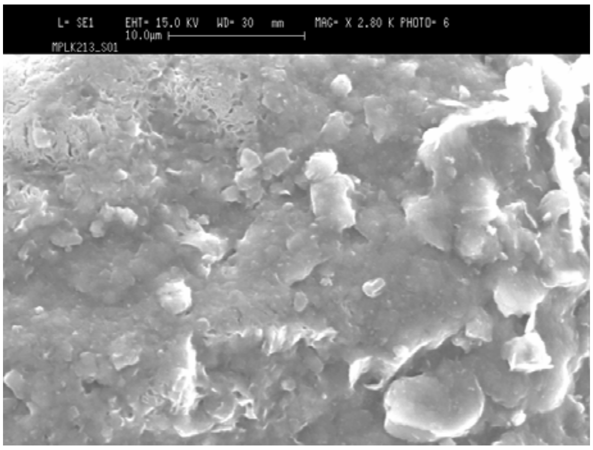
Description:

A green-grey, silty mudstone. SEM imaging reveals that this sample is a fine-grained clay rich sandstone (most grains 70-150 μm diameter, with some grains up to 1 mm), with abundant detrital framework grains of quartz and feldspar. Clays occur as tangential grain-coatings, pore-fillings and more rarely as bridges between grains. The grain-coating clays comprise thin platelets typically <5 μm diameter. These are locally crenulated, with the development of minor authigenic outgrowths. The pore-filling and grain-bridging clay is more massive in habit. Minor micro-rhombic authigenic dolomite is developed within these more massive clays. Rare framboidal pyrite is also present.

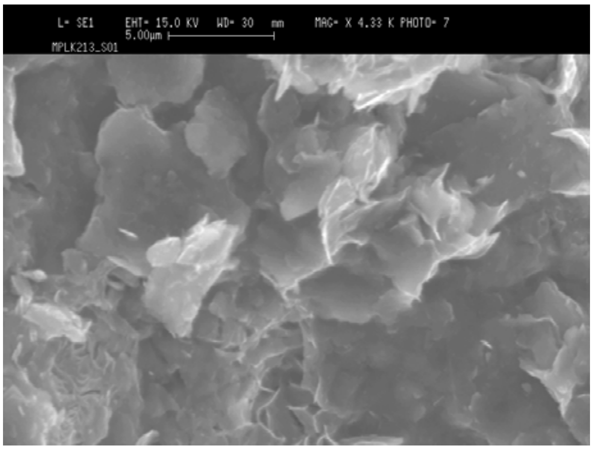
As noted in other samples, minor anhydrite/gypsum has developed in response to oxidation/drying out of the sample.



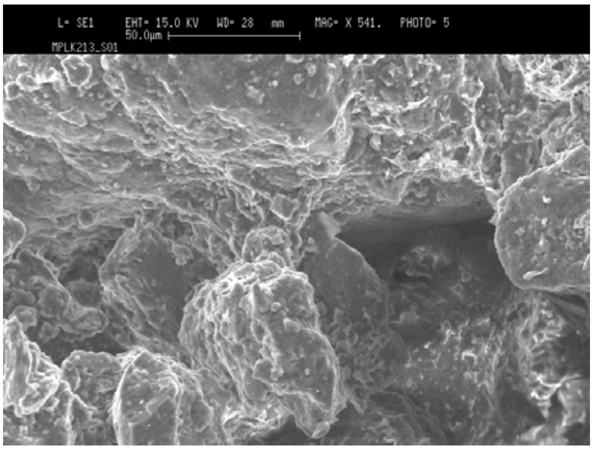
Low magnification image showing the sandy nature of the sample. Minor, coarsely crystalline, blocky gypsum/anhydrite is present near centre of image



Detail of grain-coating clay.



Detail of grain-coating clay with authigenic wispy overgrowths.



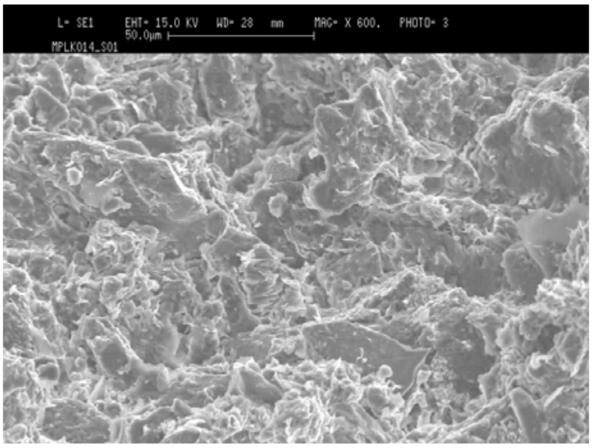
Detail of grain-bridging clay.

Site:	**Whitecliff Bay**	Sample ID:	**Whitecliff Bay S2**
Basin:	**Hampshire**	Division:	**A**
MPL Sample Code(s):	**MPLK214_S01**	Preparation:	**Air dried, fresh fracture/ cut surface**

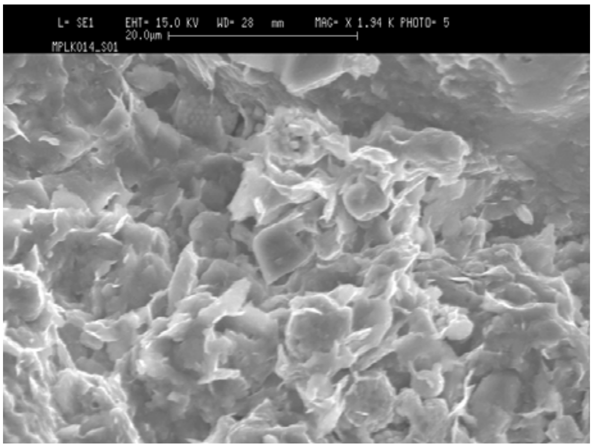
Description:

A green-grey, hard, mottled silty mudstone with rare shell fragments. Under SEM, this sample is seen to comprise abundant silt-grade particles in a clayey matrix. The fabric is laminated, with flat-lying mica flakes (unfortunately oriented parallel to surface of sample). Interparticle porosity is low. Abundant authigenic pyrite occurs disseminated throughout the clayey matrix as isolated small crystals and framboids. Micro-rhombic authigenic dolomite is also present, but only in trace amounts.

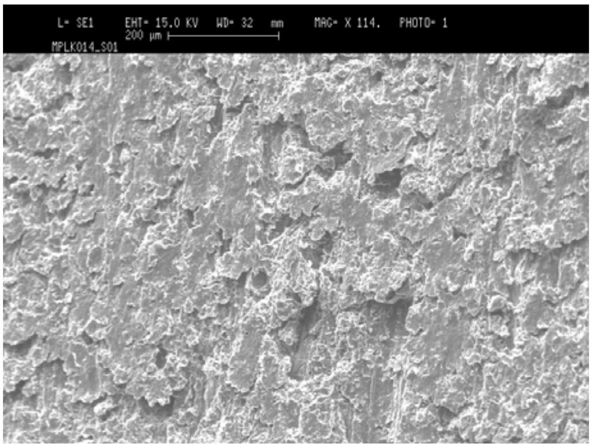
The bioclast seen in hand specimen is seen to comprise a partially preserved carbonate shell, but the body cavity has been completely in-filled with finely crystalline pyrite.



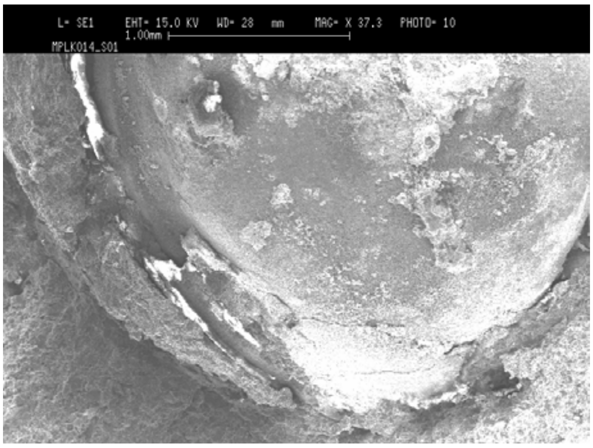
General view of this silty sample.



Detail showing loosely packed clays with pyrite framboids and dolomite euhedra (centre of image).



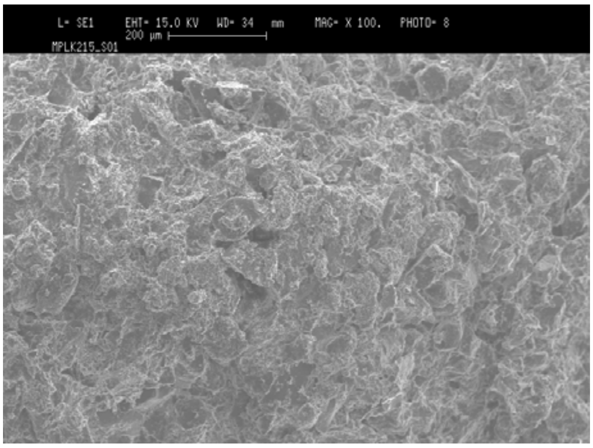
Low magnification image of the cut surface of the sample, showing it's relatively granular nature.



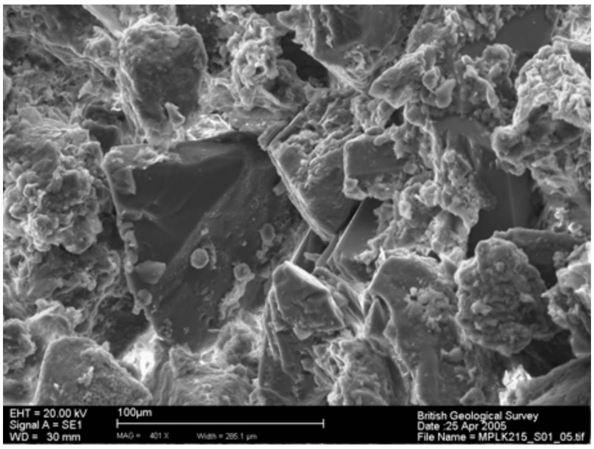
Low magnification image showing a pyritised bioclast with a clayey-coating.

Site:	**Alum Bay**	Sample ID:	**Alum Bay S1**
Basin:	**Hampshire**	Division:	**A**
MPL Sample Code(s):	**MPLK215_S01**	Preparation:	**Air dried, fresh fracture surface.**

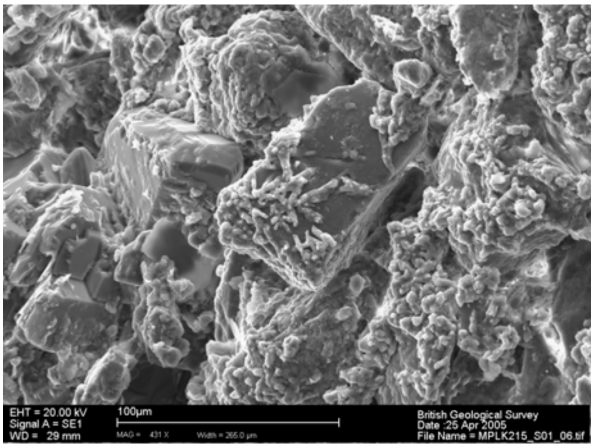
Description:
A muddy siltstone, with most framework grains between c. 50-100 µm in diameter. These grains sit in a clayey matrix. Pyrite framboids occur throughout. Minor anhydrite/gypsum is developed on some grain surfaces as a response to crying out/oxidation of the sample.



General view showing the silty nature of this sample.



Detail of silt- and fine-sand-grade particles with patchy interparticle clay.



Detail showing gypsum/anhydrite developed on exposed grain surfaces.

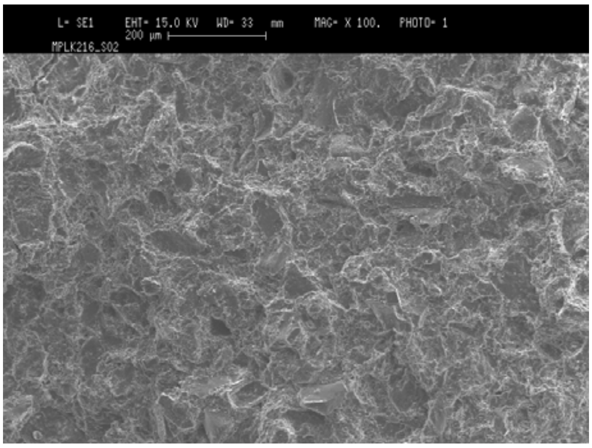
Site:	**Alum Bay**	Sample ID:	**Alum Bay S2**
Basin:	**Hampshire**	Division:	**A**
MPL Sample Code(s):	**MPLK216_S01**	Preparation:	**Air dried, fresh fracture surface.**
	MPLK216_S01		**Air dried, fresh fracture surface.**

Description:

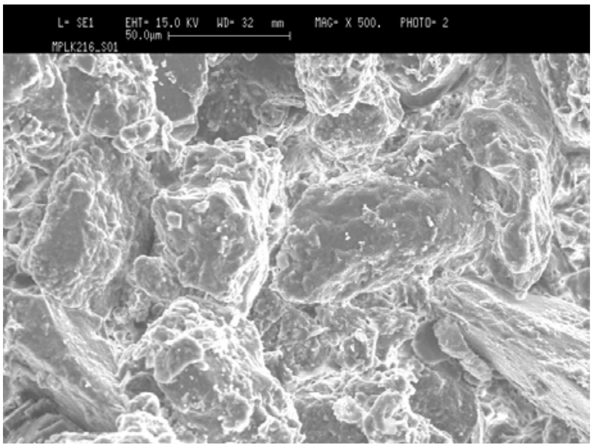
A very-fine grained sandstone, with grains between c. 50-100 μm diameter. Within MPLK216_S01, clay contents are very variable, with some clay poor domains, with high volumes of intergranular porosity, and other domains with abundant pore-filling clay. Sample MPLK216S1_02 is predominantly clay-rich and comparable to the clay-rich domains in MPLK216_S01.

Within the clay-rich domains, clay occurs in clumps which are squeezed between the more rigid grains. Whether these are “true” matrix clay or compacted mudclasts (“pseudo-matrix”) is unclear in these samples. Within the clumps, individual clay particles are fine-grained (<5 μm) with the same non-diagnostic chemistry as reported for other samples.

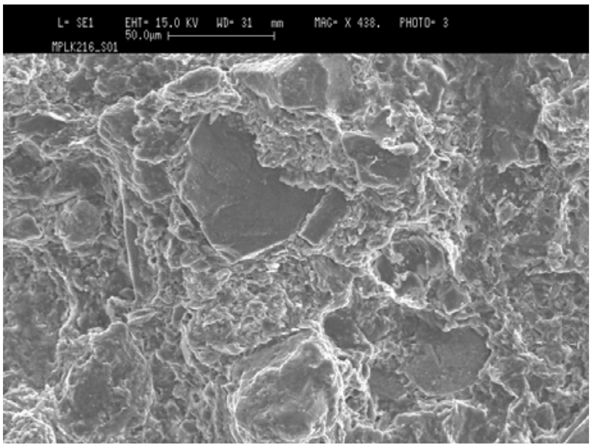
Minor framboidal pyrite is locally developed associated with the clays.



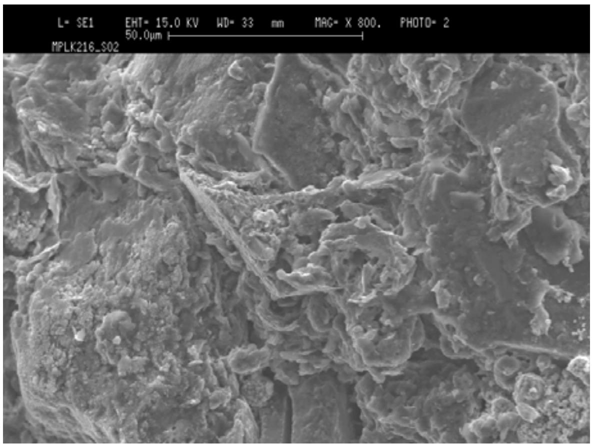
General view of this silty sample.



Detail of a relatively clay-poor domain, with some intergranular porosity.



Detail of a relatively clay-rich domain, in which the intergranular space between sand grains is filled with clay.



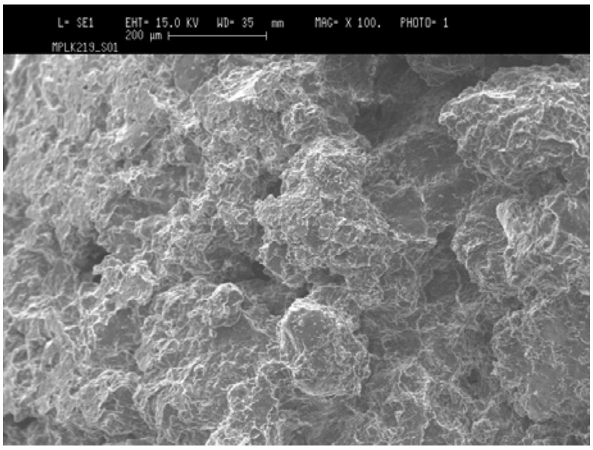
Detail of corroded feldspar grain.

Site:	**Studland**	Sample ID:	**Studland**
Basin:	**Hampshire**	Division:	**???**
MPL Sample Code(s):	**MPLK219_S01**	Preparation:	**Air dried, fresh fracture surface**
	MPLK219_S02		**Air dried, fresh fracture surface**

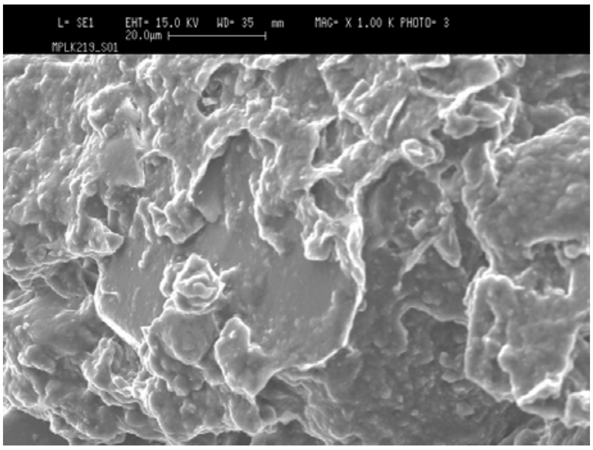
Description:

A muddy sand/siltstone. MPLK219_S01 is partially broken down into smaller rounded blocks of c. 100-300 µm in diameter. These blocks are a mixture of silt-grade grains of quartz/feldspar and mica, with clays. The clays have a relatively "lumpy" appearance, and EDXA indicates Si:Al dominated compositions (peak ratios between approx 2:1 and 2:2), locally with minor Fe.

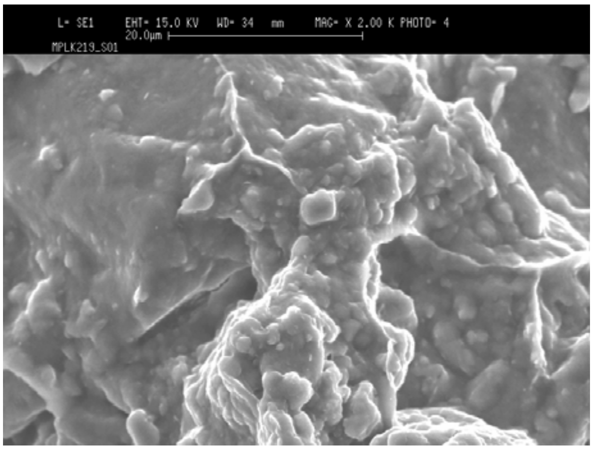
MPLK219_S02 is more clay-rich than the material sampled by MPLK219_S01, and is more massive in character. The clay is of similar chemistry though.



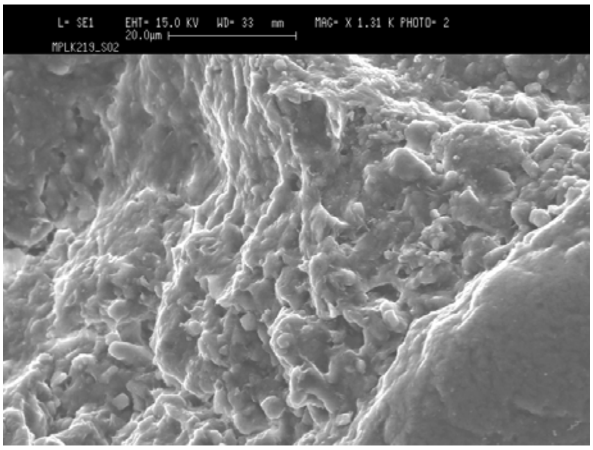
General view of the sample showing the presence of aggregates (a few 100 µm diameter) comprising a mixture of clay and silt-grade quartz and feldspar grains.



Detail of an aggregate of particles showing the development of rosettes of authigenic clay on one of the exposed surfaces.



Detail showing the relatively "lumpy" character of the clay within this sample.



Detail showing the relatively "lumpy" character of the clay within this sample.