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Mineralogy, Permeametry, Mercury Porosimetry and Scanning Electron Microscope Imaging of the Colorado Group: Shale Gas Data Release

Energy Resources Conservation Board

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Alberta Geological Survey

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Mineralogy, Permeametry, Mercury Porosimetry and Scanning Electron Microscope Imaging of the Colorado: Shale Gas Data Release

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Abstract

This report constitutes a data release of bulk and clay mineralogy, permeametry and mercury porosimetry analyses, and Scanning Electron Microscope imaging of selected samples from the Colorado Group generated for the ERCB/AGS project on shale gas resources in Alberta. This data release is complimentary to other manuscripts and data being released from the same project as listed in Table 1 of this report.

1 Introduction

The ERCB/AGS initiated a project in 2007 to evaluate shale gas resources in Alberta, to determine the quantity and spatial extent of these resources. The first formations chosen for evaluation are the Colorado Group, and the Banff and Exshaw formations. Alberta Geological Survey is releasing a series of reports to disseminate data and knowledge from the project.

This report disseminates results from bulk and clay mineralogy, permeametry, mercury porosimetry, scanning electron microscope (SEM) images and environmental scanning electron microscope (ESEM) images from selected samples of the Colorado Group. A list of all the analyses and associated reports is listed in Table 1. The data generated from the project will be combined with additional data to map and estimate shale gas resources in the province.

Table 1. Analyses performed on core and outcrop samples, and the organization that performed the analyses as part of the resource evaluation project.

Type of Analysis	Company/ Analyst	Notes
Isotherm	Schlumberger; CBM Solutions	Beaton et al. (2009a, b)
Mercury porosimetry, envelope and helium pycnometry	Department of Physics, University of Alberta (D. Schmitt)	Pawlowicz et al. (2009), this report
Permeametry	Department of Earth and Atmospheric Sciences, University of Alberta (M. Gingras)	Pawlowicz et al. (2009), this report
Rock Eval™/TOC	Geological Survey of Canada; Schlumberger; CBM Solutions	Beaton et al. (2009a, b)
Organic petrography	Geological Survey of Canada (J. Reyes)	Beaton et al. (2009a, b)
Petrographic analysis (thin section)	Vancouver Petrographics; CBM Solutions	Work in progress
Scanning electron microscope (SEM) with energy-dispersive X-ray (EDX)	Department of Earth and Atmospheric Sciences, University of Alberta (G. Braybrook)	Pawlowicz et al. (2009), this report
Environmental scanning electron microscope (ESEM)	Department of Biology, University of Alberta (R. Bhatnagar)	Pawlowicz et al. (2009), this report
X-ray diffraction (bulk and clay mineral)	SGS Minerals Services Ltd. (H. Zhou); CBM Solutions	Pawlowicz et al. (2009), this report

Alberta Geological Survey is also releasing a series of reports to introduce the project and distribute information related to specific formations (Rokosh et al., 2009a–c).

2 Sample Location and Description

The location map (Figure 1) displays all Colorado Group core and outcrop samples sites associated with the project. Tables 2 and Table 3, and Appendices 1 and 2 list the precise locations of the sample sites.

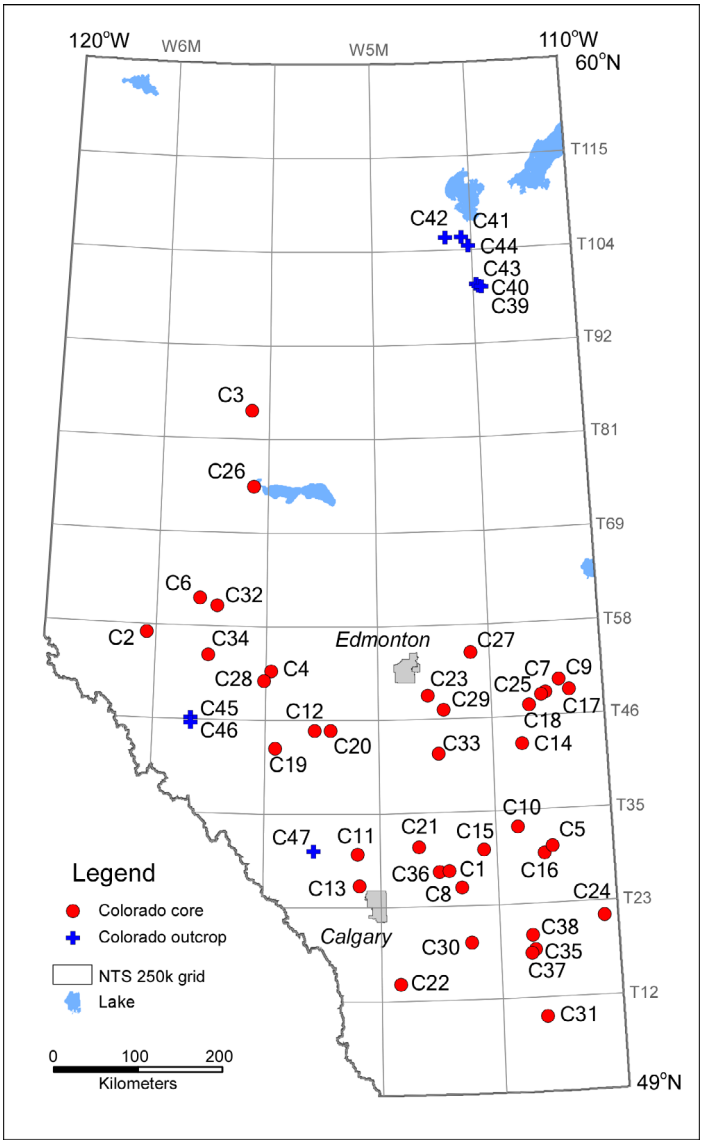

Figure 1. Core and outcrop sites sampled for the Colorado Group. See Appendices 1 to 4 for a list of all sites and the type and results of analyses run on various samples.

Table 2. Core sample sites in the Colorado Group. The site number is shown on the location map in Figure 1.

Site No.	UWI	Year Drilled	Latitude (NAD 83)	Longitude (NAD 83)	No. of Samples
C1	100/04-11-028-22W4/00	2002	51.375375	-113.000008	6
C2	100/04-13-057-02W6/00	1962	53.921689	-118.170820	4
C3	100/04-29-084-15W5/00	1952	56.306578	-116.343026	6
C4	100/04-31-052-13W5/00	2002	53.530211	-115.912450	2
C5	100/05-03-030-09W4/00	1946	51.537185	-111.195974	4
C6	100/05-27-061-22W5/00	1997	54.301584	-117.223564	4
C7	100/05-30-049-07W4/00	2005	53.252575	-111.024184	2
C8	100/06-08-026-19W4/00	1980	51.202869	-112.626651	15
C9	100/06-11-051-06W4/00	2006	53.385074	-110.785026	2
C10	100/06-15-033-12W4/00	1980	51.827956	-111.624287	6
C11	100/06-17-030-03W5/00	1982	51.568032	-114.390518	8
C12	100/06-20-045-08W5/00	1979	52.892068	-115.129925	2
C13	100/06-21-026-03W5/00	1983	51.233282	-114.365538	6
C14	100/06-23-043-11W4/00	2004	52.716100	-111.492278	9
C15	100/06-29-030-16W4/00	1969	51.595232	-112.225252	5
C16	100/06-34-030-08W4/00	1969	51.609735	-111.052452	6
C17	100/06-36-049-05W4/00	2004	53.268414	-110.606135	3
C18	100/07-12-048-10W4/00	2004	53.124039	-111.332989	7
C19	100/07-16-043-13W5/00	2006	52.703957	-115.824531	3
C20	100/07-19-045-06W5/00	1979	52.892376	-114.854086	17
C21	100/08-09-031-24W4/00	1952	51.639466	-113.338692	2
C22	100/08-24-014-28W4/00	1998	50.184098	-113.687414	4
C23	100/08-27-049-22W4/00	2004	53.254932	-113.128424	5
C24	100/09-05-022-02W4/00	2004	50.844894	-110.240303	1
C25	100/09-16-049-08W4/00	2005	53.229437	-111.107643	6
C26	100/12-16-075-15W5/00	1950	55.499580	-116.274307	7
C27	100/12-32-054-16W4/00	2004	53.709217	-112.332670	9
C28	100/13-20-051-14W5/00	2003	53.421051	-116.035363	4
C29	100/13-34-047-20W4/00	2005	53.102456	-112.853120	4
C30	100/14-18-019-18W4/00	2004	50.612176	-112.488545	6
C31	100/15-03-010-10W4/00	1949	49.798867	-111.277656	3
C32	100/15-27-060-20W5/00	1982	54.221782	-116.911726	4
C33	100/16-21-042-21W4/00	1979	52.634805	-112.960210	10
C34	100/16-29-054-21W5/00	1980	53.697729	-117.053605	7
C35	102/03-14-018-11W4/00	2004	50.515815	-111.418557	4
C36	102/10-12-028-21W4/00	2004	51.381352	-112.830195	2
C37	102/11-32-017-11W4/00	2003	50.480518	-111.484881	8
C38	102/13-03-020-11W4/00	2004	50.670810	-111.457733	4

Table 3. Outcrop sample sites in the Colorado Group. The site number is shown on the location map in Figure 1.

Site No.	UTM (NAD 83) Zone	Easting	Northing	Site Location Name	No. of Samples	Formation/ Group
C39	12	446778	6385401	Birch Mtns - NTS 84I	1	Colorado
C40	12	449178	6384521	Birch Mtns - NTS 84I	1	Colorado
C41	12	429162	6444821	Birch Mtns - NTS 84I	1	Colorado
C42	12	410496	6444999	Birch Mtns - NTS 84I	3	Colorado
C43	12	443512	6387776	Birch Mtns - Asphalt Creek	16	Colorado - 2WSP
C44	12	436680	6434329	Birch Mtns - Graystone Creek	22	Colorado - Shaftesbury
C45	11	478167	5875014	Cadomin - railroad section	30	Colorado - Blackstone

3 Analytical Methods and Results

A total of 74 outcrop and 207 core samples was selected for analysis. The analyses itemized in Table 1 were performed on selected samples, as indicated in Appendices 3 and 4.

3.1 Bulk and Clay Mineralogy

X-ray powder diffraction (XRD) will identify the mineralogy of a sample. An estimate of the weight percent (wt. %) of each mineral is provided in Appendix 5 for bulk mineralogy and Appendix 6 for clay mineralogy.

X-ray diffraction analysis and interpretation, and X-ray fluorescence spectroscopy (XRF) on core samples was done by SGS Minerals Services Ltd. (http://www.ca.sgs.com/home.htm [January 2009]), while CBM Solutions Ltd. (http://www.cbmsolutions.com [January 2009]) performed XRD analysis and interpretation on outcrop samples using industry-standard techniques.

SGS Minerals uses a Siemens D5000 diffractometer with cobalt radiation and Siemens Search/Match software for peak identification. Mineral proportions are based on relative peak heights and may be strongly influenced by crystallinity, structural group or preferred orientations (H. Zhou, SGS Minerals Services Ltd., pers. comm., 2008). The calculation of mineral abundances from both bulk mineral analysis and clay mineral separates is based on relative peak intensity and is reconciled with a whole-rock analysis by XRF (results provided in Appendix 5b). The detection limit of minerals is approximately 0.5–2.0 wt. % according to SGS, but can be as high as 3–5 wt. % (http://www.xrd.us [January 2009]). However, amorphous compounds are not detected by XRD.

CBM Solutions uses a Siemens D5000 or D500 with copper or cobalt X-ray tube and search/match software for peak identification. The XRD results were analyzed using a commercial Rietveld analysis program for quantification of the mineralogy. The accuracy of the Rietveld analysis is considered to be ±3% in minerals with fixed cell dimensions. In samples with substantial disordered clay minerals, the total percentage of clay was determined by Rietveld fitting and then the relative abundance of the clay species was quantified by integrating the areas under the 00l peak. The Lorentz and polarization contributions to the X-ray intensity in this study were corrected following the procedures of Pecharsky and Zavalij (2003, p. 192). Due to the presence of disordered phases and the need for a combination of methodologies, the accuracy of the results varies sample by sample. For samples in which substantial

montmorillonite, random mixed-layer clays and/or degraded illite are present, the percentage mineralogy reported here is best considered semiquantitative.

Bulk mineralogy and X-ray fluorescence spectroscopy data can be found in Appendix 5a and b; clay mineralogy can be found in Appendix 6a and b.

3.2 Permeametry

Spot permeametry analysis (Gingras et al., 2004) was carried out at the University of Alberta on a portable probe permeameter (CoreLabs Model PP-250), with nitrogen as the pore fluid. Note that the diameter of a nitrogen molecule is about 0.15 nm (1.5 angstroms), while the diameter of a methane molecule is about 0.4 nm (4.0 angstroms). Each sample was tested 4–6 times. The average Kl for each sample in Table 4 was calculated by removing high and low recorded values, then averaging remaining values.

Table 4. Summary of permeametry data for samples from the Colorado Group.

AGS Sample No.	Core Depth (ft)	Core Depth (m)	UWI	Formation	Average Kl (shale)	Average Kl (other)
8027		701.6-702.2	102/13-03-020-11W4/00	2WSPKS/Belle Fourche	0.0544	
8031		2017.5	100/13-20-051-14W5/00	2WSPKS	0.0243667	
8596		805.1	100/16-21-042-21W4/00	Milk River	2.75	
8669	8494.5	2589.1	100/04-13-057-02W6/00	Cardium Zone	0.023467	
7292		2120.0	100/08-24-014-28W4/00	Fish Scales	0.013303 (sand layer)	0.002475 (mud)
8516		630.0	100/14-18-019-18W4/00	1WSPKS	6.94	
8634		1740.2	100/15-27-060-20W5/00	2WSPKS	0.007535	
8656		1836.1	100/07-19-045-06W5/00	2WSPKS	0.159	

3.3 Scanning Electron Microscope and EDX analysis

The purpose of the scanning electron microscope (SEM) analysis is to characterize the microfabric of the samples, and the morphology, size and distribution of the pores. The SEM can also provide a mineralogical analysis using energy dispersive X-rays (EDX), as well as backscattering images on selected samples. Most samples were analyzed using an SEM fitted with an EDX spectrometer. Selected samples were analyzed using an environmental scanning electron microscope (ESEM), which allowed variations in sample size with minimal sample preparation; however, an EDX system was not available for this microscope.

All samples that underwent ESEM analysis were examined in high vacuum mode using a secondary electron detector at 15–20 kV with a Philips/FEI XL 30 ESEM. The ESEM equipment has a resolution of 2.5 nm and a magnification up to 200 000×. The SEM was a JEOL 6301F (field emission scanning electron microscope) with magnification ranging from 20× to 250 000×. Semiqualitative elemental analysis (EDX) was available via a PGT X-ray analysis system. The resolution of EDX mineralogical analysis is 1 μm.

The SEM and ESEM images can be found in Appendix 7. A brief description is provided with each image; the descriptions are strictly observational.

3.4 Mercury Porosimetry

Mercury porosimetry is a technique to quantify intrusion pore diameter, size range of diameters, pore volume and pore surface area of the samples (Webb and Orr, 1997). Porosimeter work was done at the University of Alberta. All samples were put under vacuum in a cold oven for degassing prior to analysis. Mercury was introduced into the sample and the volume of mercury forced into pore space in the sample used to calculate pore volume for the sample. The data graphed here is only one of a number of columns of data available for analysis.

The graphs of incremental intrusion versus pore diameter (Appendix 8) show the equivalent spherical diameter at which the pore volume is concentrated (Webb and Orr, 1997).

The data in this study were generated using the Washburn equation ($D = -4\gamma\cos\theta/P$), where γ is the surface tension, θ is the assumed contact angle of mercury, P is the applied pressure and D is the equivalent pore diameter. The term 'equivalent' is used because the equation assumes all pores are the equivalent shape of a cylinder; in reality, this is not the case. The surface tension (485 dynes/cm), contact angle (130°) and equilibration time (10 seconds) between successive increases in pressure used in the procedure are all recommended by the manufacturer.

If pores are assumed to be dominated by 'slit-like' openings, as in clay-dominated sediment, then the data may be recalculated using $W = -2\gamma\cos\theta/P$, where W is the width between plates (Webb and Orr 1997). However, the samples in this study are dominantly silt-rich shale/mudstone or shaley siltstone, so we are comfortable using the Washburn equation as a starting point of analysis.

A summary of the procedure can be found in Webb and Orr (1997) and D'Souzae and More (2008).

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Appendices

Appendix 1 – Colorado Group Core Sample Location, Depth and Lithology

Legend

Column Label	Label Description
Sample No.	AGS sample number
Site No.	Site location number
UWI	Unique well identifier
Latitude (NAD 83)	Well location - degrees latitude (North American Datum 1983)
Longitude (NAD 83)	Well location - degrees longitude (North American Datum 1983)
Sample Depth (metres)	Depth of sample from core in metres (measured from core)
Lithology	Brief lithological description of sample
Formation Division	Subdivision of formation sampled
Year Sampled	Year sample collected

Sample No.	Site No.	UWI	Latitude (NAD 83)	Longitude (NAD 83)	Core Depth (metres)	Lithology	Formation Division	Year Sampled
8501	C01	100/04-11-028-22W4/00	51.375371	-113.000011	1230.3	Black shale	Belle Fourche	2007
8502	C01	100/04-11-028-22W4/00	51.375371	-113.000011	1238.1	Black shale	Belle Fourche	2007
8503	C01	100/04-11-028-22W4/00	51.375371	-113.000011	1245.0	Black shale	Belle Fourche	2007
8504	C01	100/04-11-028-22W4/00	51.375371	-113.000011	1248.5	Black shale	Belle Fourche	2007
8505	C01	100/04-11-028-22W4/00	51.375371	-113.000011	1249.7	Black shale with very fine sandstone interbedded	Fish Scale Zone	2007
8506	C01	100/04-11-028-22W4/00	51.375371	-113.000011	1252.5	Black shale	Fish Scale Zone	2007
8668	C02	100/04-13-057-02W6/00	53.921709	-118.170803	2582.3	Black mudstone	Cardium Zone	2007
8669	C02	100/04-13-057-02W6/00	53.921709	-118.170803	2589.1	Black mudstone	Cardium Zone	2007
8670	C02	100/04-13-057-02W6/00	53.921709	-118.170803	2592.5	Black shale	Cardium Zone	2007
8671	C02	100/04-13-057-02W6/00	53.921709	-118.170803	2593.8	Dark grey silty mudstone with coaly detritus	Cardium Zone	2007
8627	C03	100/04-29-084-15W5/00	56.306578	-116.343167	292.6	Grey mudstone	Westgate	2007
8628	C03	100/04-29-084-15W5/00	56.306578	-116.343167	298.4	Dark grey mudstone	Westgate	2007
8629	C03	100/04-29-084-15W5/00	56.306578	-116.343167	300.5	Dark grey mudstone	Westgate	2007
8630	C03	100/04-29-084-15W5/00	56.306578	-116.343167	308.5	Grey mudstone	Westgate	2007
8631	C03	100/04-29-084-15W5/00	56.306578	-116.343167	314.6	Dark grey mudstone	Westgate	2007
8632	C03	100/04-29-084-15W5/00	56.306578	-116.343167	320.0	Grey mudstone	Westgate	2007
8034	C04	100/04-31-052-13W5/00	53.530131	-115.912450	1808.9-1809.5	Dark grey shale	Second White Specks	2008
8035	C04	100/04-31-052-13W5/00	53.530131	-115.912450	1818.4	Dark grey shale	Second White Specks	2008
8531	C05	100/05-03-030-09W4/00	51.537186	-111.196063	554.7	Grey mudstone with fossils	First White Specks?	2007
8532	C05	100/05-03-030-09W4/00	51.537186	-111.196063	559.6	Grey mudstone with fossils	First White Specks?	2007
8533	C05	100/05-03-030-09W4/00	51.537186	-111.196063	560.2	Grey mudstone with fossils	First White Specks?	2007
8534	C05	100/05-03-030-09W4/00	51.537186	-111.196063	565.1	Grey speckled mudstone	First White Specks?	2007
8644	C06	100/05-27-061-22W5/00	54.301586	-117.223691	1852.8	Dark grey shale	Shaftesbury	2007
8645	C06	100/05-27-061-22W5/00	54.301586	-117.223691	1854.4	Dark grey mudstone	Shaftesbury	2007
8646	C06	100/05-27-061-22W5/00	54.301586	-117.223691	1857.0	Black coaly shale?	Shaftesbury	2007
8647	C06	100/05-27-061-22W5/00	54.301586	-117.223691	1860.5	Black shale	Shaftesbury	2007
8540	C07	100/05-30-049-07W4/00	53.252497	-111.024094	428.8	Grey siltstone	Card. Equiv. Zone	2007
8541	C07	100/05-30-049-07W4/00	53.252497	-111.024094	432.3	Grey siltstone	Card. Equiv. Zone	2007
8581	C08	100/06-08-026-19W4/00	51.202794	-112.626775	811.5	Black shale	Milk River	2007
8582	C08	100/06-08-026-19W4/00	51.202794	-112.626775	813.8	Dark grey shale	Milk River	2007
8583	C08	100/06-08-026-19W4/00	51.202794	-112.626775	818.0	Dark grey shale	First White Specks	2007
8584	C08	100/06-08-026-19W4/00	51.202794	-112.626775	822.4	Shaley siltstone laminated	First White Specks	2007
8585	C08	100/06-08-026-19W4/00	51.202794	-112.626775	823.0	Interbedded mudstone and siltstone	First White Specks	2007
8586	C08	100/06-08-026-19W4/00	51.202794	-112.626775	825.0	Dark grey shale	First White Specks	2007
8587	C08	100/06-08-026-19W4/00	51.202794	-112.626775	828.5	Grey siltstone	First White Specks	2007
8588	C08	100/06-08-026-19W4/00	51.202794	-112.626775	832.4	Dark grey mudstone	First White Specks	2007
8589	C08	100/06-08-026-19W4/00	51.202794	-112.626775	833.7	Dark grey shale	First White Specks	2007
8590	C08	100/06-08-026-19W4/00	51.202794	-112.626775	836.1	Dark grey silty shale	First White Specks	2007
8591	C08	100/06-08-026-19W4/00	51.202794	-112.626775	841.4	Dark grey shale	First White Specks	2007
8592	C08	100/06-08-026-19W4/00	51.202794	-112.626775	847.8	Dark grey shale	Medicine Hat	2007
8593	C08	100/06-08-026-19W4/00	51.202794	-112.626775	850.4	Dark grey shale	Medicine Hat	2007
8594	C08	100/06-08-026-19W4/00	51.202794	-112.626775	853.7	Black shale	Medicine Hat	2007
8595	C08	100/06-08-026-19W4/00	51.202794	-112.626775	856.2	Dark grey shale	Medicine Hat	2007
8529	C09	100/06-11-051-06W4/00	53.385156	-110.785097	332.6	Grey siltstone	Card. Equiv. Zone	2007

Sample No.	Site No.	UWI	Latitude (NAD 83)	Longitude (NAD 83)	Core Depth (metres)	Lithology	Formation Division	Year Sampled
8530	C09	100/06-11-051-06W4/00	53.385156	-110.785097	333.4	Grey siltstone	Card. Equiv. Zone	2007
8575	C10	100/06-15-033-12W4/00	51.827959	-111.624249	799.6	Black shale	Card. Equiv. Zone	2007
8576	C10	100/06-15-033-12W4/00	51.827959	-111.624249	800.7	Black shale interbedded with siltstone	Card. Equiv. Zone	2007
8577	C10	100/06-15-033-12W4/00	51.827959	-111.624249	806.6	Dark grey speckled shale	Second White Specks	2007
8578	C10	100/06-15-033-12W4/00	51.827959	-111.624249	809.8	Dark grey shale	Second White Specks	2007
8579	C10	100/06-15-033-12W4/00	51.827959	-111.624249	814.1	Dark grey speckled shale	Second White Specks	2007
8580	C10	100/06-15-033-12W4/00	51.827959	-111.624249	816.3	Dark grey shale	Second White Specks	2007
8042	C11	100/06-17-030-03W5/00	51.568035	-114.390524	2319.7-2328.9	Combined samples: 8606, 07, 08, 09	Fish Scale Zone	2007
8606	C11	100/06-17-030-03W5/00	51.568035	-114.390524	2319.7	Black laminated shale	Fish Scale Zone	2007
8607	C11	100/06-17-030-03W5/00	51.568035	-114.390524	2323.5	Black laminated shale	Fish Scale Zone	2007
8608	C11	100/06-17-030-03W5/00	51.568035	-114.390524	2326.0	Black shale	Fish Scale Zone	2007
8609	C11	100/06-17-030-03W5/00	51.568035	-114.390524	2328.9	Black shale	Fish Scale Zone	2007
8610	C11	100/06-17-030-03W5/00	51.568035	-114.390524	2330.2	Black shale	Westgate	2007
8611	C11	100/06-17-030-03W5/00	51.568035	-114.390524	2333.0	Black shale	Westgate	2007
8612	C11	100/06-17-030-03W5/00	51.568035	-114.390524	2336.3	Black laminated shale	Westgate	2007
8613	C12	100/06-20-045-08W5/00	52.892068	-115.129927	1772.4	Black shale	Blackstone	2007
8614	C12	100/06-20-045-08W5/00	52.892068	-115.129927	1773.6	Black shale	Blackstone	2007
8507	C13	100/06-21-026-03W5/00	51.233362	-114.365477	2239.5	Black shaley mudstone	First White Specks	2007
8508	C13	100/06-21-026-03W5/00	51.233362	-114.365477	2241.5	Black shaley mudstone	First White Specks	2007
8509	C13	100/06-21-026-03W5/00	51.233362	-114.365477	2249.0	Black mudstone with very fine sandstone lenses	Cardium Zone	2007
8510	C13	100/06-21-026-03W5/00	51.233362	-114.365477	2256.3	Dark grey silty mudstone	Cardium Zone	2007
8511	C13	100/06-21-026-03W5/00	51.233362	-114.365477	2264.3	Dark grey mudstone	Cardium Zone	2007
8512	C13	100/06-21-026-03W5/00	51.233362	-114.365477	2279.8	Dark grey mudstone	Cardium Zone	2007
8041	C14	100/06-23-043-11W4/00	52.716098	-111.492145	548.9-560.4	Combined samples: 8523, 24, 25, 27, 28	Second White Specks	2007
8521	C14	100/06-23-043-11W4/00	52.716098	-111.492145	542.9	Black shale	top of Second White Specks	2007
8522	C14	100/06-23-043-11W4/00	52.716098	-111.492145	546.2	Interbedded silt, shale, very fine sandstone	Second White Specks	2007
8523	C14	100/06-23-043-11W4/00	52.716098	-111.492145	548.9	Silty shale	Second White Specks	2007
8524	C14	100/06-23-043-11W4/00	52.716098	-111.492145	550.4	Silty shale	Second White Specks	2007
8525	C14	100/06-23-043-11W4/00	52.716098	-111.492145	553.4	Muddy siltstone with very fine sandstone lenses	Second White Specks	2007
8526	C14	100/06-23-043-11W4/00	52.716098	-111.492145	555.5	Muddy siltstone with very fine sandstone lenses	Second White Specks	2007
8527	C14	100/06-23-043-11W4/00	52.716098	-111.492145	557.2	Dark grey shale	Second White Specks	2007
8528	C14	100/06-23-043-11W4/00	52.716098	-111.492145	560.4	Laminated muddy siltstone and very fine sandstone	Second White Specks	2007
8535	C15	100/06-29-030-16W4/00	51.595231	-112.225340	1060.7	Black shale	Fish Scale Zone	2007
8536	C15	100/06-29-030-16W4/00	51.595231	-112.225340	1062.2	Black shale	Fish Scale Zone	2007
8537	C15	100/06-29-030-16W4/00	51.595231	-112.225340	1064.1	Black shale and siltstone with fossils	Fish Scale Zone	2007
8538	C15	100/06-29-030-16W4/00	51.595231	-112.225340	1069.5	Dark grey shale	Fish Scale Zone	2007
8539	C15	100/06-29-030-16W4/00	51.595231	-112.225340	1077.9	Dark grey shale	Westgate	2007
8556	C16	100/06-34-030-08W4/00	51.609735	-111.052456	647.7	Dark grey mudstone	First White Specks	2007
8557	C16	100/06-34-030-08W4/00	51.609735	-111.052456	656.2	Grey mudstone	Card. Equiv. Zone?	2007
8558	C16	100/06-34-030-08W4/00	51.609735	-111.052456	662.3	Grey mudstone	Card. Equiv. Zone?	2007
8559	C16	100/06-34-030-08W4/00	51.609735	-111.052456	673.5	Grey shale with fossils	Card. Equiv. Zone?	2007
8560	C16	100/06-34-030-08W4/00	51.609735	-111.052456	680.5	Dark grey mudstone	Card. Equiv. Zone?	2007
8561	C16	100/06-34-030-08W4/00	51.609735	-111.052456	687.0	Dark grey mudstone	Card. Equiv. Zone?	2007
8542	C17	100/06-36-049-05W4/00	53.268492	-110.606221	410.0	Grey silty shale	Card. Equiv. Zone	2007

Sample No.	Site No.	UWI	Latitude (NAD 83)	Longitude (NAD 83)	Core Depth (metres)	Lithology	Formation Division	Year Sampled
8543	C17	100/06-36-049-05W4/00	53.268492	-110.606221	414.0	Grey siltstone	Card. Equiv. Zone	2007
8544	C17	100/06-36-049-05W4/00	53.268492	-110.606221	417.5	Dark grey shale with silty laminea	Card. Equiv. Zone	2007
7294	C18	100/07-12-048-10W4/00	53.124039	-111.332969	498.7	Shale	Cardium Zone	2006
7295	C18	100/07-12-048-10W4/00	53.124039	-111.332969	504.4	Shale	Cardium Zone	2006
7296	C18	100/07-12-048-10W4/00	53.124039	-111.332969	507.1	Shale	Cardium Zone	2006
7297	C18	100/07-12-048-10W4/00	53.124039	-111.332969	507.7	Shale	Cardium Zone	2006
7298	C18	100/07-12-048-10W4/00	53.124039	-111.332969	508.2	Shale	Cardium Zone	2006
7299	C18	100/07-12-048-10W4/00	53.124039	-111.332969	512.1	Shale	Cardium Zone	2006
7300	C18	100/07-12-048-10W4/00	53.124039	-111.332969	519.4	Shale	Cardium Zone	2006
8641	C19	100/07-16-043-13W5/00	52.703956	-115.824539	2916.6-2932	Black shale	Westgate	2007
8642	C19	100/07-16-043-13W5/00	52.703956	-115.824539	2916.6-2932	Black shale	Westgate	2007
8643	C19	100/07-16-043-13W5/00	52.703956	-115.824539	2916.6-2932	Black shale	Westgate	2007
8045	C20	100/07-19-045-06W5/00	52.892373	-114.854086	1816.6-1821.9	Combined samples: 8650, 51, 52	Second White Specks	2007
8648	C20	100/07-19-045-06W5/00	52.892373	-114.854086	1810.9	Black mudstone	Second White Specks	2007
8649	C20	100/07-19-045-06W5/00	52.892373	-114.854086	1814.3	Black mudstone	Second White Specks	2007
8650	C20	100/07-19-045-06W5/00	52.892373	-114.854086	1816.6	Black mudstone	Second White Specks	2007
8651	C20	100/07-19-045-06W5/00	52.892373	-114.854086	1819.8	Black mudstone	Second White Specks	2007
8652	C20	100/07-19-045-06W5/00	52.892373	-114.854086	1821.9	Black mudstone	Second White Specks	2007
8653	C20	100/07-19-045-06W5/00	52.892373	-114.854086	1825.3	Dark grey shale	Second White Specks	2007
8654	C20	100/07-19-045-06W5/00	52.892373	-114.854086	1827.6	Dark grey shale	Second White Specks	2007
8655	C20	100/07-19-045-06W5/00	52.892373	-114.854086	1832.8	Black mudstone	Second White Specks	2007
8656	C20	100/07-19-045-06W5/00	52.892373	-114.854086	1836.1	Dark grey mudstone	Second White Specks	2007
8657	C20	100/07-19-045-06W5/00	52.892373	-114.854086	1840.1	Black mudstone	Second White Specks	2007
8658	C20	100/07-19-045-06W5/00	52.892373	-114.854086	1846.8	Black mudstone	Second White Specks	2007
8659	C20	100/07-19-045-06W5/00	52.892373	-114.854086	1852.0	Black mudstone	Second White Specks	2007
8660	C20	100/07-19-045-06W5/00	52.892373	-114.854086	1856.0	Black mudstone	Belle Fourche?	2007
8661	C20	100/07-19-045-06W5/00	52.892373	-114.854086	1859.8	Black shale	Belle Fourche?	2007
8662	C20	100/07-19-045-06W5/00	52.892373	-114.854086	1865.2	Black mudstone	Belle Fourche?	2007
8663	C20	100/07-19-045-06W5/00	52.892373	-114.854086	1869.6	Black mudstone	Belle Fourche?	2007
8554	C21	100/08-09-031-24W4/00	51.639470	-113.338736	1448.6	Black shale	Westgate	2007
8555	C21	100/08-09-031-24W4/00	51.639470	-113.338736	1449.0	Black shale	Westgate	2007
7289	C22	100/08-24-014-28W4/00	50.184105	-113.687534	2104.0	Shale	Fish Scale Zone	2006
7290	C22	100/08-24-014-28W4/00	50.184105	-113.687534	2112.1	Shale	Fish Scale Zone	2006
7291	C22	100/08-24-014-28W4/00	50.184105	-113.687534	2117.4	Shale	Fish Scale Zone	2006
7292	C22	100/08-24-014-28W4/00	50.184105	-113.687534	2120.0	Shale	Fish Scale Zone	2006
8048	C23	100/08-27-049-22W4/00	53.254931	-113.128424	745.0-747.5	Combined samples: 8666, 67	First White Specks	2007
8664	C23	100/08-27-049-22W4/00	53.254931	-113.128424	738.3	Dark grey shale	First White Specks	2007
8665	C23	100/08-27-049-22W4/00	53.254931	-113.128424	742.5	Dark grey shale	First White Specks	2007
8666	C23	100/08-27-049-22W4/00	53.254931	-113.128424	745.0	Dark grey shale	First White Specks	2007
8667	C23	100/08-27-049-22W4/00	53.254931	-113.128424	747.5	Dark grey shale	First White Specks	2007
8029	C24	100/09-05-022-02W4/00	50.844880	-110.240286	622.0-622.4	Shale	Fish Scale Zone	2008
8548	C25	100/09-16-049-08W4/00	53.229438	-111.107681	447.9	Dark grey shale	First White Specks	2007
8549	C25	100/09-16-049-08W4/00	53.229438	-111.107681	450.0	Grey interbedded silt and shale	Card. Equiv. Zone	2007
8550	C25	100/09-16-049-08W4/00	53.229438	-111.107681	455.4	Dark grey silty shale	Card. Equiv. Zone	2007

Sample No.	Site No.	UWI	Latitude (NAD 83)	Longitude (NAD 83)	Core Depth (metres)	Lithology	Formation Division	Year Sampled
8551	C25	100/09-16-049-08W4/00	53.229438	-111.107681	457.7	Dark grey silty shale	Card. Equiv. Zone	2007
8552	C25	100/09-16-049-08W4/00	53.229438	-111.107681	462.5	Grey siltstone	Card. Equiv. Zone	2007
8553	C25	100/09-16-049-08W4/00	53.229438	-111.107681	470.2	Grey shaley siltstone	Card. Equiv. Zone	2007
8620	C26	100/12-16-075-15W5/00	55.499583	-116.274312	211.1	Dark grey silty shale	1stWS or Card. Equiv	2007
8621	C26	100/12-16-075-15W5/00	55.499583	-116.274312	216.1	Grey silty shale	1stWS or Card. Equiv	2007
8622	C26	100/12-16-075-15W5/00	55.499583	-116.274312	240.5	Grey silty shale	Second White Specks?	2007
8623	C26	100/12-16-075-15W5/00	55.499583	-116.274312	245.4	Grey silty shale	Second White Specks?	2007
8624	C26	100/12-16-075-15W5/00	55.499583	-116.274312	271.0	Grey silty shale	Second White Specks?	2007
8625	C26	100/12-16-075-15W5/00	55.499583	-116.274312	275.2	Grey silty shale	Second White Specks?	2007
8626	C26	100/12-16-075-15W5/00	55.499583	-116.274312	280.7	Grey silty shale	Second White Specks?	2007
8566	C27	100/12-32-054-16W4/00	53.709219	-112.332668	417.3	Silty shale	First White Specks	2007
8567	C27	100/12-32-054-16W4/00	53.709219	-112.332668	420.5	Dark grey shale	First White Specks	2007
8568	C27	100/12-32-054-16W4/00	53.709219	-112.332668	423.0	Dark grey shale	First White Specks	2007
8569	C27	100/12-32-054-16W4/00	53.709219	-112.332668	425.5	Dark grey shale	First White Specks	2007
8570	C27	100/12-32-054-16W4/00	53.709219	-112.332668	459.0	Dark grey shale	First White Specks	2007
8571	C27	100/12-32-054-16W4/00	53.709219	-112.332668	461.3	Grey shale	Card. Equiv. Zone	2007
8572	C27	100/12-32-054-16W4/00	53.709219	-112.332668	464.0	Grey shale	Card. Equiv. Zone	2007
8573	C27	100/12-32-054-16W4/00	53.709219	-112.332668	466.6	Grey mudstone	Card. Equiv. Zone	2007
8574	C27	100/12-32-054-16W4/00	53.709219	-112.332668	471.2	Grey siltstone	Card. Equiv. Zone	2007
8637	C28	100/13-20-051-14W5/00	53.421052	-116.035361	2017.5	Black mudstone	Second White Specks	2007
8638	C28	100/13-20-051-14W5/00	53.421052	-116.035361	2021.8	Black mudstone	Second White Specks	2007
8639	C28	100/13-20-051-14W5/00	53.421052	-116.035361	2071.5	Black shale	Second White Specks	2007
8640	C28	100/13-20-051-14W5/00	53.421052	-116.035361	2078.0	Black shale	Second White Specks	2007
8562	C29	100/13-34-047-20W4/00	53.102458	-112.853229	844.5	Dark grey muddy siltstone	Card. Equiv. Zone	2007
8563	C29	100/13-34-047-20W4/00	53.102458	-112.853229	864.5	Dark grey muddy siltstone	Card. Equiv. Zone	2007
8564	C29	100/13-34-047-20W4/00	53.102458	-112.853229	849.0	Grey siltstone with sandstone laminea	Second White Specks	2007
8565	C29	100/13-34-047-20W4/00	53.102458	-112.853229	852.4	Grey siltstone with sandstone laminea	Second White Specks	2007
8023	C30	100/14-18-019-18W4/00	50.612334	-112.488539	608.8-609.35	Grey mudstone	First White Specks	2008
8024	C30	100/14-18-019-18W4/00	50.612334	-112.488539	622.7-623.25	Grey mudstone	First White Specks	2008
8513	C30	100/14-18-019-18W4/00	50.612334	-112.488539	605.5	Dark grey mudstone	Milk River	2007
8514	C30	100/14-18-019-18W4/00	50.612334	-112.488539	612.0	Grey mudstone with fossils	Milk River	2007
8515	C30	100/14-18-019-18W4/00	50.612334	-112.488539	616.2	Grey shaley mudstone	First White Specks	2007
8516	C30	100/14-18-019-18W4/00	50.612334	-112.488539	630.0	Grey shale with fossils	First White Specks	2007
8545	C31	100/15-03-010-10W4/00	49.798865	-111.277533	381.3	Dark grey silty shale with fossils	First White Specks?	2007
8546	C31	100/15-03-010-10W4/00	49.798865	-111.277533	711.7	Dark grey silty shale	Westgate	2007
8547	C31	100/15-03-010-10W4/00	49.798865	-111.277533	715.1	Dark grey silty shale	Westgate	2007
8633	C32	100/15-27-060-20W5/00	54.221784	-116.911727	1732.4	Dark grey shale	Second White Specks	2007
8634	C32	100/15-27-060-20W5/00	54.221784	-116.911727	1740.2	Dark grey shale	Second White Specks	2007
8635	C32	100/15-27-060-20W5/00	54.221784	-116.911727	1745.4	Dark grey shale	Second White Specks	2007
8636	C32	100/15-27-060-20W5/00	54.221784	-116.911727	1755.0	Dark grey shale	Second White Specks	2007
8596	C33	100/16-21-042-21W4/00	52.634819	-112.960441	805.1	Dark grey shale	Milk River	2007
8597	C33	100/16-21-042-21W4/00	52.634819	-112.960441	808.4	Dark grey shale with fossils	Milk River	2007
8598	C33	100/16-21-042-21W4/00	52.634819	-112.960441	811.5	Dark grey shale	First White Specks	2007
8599	C33	100/16-21-042-21W4/00	52.634819	-112.960441	814.6	Laminated siltstone and shale	First White Specks	2007

Sample No.	Site No.	UWI	Latitude (NAD 83)	Longitude (NAD 83)	Core Depth (metres)	Lithology	Formation Division	Year Sampled
8600	C33	100/16-21-042-21W4/00	52.634819	-112.960441	817.9	Dark grey mudstone	First White Specks	2007
8601	C33	100/16-21-042-21W4/00	52.634819	-112.960441	1029.1	Black shale	Card. Equiv. Zone	2007
8602	C33	100/16-21-042-21W4/00	52.634819	-112.960441	1032.1	Dark grey laminated mudstone	Card. Equiv. Zone	2007
8603	C33	100/16-21-042-21W4/00	52.634819	-112.960441	1035.3	Shale with interbedded siltstone/sandstone	Second White Specks	2007
8604	C33	100/16-21-042-21W4/00	52.634819	-112.960441	1042.5	Black shale and very fine sandstone interbedded	Second White Specks	2007
8605	C33	100/16-21-042-21W4/00	52.634819	-112.960441	1043.8	Dark grey shale with interbedded siltstone	Second White Specks	2007
8043	C34	100/16-29-054-21W5/00	53.697805	-117.053719	2319.1-2323.7	Combined samples: 8615, 16	Blackstone	2007
8044	C34	100/16-29-054-21W5/00	53.697805	-117.053719	2480.0-2498	Combined samples: 8618, 19	Belle Fourche?	2007
8615	C34	100/16-29-054-21W5/00	53.697805	-117.053719	2319.1	Black mudstone	Blackstone	2007
8616	C34	100/16-29-054-21W5/00	53.697805	-117.053719	2323.7	Black mudstone	Blackstone	2007
8617	C34	100/16-29-054-21W5/00	53.697805	-117.053719	2325.4	Black mudstone	Blackstone	2007
8618	C34	100/16-29-054-21W5/00	53.697805	-117.053719	2480.0-2498	Black mudstone	Belle Fourche?	2007
8619	C34	100/16-29-054-21W5/00	53.697805	-117.053719	2480.0-2498	Black mudstone	Belle Fourche?	2007
8517	C35	102/03-14-018-11W4/00	50.515811	-111.418574	400.0	Dark grey speckled shale	First White Specks	2007
8518	C35	102/03-14-018-11W4/00	50.515811	-111.418574	407.5	Dark grey shale and very fine sandstone with fossils	First White Specks	2007
8519	C35	102/03-14-018-11W4/00	50.515811	-111.418574	410.1	Dark grey silty shale with fossils	First White Specks	2007
8520	C35	102/03-14-018-11W4/00	50.515811	-111.418574	417.8	Black mudstone with fossils	1stWS or just below	2007
8036	C36	102/10-12-028-21W4/00	51.381280	-112.830199	1075-1075.75	Dark grey shale	Second White Specks	2008
8037	C36	102/10-12-028-21W4/00	51.381280	-112.830199	1089.3-1090	Dark grey shale	Second White Specks	2008
6901	C37	102/11-32-017-11W4/00	50.480595	-111.484723	661.6	Shale	Second White Specks	2006
6902	C37	102/11-32-017-11W4/00	50.480595	-111.484723	669.8	Shale	Second White Specks	2006
6903	C37	102/11-32-017-11W4/00	50.480595	-111.484723	670.3	Shale	Second White Specks	2006
6904	C37	102/11-32-017-11W4/00	50.480595	-111.484723	671.2	Shale	Second White Specks	2006
6905	C37	102/11-32-017-11W4/00	50.480595	-111.484723	675.9	Shale	Second White Specks	2006
6906	C37	102/11-32-017-11W4/00	50.480595	-111.484723	677.0	Shale	Second White Specks	2006
8032	C37	102/11-32-017-11W4/00	50.480595	-111.484723	664.5-665	Shale	Second White Specks	2008
8033	C37	102/11-32-017-11W4/00	50.480595	-111.484723	677.3-678.8	Shale	Second White Specks	2008
8025	C38	102/13-03-020-11W4/00	50.670811	-111.457734	452.9-453.3	Grey shale	First White Specks	2008
8026	C38	102/13-03-020-11W4/00	50.670811	-111.457734	666.2-666.7	Grey shale	Base 1stWS	2008
8027	C38	102/13-03-020-11W4/00	50.670811	-111.457734	701.6-702.15	Grey shale	Second White Specks	2008
8028	C38	102/13-03-020-11W4/00	50.670811	-111.457734	709.9-710.45	Dark grey shale	Second White Specks	2008
6916	Duplicate	Duplicate of 7291	50.184105	-113.687534	2112.1	Shale	Fish Scale Zone	2006
8672	Duplicate	Duplicate of 8502	51.375371	-113.000011		Black shale	Belle Fourche	2007
8673	Duplicate	Duplicate of 8507	51.233362	-114.365477		Black shaley mudstone	First White Specks	2007
8674	Duplicate	Duplicate of 8604	52.634819	-112.960441		Black shale and very fine sandstone interbedded	Second White Specks	2007
8675	Duplicate	Duplicate of 8562	53.102458	-112.853229		Dark grey muddy siltstone	Card. Equiv. Zone	2007
8676	Duplicate	Duplicate of 8593	51.202794	-112.626775		Dark grey shale	Medicine Hat?	2007
8677	Duplicate	Duplicate of 8645	54.301586	-117.223691		Dark grey mudstone	Shaftesbury	2007
8030	Resample	Resample of 8639	53.421052	-116.035361	2071.5	Black shale	Second White Specks	2008
8031	Resample	Resample of 8637	53.421052	-116.035361	2017.5	Black mudstone	Second White Specks	2008

Appendix 2 – Colorado Group Outcrop Sample Location, Depth and Lithology

Legend

Column Label	Label Description
Sample No.	AGS sample number
Site No.	Site location number
Site Location	Description of outcrop site
Zone	Site location - UTM Zone (North American Datum 1983)
Easting	Site location - UTM easting
Northing	Site location - UTM northing
Elevation (metres ASL)	Elevation of sampled site in metres above sea level
Lithology	Brief lithological description of sample
Formation or Group	Geologic formation or group at depth of sample
Formation Division	Subdivision of formation sampled
Sample Depth and Description	Sample location on section

Sample No.	Site No.	Site Location	Year	UTM (NAD 83)			Elevation (metres ASL)	Lithology	Formation or Group	Formation Division	Sample Depth and Description
				Zone	Easting	Northing					
5746	C39	Birch Mtns - NTS 84I	2007	12	446778	6385401	536	Shale	Colorado	Fish Scale Zone	Colorado shale
5747	C40	Birch Mtns - NTS 84I	2007	12	449178	6384521	512	Shale	Colorado	Westgate	30 cm above Pelican contact
5748	C41	Birch Mtns - NTS 84I	2007	12	429162	6444821	480	Shale	Grand Rapids	Grand Rapids	Colorado shale
6825	C42	Birch Mtns - NTS 84I	2007	12	410496	6444999	530.3	Shale	Colorado	Westgate Fm	1 m above Pelican contact
6826	C42	Birch Mtns - NTS 84I	2007	12	410479	6445015	545.7	Shale	Colorado	Westgate Fm	30 cm below Base Fish Scales Zone
6827	C42	Birch Mtns - NTS 84I	2007	12	410479	6445019	546	Shale	Colorado	Fish Scale Zone	0.1 m above Base Fish Scales Zone
7293	C43	Birch Mtns - Asphalt Creek	2007	12	443512	6387776	651	Shale	Colorado	Second White Specks	Duplicate of 7322
7315	C43	Birch Mtns - Asphalt Creek	2007	12	443512	6387776	651	Shale	Colorado	Second White Specks	1.0 m above creek
7316	C43	Birch Mtns - Asphalt Creek	2007	12	443512	6387776	651	Shale	Colorado	Second White Specks	2.0 m above creek
7317	C43	Birch Mtns - Asphalt Creek	2007	12	443512	6387776	651	Shale	Colorado	Second White Specks	3.0 m above creek
7318	C43	Birch Mtns - Asphalt Creek	2007	12	443512	6387776	651	Shale	Colorado	Second White Specks	4.0 m above creek
7319	C43	Birch Mtns - Asphalt Creek	2007	12	443512	6387776	651	Shale	Colorado	Second White Specks	4.5 m above creek
7320	C43	Birch Mtns - Asphalt Creek	2007	12	443512	6387776	651	Shale	Colorado	Second White Specks	5.0 m above creek
7321	C43	Birch Mtns - Asphalt Creek	2007	12	443512	6387776	651	Bentonite	Colorado	Second White Specks	5.25 m above creek (10 cm bed)
7322	C43	Birch Mtns - Asphalt Creek	2007	12	443512	6387776	651	Shale	Colorado	Second White Specks	5.5 m above creek
7323	C43	Birch Mtns - Asphalt Creek	2007	12	443512	6387776	651	Shale	Colorado	Second White Specks	6.0 m above creek
7324	C43	Birch Mtns - Asphalt Creek	2007	12	443512	6387776	651	Shale	Colorado	Second White Specks	7.0 m above creek
7325	C43	Birch Mtns - Asphalt Creek	2007	12	443512	6387776	651	Shale	Colorado	Second White Specks	8.0 m above creek
7326	C43	Birch Mtns - Asphalt Creek	2007	12	443512	6387776	651	Shale	Colorado	Second White Specks	9.0 m above creek
7327	C43	Birch Mtns - Asphalt Creek	2007	12	443512	6387776	651	Shale	Colorado	Second White Specks	10.0 m above creek
7328	C43	Birch Mtns - Asphalt Creek	2007	12	443512	6387776	651	Shale	Colorado	Second White Specks	11.0 m above creek
7329	C43	Birch Mtns - Asphalt Creek	2007	12	443512	6387776	651	Bone-bed shale	Colorado	Second White Specks	1.0 m above creek
7251	C44	Birch Mtns - Graystone Creek	2007	12	436714	6434287	509	Mudstone	Colorado	Pelican	-25.0 m from Base of Fish Scale Zone
7306	C44	Birch Mtns - Graystone Creek	2007	12	436680	6434329	536	Shale/sandstone	Colorado	Fish Scale Zone	Duplicate of 7337
7330	C44	Birch Mtns - Graystone Creek	2007	12	436680	6434329	536	Shale/mudstone	Colorado	Base of Fish Scale	0 m, Base of Fish Scale Zone contact
7331	C44	Birch Mtns - Graystone Creek	2007	12	436680	6434329	536	Shale/mudstone	Colorado	Belle Fourche	+6.3 m from Base of Fish Scale Zone
7332	C44	Birch Mtns - Graystone Creek	2007	12	436680	6434329	536	Shale/mudstone	Colorado	Fish Scale Zone	+5.3 m from Base of Fish Scale Zone
7333	C44	Birch Mtns - Graystone Creek	2007	12	436680	6434329	536	Shale/mudstone	Colorado	Fish Scale Zone	+4.3 m from Base of Fish Scale Zone
7334	C44	Birch Mtns - Graystone Creek	2007	12	436680	6434329	536	Shale/mudstone	Colorado	Fish Scale Zone	+3.3 m from Base of Fish Scale Zone
7335	C44	Birch Mtns - Graystone Creek	2007	12	436680	6434329	536	Shale	Colorado	Fish Scale Zone	+2.3m from Base of Fish Scale Zone
7336	C44	Birch Mtns - Graystone Creek	2007	12	436680	6434329	536	Shale/sandstone	Colorado	Fish Scale Zone	+1.3 m from Base of Fish Scale Zone
7337	C44	Birch Mtns - Graystone Creek	2007	12	436680	6434329	536	Shale/sandstone	Colorado	Fish Scale Zone	+0.1 m from Base of Fish Scale Zone
7338	C44	Birch Mtns - Graystone Creek	2007	12	436680	6434329	536	Shale/sandstone	Colorado	Fish Scale Zone	+0.8m from Base of Fish Scale Zone
7339	C44	Birch Mtns - Graystone Creek	2007	12	436680	6434329	536	Mudstone	Colorado	Westgate	-0.2 m from Base of Fish Scale Zone
7340	C44	Birch Mtns - Graystone Creek	2007	12	436680	6434329	536	Mudstone	Colorado	Westgate	-2.0 m from Base of Fish Scale Zone
7341	C44	Birch Mtns - Graystone Creek	2007	12	436680	6434329	536	Mudstone	Colorado	Westgate	-4.0 m from Base of Fish Scale Zone
7342	C44	Birch Mtns - Graystone Creek	2007	12	436680	6434329	536	Mudstone	Colorado	Westgate	-6.0 m from Base of Fish Scale Zone
7343	C44	Birch Mtns - Graystone Creek	2007	12	436680	6434329	536	Mudstone	Colorado	Westgate	-8.0 m from Base of Fish Scale Zone
7344	C44	Birch Mtns - Graystone Creek	2007	12	436680	6434329	536	Mudstone	Colorado	Westgate	-10.0 m from Base of Fish Scale Zone
7345	C44	Birch Mtns - Graystone Creek	2007	12	436680	6434329	536	Mudstone	Colorado	Westgate	-12.0 m from Base of Fish Scale Zone

Sample No.	Site No.	Site Location	Year	UTM (NAD 83)			Elevation (metres ASL)	Lithology	Formation or Group	Formation Division	Sample Depth and Description
				Zone	Easting	Northing					
7346	C44	Birch Mtns - Graystone Creek	2007	12	436680	6434329	536	Mudstone	Colorado	Westgate	-14.0 m from Base of Fish Scale Zone
7347	C44	Birch Mtns - Graystone Creek	2007	12	436680	6434329	536	Sandstone	Colorado	Pelican	-17.0 m from Base of Fish Scale Zone
7348	C44	Birch Mtns - Graystone Creek	2007	12	436680	6434329	536	Mudstone/sandstone	Colorado	Pelican	-21.0 m from Base of Fish Scale Zone
7350	C44	Birch Mtns - Graystone Creek	2007	12	436680	6434329	536	Mudstone	Colorado	Pelican	-23.0 m from Base of Fish Scale Zone
7252	C45	Cadomin - Blackstone railway sec.	2007	11	478167	5875014	1533	Shale	Colorado	Blackstone	3-4 m above Mountain Pk sandstone contact
7254	C45	Cadomin - Blackstone railway sec.	2007	11	478188	5875048	1534	Shale	Colorado	Blackstone	Sampled south to north along section
7255	C45	Cadomin - Blackstone railway sec.	2007	11	478188	5875048	1534	Shale	Colorado	Blackstone	Sampled south to north along section
7256	C45	Cadomin - Blackstone railway sec.	2007	11	478188	5875048	1534	Shale	Colorado	Blackstone	Sampled south to north along section
7257	C45	Cadomin - Blackstone railway sec.	2007	11	478217	5875092	1530	Shale	Colorado	Blackstone	Sampled south to north along section
7258	C45	Cadomin - Blackstone railway sec.	2007	11	478387	5875406	1537	Shale	Colorado	Blackstone	Sampled south to north along section
7259	C45	Cadomin - Blackstone railway sec.	2007	11	478445	5875515	1532	Shale	Colorado	Blackstone	Sampled south to north along section
7260	C45	Cadomin - Blackstone railway sec.	2007	11	478483	58775665	1523	Sulphide	Colorado	Blackstone	Sampled south to north along section
7261	C45	Cadomin - Blackstone railway sec.	2007	11	478504	5875769	1522	Shale	Colorado	Blackstone	Sampled south to north along section
7262	C45	Cadomin - Blackstone railway sec.	2007	11	478504	5875769	1522	Shale	Colorado	Blackstone	Sampled south to north along section
7263	C45	Cadomin - Blackstone railway sec.	2007	11	478504	5875769	1522	Shale	Colorado	Blackstone	Sampled south to north along section
7264	C45	Cadomin - Blackstone railway sec.	2007	11	478504	5875769	1522	Shale	Colorado	Blackstone	Sampled south to north along section
7265	C45	Cadomin - Blackstone railway sec.	2007	11	478504	5875769	1522	Shale	Colorado	Blackstone	Sampled south to north along section
7266	C45	Cadomin - Blackstone railway sec.	2007	11	478498	5875885	1522	Shale	Colorado	Blackstone	Sampled south to north along section
7267	C45	Cadomin - Blackstone railway sec.	2007	11	478498	5875885	1522	Shale	Colorado	Blackstone	Sampled south to north along section
7269	C45	Cadomin - Blackstone railway sec.	2007	11	478497	5876037	1519	Shale	Colorado	Blackstone	Sampled south to north along section
7270	C45	Cadomin - Blackstone railway sec.	2007	11	478497	5876037	1519	Shale	Colorado	Blackstone	Sampled south to north along section
7271	C45	Cadomin - Blackstone railway sec.	2007	11	478497	5876037	1519	Shale	Colorado	Blackstone	Sampled south to north along section
7272	C45	Cadomin - Blackstone railway sec.	2007	11	478497	5876037	1519	Shale	Colorado	Blackstone	Sampled south to north along section
7273	C45	Cadomin - Blackstone railway sec.	2007	11	478522	5876250	1518	Shale	Colorado	Blackstone	Sampled south to north along section
7274	C45	Cadomin - Blackstone railway sec.	2007	11	478522	5876250	1518	Shale	Colorado	Blackstone	Sampled south to north along section
7275	C45	Cadomin - Blackstone railway sec.	2007	11	478551	5876680	1522	Shale	Colorado	Blackstone	Sampled south to north along section
7276	C45	Cadomin - Blackstone railway sec.	2007	11	478558	5876830	1518	Shale	Colorado	Blackstone	Sampled south to north along section
7280	C45	Cadomin - Blackstone railway sec.	2007	11	478592	5877460	1502	Shale	Colorado	Blackstone	Sampled south to north along section
7281	C45	Cadomin - Blackstone railway sec.	2007	11	478523	5877234	1505	Shale	Colorado	Blackstone	Sampled south to north along section
7282	C45	Cadomin - Blackstone railway sec.	2007	11	479087	5878965	1513	Shale	Colorado	Blackstone	27.5 m below Cardium sandstone contact
7283	C45	Cadomin - Blackstone railway sec.	2007	11	479087	5878965	1513	Shale	Colorado	Blackstone	17.5-18.5 m below Cardium sandstone contact
7284	C45	Cadomin - Blackstone railway sec.	2007	11	479087	5878965	1513	Shale	Colorado	Blackstone	9.5-10.5 m below Cardium sandstone contact
7285	C45	Cadomin - Blackstone railway sec.	2007	11	479087	5878965	1513	Shale	Colorado	Blackstone	1.0 m below Cardium sandstone contact
7286	C45	Cadomin - Blackstone railway sec.	2007	11	479087	5878965	1513	Shale	Colorado	Blackstone	~52 m below Cardium sandstone contact
6544		AGS Standard	2007	AGS Standard	AGS Standard	AGS Standard	AGS Standard	Rock powder	AGS Standard	AGS Standard	AGS Standard
6914		AGS Standard	2007	AGS Standard	AGS Standard	AGS Standard	AGS Standard	Rock powder	AGS Standard	AGS Standard	AGS Standard
7253		AGS Standard	2007	AGS Standard	AGS Standard	AGS Standard	AGS Standard	Rock powder	AGS Standard	AGS Standard	AGS Standard
7279		AGS Standard	2007	AGS Standard	AGS Standard	AGS Standard	AGS Standard	Rock powder	AGS Standard	AGS Standard	AGS Standard
7349		AGS Standard	2007	AGS Standard	AGS Standard	AGS Standard	AGS Standard	Rock powder	AGS Standard	AGS Standard	AGS Standard

Appendix 3 – Colorado Group Core Samples Analysed

Legend

Y = Sample data presented in this report

x = Sample data presented in other Alberta Geological Survey reports (see Table 1 for details)

Analyses presented in this report

Column Label	Label Description
Sample No.	AGS sample number
Site No.	Site location number
Rock Eval™	Analysis to test for organic maturity and total organic carbon (TOC)
X-ray Diff-Bulk	X-Ray diffraction analysis of whole-rock mineralogy
X-ray Diff-Clay	X-Ray diffraction analysis of clay mineralogy
Organic Pet.	Organic petrology examines organic macerals
Thin Section	Thin section of sample
Thin Section Photo	Photograph of thin section
Adsorption Isotherm	Gas adsorption analysis to determine gas-holding capacity of sample
SEM	Scanning electron microscope
ESEM	Environmental scanning electron microscope
Mini-perm	Analysis to determine permeability
Porosity	Analysis to determine porosity

Sample No.	Site No.	Rock Eval™	Xray Diff-Bulk	Xray Diff-Clay	Organic Pet.	Thin Section	Thin Sections Photo	Adsorption Isotherm	SEM	ESEM	Mini-perm	Porosity
8501	C01	x										Y
8502	C01	x										
8503	C01	x										
8504	C01	x										
8505	C01	x										Y
8506	C01	x										
8668	C02	x										Y
8669	C02	x									Y	
8670	C02	x										
8671	C02	x										
8627	C03	x										
8628	C03	x	Y	Y								
8629	C03	x										
8630	C03	x										
8631	C03	x										Y
8632	C03	x				x	x					
8034	C04	x										
8035	C04	x										
8531	C05	x										
8532	C05	x										
8533	C05	x										
8534	C05	x										
8644	C06	x										
8645	C06	x										
8646	C06	x										
8647	C06	x				x						Y
8540	C07	x				x						Y
8541	C07	x										
8581	C08	x										
8582	C08	x										
8583	C08	x										
8584	C08	x										
8585	C08	x										
8586	C08	x										
8587	C08	x										
8588	C08	x										Y
8589	C08	x										
8590	C08	x										
8591	C08	x										
8592	C08	x										
8593	C08	x										
8594	C08	x										
8595	C08	x										
8529	C09	x										
8530	C09	x										Y
8575	C10	x										Y
8576	C10	x										
8577	C10	x										
8578	C10	x										
8579	C10	x										
8580	C10	x										
8042	C11	x						x				
8606	C11	x				x						
8607	C11	x										
8608	C11	x										
8609	C11	x	Y	Y								
8610	C11	x										
8611	C11	x								Y		Y
8612	C11	x										
8613	C12	x										
8614	C12	x				x						Y
8507	C13	x										Y
8508	C13	x										
8509	C13	x										
8510	C13	x										
8511	C13	x										
8512	C13	x				x						Y
8041	C14	x						x				
8521	C14	x										
8522	C14	x				x						
8523	C14	x										
8524	C14	x										

Sample No.	Site No.	Rock Eval™	Xray Diff-Bulk	Xray Diff-Clay	Organic Pet.	Thin Section	Thin Sections Photo	Adsorption Isotherm	SEM	ESEM	Mini-perm	Porosity
8525	C14	x										
8526	C14	x	Y	Y								
8527	C14	x										
8528	C14	x										
8535	C15	x										
8536	C15	x										
8537	C15	x								Y		Y
8538	C15	x										
8539	C15	x										
8556	C16	x										
8557	C16	x										
8558	C16	x										
8559	C16	x										
8560	C16	x										
8561	C16	x										Y
8542	C17	x							Y	Y		Y
8543	C17	x										
8544	C17	x										
7294	C18	x										
7295	C18	x										
7296	C18	x										
7297	C18	x				x						
7298	C18	x	Y	Y								
7299	C18	x										
7300	C18	x										Y
8641	C19	x										
8642	C19	x										
8643	C19	x				x						Y
8045	C20	x						x				
8648	C20	x										
8649	C20	x										
8650	C20	x										
8651	C20	x										Y
8652	C20	x										
8653	C20	x										
8654	C20	x										
8655	C20	x										
8656	C20	x				x					Y	
8657	C20	x	Y	Y								
8658	C20	x										
8659	C20	x										
8660	C20	x										
8661	C20	x										
8662	C20	x										
8663	C20	x										
8554	C21	x										
8555	C21	x										
7289	C22	x										
7290	C22	x										
7291	C22	x										
7292	C22	x				x	x				Y	Y
8048	C23		Y	Y								
8664	C23	x										
8665	C23	x										Y
8666	C23	x										
8667	C23	x										
8029	C24	x										Y
8548	C25	x										
8549	C25	x										
8550	C25	x										
8551	C25	x										Y
8552	C25	x				x	x					Y
8553	C25	x										
8620	C26	x				x						Y
8621	C26	x										
8622	C26	x										
8623	C26	x										
8624	C26	x										Y
8625	C26	x										
8626	C26	x										
8566	C27	x				x						
8567	C27	x										

Sample No.	Site No.	Rock Eval™	Xray Diff-Bulk	Xray Diff-Clay	Organic Pet.	Thin Section	Thin Sections Photo	Adsorption Isotherm	SEM	ESEM	Mini-perm	Porosity
8568	C27	x										
8569	C27	x										Y
8570	C27	x										
8571	C27	x										
8572	C27	x										
8573	C27	x										
8574	C27	x										
8637	C28	x										
8638	C28	x				x						Y
8639	C28	x										
8640	C28	x										
8562	C29	x										
8563	C29	x				x						Y
8564	C29	x										
8565	C29	x				x				Y		
8023	C30	x										
8024	C30	x										
8513	C30	x										
8514	C30	x				x						
8515	C30	x										Y
8516	C30	x									Y	
8545	C31	x										
8546	C31	x										
8547	C31	x										Y
8633	C32	x										
8634	C32	x				x					Y	
8635	C32	x										
8636	C32	x										
8596	C33	x									Y	
8597	C33	x										
8598	C33	x										
8599	C33	x										
8600	C33	x										Y
8601	C33	x										
8602	C33	x										Y
8603	C33	x										
8604	C33	x										Y
8605	C33	x										
8043	C34	x						x				
8044	C34	x						x				
8615	C34	x										
8616	C34	x										Y
8617	C34	x				x	x					
8618	C34	x										
8619	C34	x				x						
8517	C35	x										
8518	C35	x				x	x		Y	Y		Y
8519	C35	x										
8520	C35	x				x						
8036	C36	x										
8037	C36	x										Y
6901	C37	x										
6902	C37	x	Y	Y								
6903	C37	x										
6904	C37	x				x	x					Y
6905	C37	x										
6906	C37	x										
8032	C37	x										
8033	C37	x										
8025	C38	x										Y
8026	C38	x										
8027	C38	x				x					Y	
8028	C38	x										
6916	Duplicate	x										
8672	Duplicate	x										
8673	Duplicate	x										
8674	Duplicate	x										
8675	Duplicate	x										
8676	Duplicate	x										
8677	Duplicate	x										
8030	Resample											
8031	Resample										Y	

Appendix 4 – Colorado Group Outcrop Samples Analysed

Legend

Y = Sample data presented in this report

x = Sample data presented in other Alberta Geological Survey reports (see Table 1) for details.

xx = Clay separated

Analyses presented in this report

Column Label	Label Description
Sample No.	AGS sample number
Site No.	Site location number
Inorganic Geochem	Inorganic geochemical analysis
Rock Eval™	Analysis for organic maturity and total organic carbon (TOC)
X-ray Diff-Bulk	X-Ray diffraction analysis of whole-rock mineralogy
X-ray Diff-Clay	X-Ray diffraction analysis of clay mineralogy
Organic Pet.	Organic petrology examines organic macerals
Thin Section	Thin section of sample
Thin Section Photo	Photograph of thin section
Adsorption Isotherm	Gas adsorption analysis to determine gas-bearing capacity

Sample No.	Site No.	Inorganic Geochem	Rock Eval™	Xray Diff-Bulk	Xray Diff-Clay	Organic Pet.	Thin Section	Thin Section Photo	Adsorption Isotherm
5746	C39	x	x	Y	Y				
5747	C40	x	x	Y	Y				
5748	C41	x	x	Y	Y				
6825	C42	x	x	Y	Y				
6826	C42	x	x	Y	Y				
6827	C42	x	x	Y	Y	x			
7293	C43	x	x			x			
7315	C43	x	x	Y	YY				
7316	C43	x	x	Y	Y				
7317	C43	x	x	Y	Y	x			
7318	C43	x	x	Y	YY				x
7319	C43	x	x	Y	Y	x			
7320	C43	x	x	Y	Y				
7321	C43	x							
7322	C43	x	x	Y	Y				
7323	C43	x	x	Y	Y				
7324	C43	x	x	Y	Y				
7325	C43	x	x	Y	Y				
7326	C43	x	x	Y	Y				
7327	C43	x	x	Y	YY				x
7328	C43	x	x	Y	Y				
7329	C43	x	x			x	x	x	
7251	C44	x	x	Y	YY				x
7306	C44	x	x						
7330	C44	x	x	Y	Y	x			
7331	C44	x	x	Y	Y				
7332	C44	x	x	Y	YY				
7333	C44	x	x	Y	Y				
7334	C44	x	x	Y	Y				
7335	C44	x	x	Y	YY				
7336	C44	x	x	Y	Y				
7337	C44	x	x	Y	Y				
7338	C44	x	x	Y	YY	x			x
7339	C44	x	x	Y	Y				
7340	C44	x	x	Y	YY				
7341	C44	x	x	Y	Y				
7342	C44	x	x	Y	Y				
7343	C44	x	x	Y	YY	x			x
7344	C44	x	x	Y	Y				
7345	C44	x	x	Y	Y				
7346	C44	x	x	Y	Y				
7347	C44								
7348	C44	x	x	Y	Y				
7350	C44	x	x	Y	Y				
7252	C45	x	x	Y	Y				
7254	C45	x	x	Y	Y		x	x	
7255	C45	x	x	Y	Y				
7256	C45	x	x	Y	Y				
7257	C45	x	x	Y	YY				x
7258	C45	x	x	Y	Y				
7259	C45	x	x	Y	Y				
7260	C45	x							
7261	C45	x	x	Y	Y				
7262	C45	x	x	Y	Y				
7263	C45	x	x	Y	Y				
7264	C45	x	x	Y	Y	x			

Sample No.	Site No.	Inorganic Geochem	Rock Eval™	Xray Diff-Bulk	Xray Diff-Clay	Organic Pet.	Thin Section	Thin Section Photo	Adsorption Isotherm
7265	C45	x	x	Y	Y				
7266	C45	x	x	Y	Y				
7267	C45	x	x	Y	Y	x			
7269	C45	x	x	Y	YY				
7270	C45	x	x	Y	Y				
7271	C45	x	x	Y	Y				
7272	C45	x	x	Y	Y				
7273	C45	x	x	Y	Y				
7274	C45	x	x	Y	Y				
7275	C45	x	x	Y	Y	x			
7276	C45	x	x	Y	Y				
7280	C45	x	x	Y	Y				
7281	C45	x	x	Y	Y				
7282	C45	x	x	Y	Y				
7283	C45	x	x	Y	Y				
7284	C45	x	x	Y	Y				
7285	C45	x	x	Y	Y				
7286	C45	x	x	Y	YY				x
6544		x							
6914		x							
7253		x							
7279		x							
7349		x							

YY = clay separated

Appendix 5 – Colorado Group Bulk Sample Mineralogy (XRD)

Appendix 5a – Bulk X-Ray Diffraction

Legend

Anat.	Anatase	Jaro.	Jarosite
Ank.	Ankerite	Kaol.	Kaolinite
Apa.	Apatite	Micro.	Microcline
Bass.	Bassanite	Mont.	Montmorillonite
Bio.	Biotite	Musc.	Muscovite
Chlo.	Chlorite	Ortho.	Orthoclase
ClCh.	Clinochlore	Rhod.	Rhodochrosite
DI	Degraded illite	RMLC	Random mixed layer clays
Dolo.	Dolomite	Rut.	Rutile
FlAp.	Fluorapatite	Sep.	Sepiolite
Gyp.	Gypsum	Sid.	Siderite
Heul.	Heulandite	tr	Trace amounts
Ilme.	Ilmenite		

Note: outcrop samples were tested by CBM Solutions and core samples were tested by SGS Minerals

Sample No.	Sample Type	Sample Site	Quartz	Feldspar			Pyrite	Clay Minerals									Carbonate				Rhod.	Sulphates			Heul.	FlAp.	Apa.	Rut.	Anat.	Ilme.	Total
				Albite	Micro.	Ortho.		Musc.	Bio.	Kaol.	Illite	Sep.	RMLC	Mont.	ClCh.	Chlo.	Calcite	Sid.	Dolo.	Ank.		Gyp.	Bass.	Jaro.							
5746	outcrop	C39	30.2	3.0							1.6			41.0			14.2					5.0					5.0				100.0
5747	outcrop	C40	43.2	8.2			1.7			2.9	4.5			37.2			2.3														100.0
6825	outcrop	C42	37.4	3.5		4.0				1.4	11.2			39.4			3.3														100.0
6826	outcrop	C42	30.4	2.5		2.8				2.0	36.4		26.0																		100.0
6827	outcrop	C42	33.0	1.9		2.3				11.7	17.0			34.1																	100.0
6902	core	C37	41.4	6.7	6.2		7.4	9.5		6.5					2.5		15.2					2.2				1.7		0.8			100.1
7251	outcrop	C44	35.5	11.3		3.7				0.4	2.5			41.0			4.2					1.4									100.0
7252	outcrop	C45	49.5	10.5		3.2				6.3	14.2		14.2				2.2														100.0
7254	outcrop	C45	58.4	3.7		2.4	1.3			2.8	14.9						7.0		9.6												100.0
7255	outcrop	C45	45.3	6.8		1.9	2.1			4.6	32.5						2.4		2.8			1.6									100.0
7256	outcrop	C45	39.2	5.3		3.0	0.3			5.2	20.1		19.8	7.2																	100.0
7257	outcrop	C45	46.4	12.8		3.3				4.8	7.7		8.0	10.9			6.1														100.0
7258	outcrop	C45	63.0	4.7		1.9	1.3			5.3	19.5						4.2														100.0
7259	outcrop	C45	52.7	13.0		2.2				1.4			25.1				2.8					2.8									100.0
7261	outcrop	C45	50.2	4.4		2.8	0.3			11.5	29.0						1.8														100.0
7262	outcrop	C45	50.6	3.9		2.3	0.5			10.1	31.6						1.2														100.0
7263	outcrop	C45	52.9	3.6		2.4	0.2			16.2	23.5						1.2														100.0
7264	outcrop	C45	51.0	4.9		2.9	0.5			11.9	26.0						2.9														100.0
7265	outcrop	C45	49.7	5.3		2.8	0.3			4.6	20.8		13.5				2.0					1.0									100.0
7266	outcrop	C45	42.8	2.9		4.0	1.6			13.8	32.2						1.9					0.8									100.0
7267	outcrop	C45	26.1	3.0		6.3	1.7			4.9							39.4	4.5		14.1											100.0
7269	outcrop	C45	58.8	11.3		2.3				7.6	5.2		9.6			3.1	2.1														100.0
7270	outcrop	C45	46.4	6.0		4.7	0.2			11.0	26.7		DI				3.3					1.8									100.0
7271	outcrop	C45	46.8	4.3		2.4	0.3			16.0	25.9		DI				2.6					1.8									100.0
7272	outcrop	C45	43.5	4.2		2.6	0.6			12.0	33.6		DI				3.6														100.1
7273	outcrop	C45	40.9	4.7		2.1	3.9			12.2	30.9		DI				2.0		0.6			2.7									100.0
7274	outcrop	C45	41.4	5.4		1.6	3.3			18.0	23.7		DI				2.1		0.7			3.9									100.0
7275	outcrop	C45	37.9	3.2		2.2	4.0			6.5	25.5		8.0				5.2		0.2	6.2		1.2									100.0
7276	outcrop	C45	38.1	3.4		2.2	4.1			12.2	31.5						3.2		0.2	3.9		1.4									100.0
7280	outcrop	C45	40.9	4.6		3.1	3.7			14.3	30.3						3.2														100.0
7281	outcrop	C45	40.2	4.1		2.4	3.3			18.2			29.2				2.5														100.0
7282	outcrop	C45	55.1	2.5		1.3	0.1			7.4	15.6		12.0				6.1														100.0
7283	outcrop	C45	54.7	2.4		1.7				7.3	31.9						1.9														100.0
7284	outcrop	C45	46.6	3.2		2.2	0.5			5.6	34.5						5.4		2.1												100.0
7285	outcrop	C45	46.7	1.9		1.6				12.1	33.7						3.6		0.4												100.0
7286	outcrop	C45	60.4	6.8		3.5	0.2			4.6	6.3		10.8				6.5		1.0												100.0
7298	core	C18	45.6	4.8	8.5		1.6	14.9	2.5	9.1					9.5		2.6											0.9			100.0
7315	outcrop	C43	22.8	10.4		8.4				4.0	9.7		10.0	5.4			4.7			4.6		20.0									100.0
7316	outcrop	C43	27.4	4.7		4.3	3.0			1.4	4.3			35.5			4.8		2.7			12.0									100.0
7317	outcrop	C43	20.7	2.4		2.9	2.5			4.0	7.7			24.5			28.1		0.4			6.9									100.0
7318	outcrop	C43	21.5	6.2		5.1				11.0	0.9			33.1			2.9					19.3									100.0

Sample No.	Sample Type	Sample Site	Quartz	Feldspar			Pyrite	Clay Minerals									Carbonate				Rhod.	Sulphates			Heul.	FlAp.	Apa.	Rut.	Anat.	Ilme.	Total
				Albite	Micro.	Ortho.		Musc.	Bio.	Kaol.	Illite	Sep.	RMLC	Mont.	ClCh.	Chlo.	Calcite	Sid.	Dolo.	Ank.		Gyp.	Bass.	Jaro.							
7319	outcrop	C43	13.5	8.8		10.5	0.2			0.9	1.6			33.9			3.9					14.8	6.9	5.2							100.0
7320	outcrop	C43	6.3	8.1		8.2	0.2			17.3				20.2			4.3	0.3				12.1	7.0	16.1							100.0
7322	outcrop	C43	18.8	5.2		6.5				7.2	13.3			5.0			3.2					0.9	35.0	5.0							100.0
7323	outcrop	C43	26.3	6.2		7.1				9.2	15.4			28.3			1.0					1.9		4.6							100.0
7324	outcrop	C43	23.1	5.5		10.0				6.6	21.5		20.8									5.1		7.4							100.0
7325	outcrop	C43	31.7	12.2		12.6				4.3	12.6		21.2									5.3									100.0
7326	outcrop	C43	37.9	11.5		6.5				0.9	1.9			35.1								6.2									100.0
7327	outcrop	C43	24.6	2.8		1.7				2.5	21.3		44.8				0.8		0.2			1.3									100.0
7328	outcrop	C43	45.9	7.0		6.0				16.8	8.5		6.0	6.0					0.0			1.4	2.4								100.0
7330	outcrop	C44	38.0	8.7		6.9				9.8	15.6			12.7			1.7		0.6			0.2		5.9							100.0
7331	outcrop	C44	18.1	2.3		2.7				2.2	3.1			66.2			0.5		0.5			0.6		3.8							100.0
7332	outcrop	C44	24.6	2.8		1.7				1.6	2.0			64.9			0.8		0.2			1.3									100.0
7333	outcrop	C44	17.8	2.7		3.7				2.5	0.6			68.2			0.9		0.3			1.4		1.8							100.0
7334	outcrop	C44	22.7	4.3		3.2				3.9	3.4			56.5			0.5		0.6			1.0		3.9							100.0
7335	outcrop	C44	26.8	3.5		2.0				0.6	5.8			55.4			2.0								3.9						100.0
7336	outcrop	C44	35.1	4.3		2.8								39.6			4.5		0.8			2.6			10.3						100.0
7337	outcrop	C44	36.3	4.9		2.2				2.2	8.6		30.0				2.2		0.6			6.2			6.7						100.0
7338	outcrop	C44	28.3	7.4		3.5				1.9	4.6		46.8				2.9								4.6						100.0
7339	outcrop	C44	32.3	9.3		3.9				0.7	1.3			45.3			3.4		0.6			3.2									100.0
7340	outcrop	C44	24.9	8.3		3.0				3.8	4.7			54.8			0.5														100.0
7341	outcrop	C44	34.3	7.8		4.5				1.7	1.8			47.5			2.5														100.0
7342	outcrop	C44	37.7	8.5		4.9				1.0	1.1			42.5			1.4		0.7			2.2									100.0
7343	outcrop	C44	16.6	7.9		2.7				1.5	4.3			64.6			1.3					1.1									100.0
7344	outcrop	C44	29.1	10.9		4.3				1.4	2.4			43.1			3.8		1.0			2.8			1.2						100.0
7345	outcrop	C44	34.4	8.9		4.4				0.5	2.7			46.0			1.0	0.3				0.7			1.0						100.0
7346	outcrop	C44	33.5	12.1		4.9				0.5	0.9			40.8			3.4					4.0									100.0
7348	outcrop	C44	89.8							4.7							5.5														100.0
7350	outcrop	C44	37.3	11.9		3.9				3.1	2.3			34.5			2.5					4.6									100.0
8048	core	C23	40.5	5.6		3.5	7.1	21.2		7.5	7.4				5.3		1.1												0.8		100.0
8526	core	C14	19.3	6.9	1.8		5.5	17.2						13.3			31.5		2.7		1.3	0.1						0.5			100.1
8609	core	C11	44.5	5.5			7.1	21.0		6.2					5.4				0.7	8.7									0.9		100.0
8628	core	C03	31.2	12.7			4.4	21.6		5.2	10.8			13.1														0.4		0.6	100.0
8657	core	C20	33.4				9.8	26.0		15.5		5.8			2.4		6.1												1.0		100.0

Appendix 5b – X-Ray Fluorescence

Legend

Sample No.	AGS sample number
SiO_2	Silica oxide
Al_2O_3	Aluminum oxide
Fe_2O_3	Iron oxide
MgO	Magnesium oxide
CaO	Calcium oxide
Na_2O	Sodium oxide
K_2O	Potassium oxide

TiO_2	Titanium oxide
P_2O_5	Phosphorous oxide
MnO	Manganese oxide
Cr_2O_3	Chromium oxide
V_2O_5	Vanadium oxide
LOI	loss on ignition - amount of material loss due to heating
Total	Total weight percent
%	Percent
DUP	Duplicate

Sample No.	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	MgO (%)	CaO (%)	Na_2O (%)	K_2O (%)	TiO_2 (%)	P_2O_5 (%)	MnO (%)	Cr_2O_3 (%)	V_2O_5 (%)	LOI (%)	Total (%)
6902	56.10	9.20	5.28	0.95	9.32	0.76	1.86	0.45	0.61	0.04	0.01	0.03	12.00	96.50
7298	67.40	12.80	3.52	1.05	1.40	0.77	2.33	0.74	0.13	0.01	0.03	0.05	8.51	98.70
8526	39.80	8.70	3.08	1.47	16.00	0.90	1.51	0.35	0.17	0.03	0.01	0.09	25.90	98.10
8609	61.10	11.20	6.66	2.24	2.24	0.62	2.44	0.55	0.18	0.02	0.02	0.05	10.70	98.00
8628	60.60	16.40	5.11	1.41	0.28	1.35	2.38	0.85	0.13	0.02	0.02	0.03	9.87	98.40
8657	55.40	16.40	5.91	1.34	2.88	0.64	2.93	0.75	0.18	0.01	0.02	0.04	11.80	98.20
8048	62.90	15.80	4.38	1.57	0.45	0.86	2.96	0.75	0.16	0.02	0.03	0.06	8.33	98.20
8609DUP	61.00	11.30	6.62	2.29	2.22	0.67	2.40	0.55	0.18	0.02	0.02	0.03	10.50	97.80

Appendix 6 – Colorado Group Clay Mineralogy (XRD)

Appendix 6a – Clay X-Ray Diffraction (Quantitative)

RMLC	Random mixed layered clays
Mont.	Montmorillonite
*	Clay separation done on sample before clay XRD

Sample No.	Sample Type	Sample Site	Clay Minerals				
			Kaolinite	Illite	RMLC	Mont.	Chlorite
5746	outcrop	C39		4		96	
5747	outcrop	C40	7	10		83	
6825	outcrop	C42	3	21		76	
6826	outcrop	C42	3	57	40		
6827	outcrop	C42	19	27		54	
7251*	outcrop	C44	1	6		93	
7252*	outcrop	C45	18	41	41		
7254	outcrop	C45	16	84			
7255	outcrop	C45	12	88			
7256	outcrop	C45	10	38	38	14	
7257*	outcrop	C45	15	24	25	35	
7258	outcrop	C45	21	79			
7259*	outcrop	C45	5	0	95		
7261	outcrop	C45	28	72			
7262	outcrop	C45	24	76			
7263	outcrop	C45	41	59			
7264	outcrop	C45	31	69			
7265	outcrop	C45	12	53	35		
7266	outcrop	C45	30	70			
7267	outcrop	C45	100				
7269*	outcrop	C45	30	20	37		12
7270	outcrop	C45	29	71			
7271	outcrop	C45	38	62			
7272	outcrop	C45	26	74			
7273	outcrop	C45	28	72			
7274	outcrop	C45	43	57			
7275	outcrop	C45	16	64	20		
7276	outcrop	C45	28	72			
7280	outcrop	C45	32	68			
7281	outcrop	C45	38	0	62		
7282	outcrop	C45	21	45	34		
7283	outcrop	C45	19	81			
7284	outcrop	C45	14	86			
7285	outcrop	C45	26	74			
7286*	outcrop	C45	21	29	50		
7315*	outcrop	C43	14	33	34	19	
7316	outcrop	C43	3	10		86	
7317	outcrop	C43	11	21		68	
7318*	outcrop	C43	24	2		74	
7319	outcrop	C43	2	4		93	
7320	outcrop	C43	46			54	
7322	outcrop	C43	28	52		20	
7323	outcrop	C43	17	29		53	
7324	outcrop	C43	14	44	43		
7325	outcrop	C43	11	33	56		
7326	outcrop	C43	2	5	0	93	
7327*	outcrop	C43	4	31	65		
7328	outcrop	C43	45	23	16	16	
7330	outcrop	C44	26	41		33	
7331	outcrop	C44	3	4		93	
7332*	outcrop	C44	2	3		95	
7333	outcrop	C44	4	1		96	
7334	outcrop	C44	6	5		88	
7335*	outcrop	C44	1	9		90	
7336	outcrop	C44				100	
7337	outcrop	C44	5	21	74		
7338*	outcrop	C44	4	9	88		
7339	outcrop	C44	1	3		96	
7340*	outcrop	C44	6	7		87	
7341	outcrop	C44	3	4		93	
7342	outcrop	C44	2	2		95	
7343*	outcrop	C44	2	6		92	
7344	outcrop	C44	3	5		92	
7345	outcrop	C44	1	5		93	
7346	outcrop	C44	1	2		97	
7348	outcrop	C44	100				
7350	outcrop	C44	8	6		87	

Appendix 6b – Clay X-Ray Diffraction (Qualitative)

Sample No.	Sample Site	Sample Type	Crystalline Mineral Assemblage (relative proportions based on peak height)			
			Major	Moderate	Minor	Trace
6902	C37	core	(quartz)	illite, kaolinite	chlorite, (calcite)	
7298	C18	core	illite	kaolinite, (quartz)	chlorite	(*calcite)
8048	C23	core	(quartz)	illite	chlorite, kaolinite	
8526	C14	core	montmorillonite		illite, (quartz), (calcite), kaolinite	(*dolomite),(*rhodochrosite)
8609	C11	core	(quartz)	illite	chlorite, kaolinite, sepiolite	(*pyrite)
8628	C03	core	montmorillonite	illite	kaolinite, (quartz)	
8657	C20	core		illite, sepiolite, (quartz)	kaolinite, chlorite	(*pyrite)

* Tentative identification due to low concentrations, diffraction line overlap or poor crystallinity

( ) Not a clay mineral

Appendix 7 – Colorado Group Scanning Electron Microscope (SEM) and Environmental Scanning Electron Microscope (ESEM) Images and Descriptions

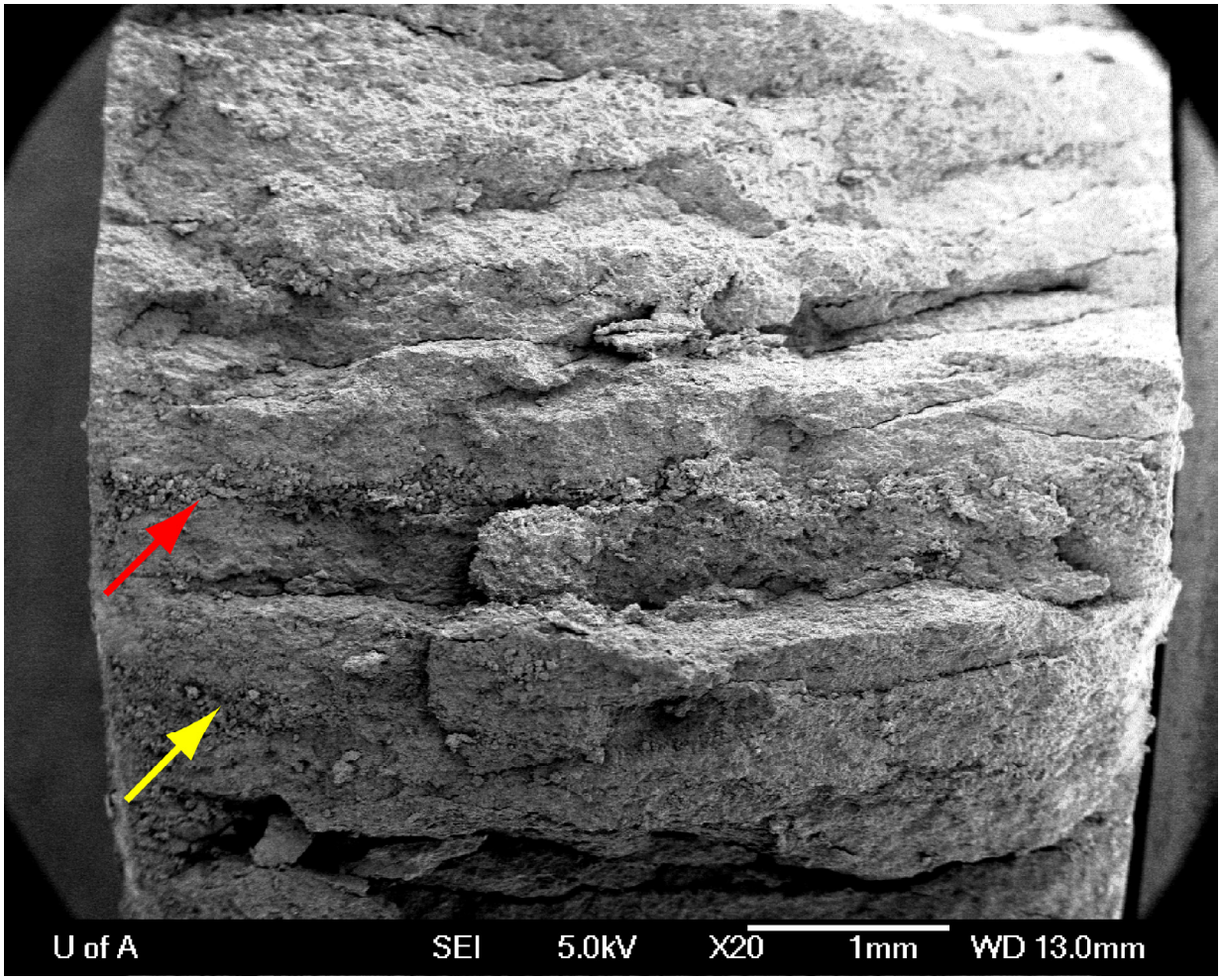
Scanning Electron Microscope (SEM) Images

1) Upper Colorado Group, possible Cardium Fm. equivalent, Sample 8542; 100/06-36-049-05W4/00, 410 m core depth.

The sample is grey silty shale. The bedding plane trends east in all images, and up is to the top of the image.

a)

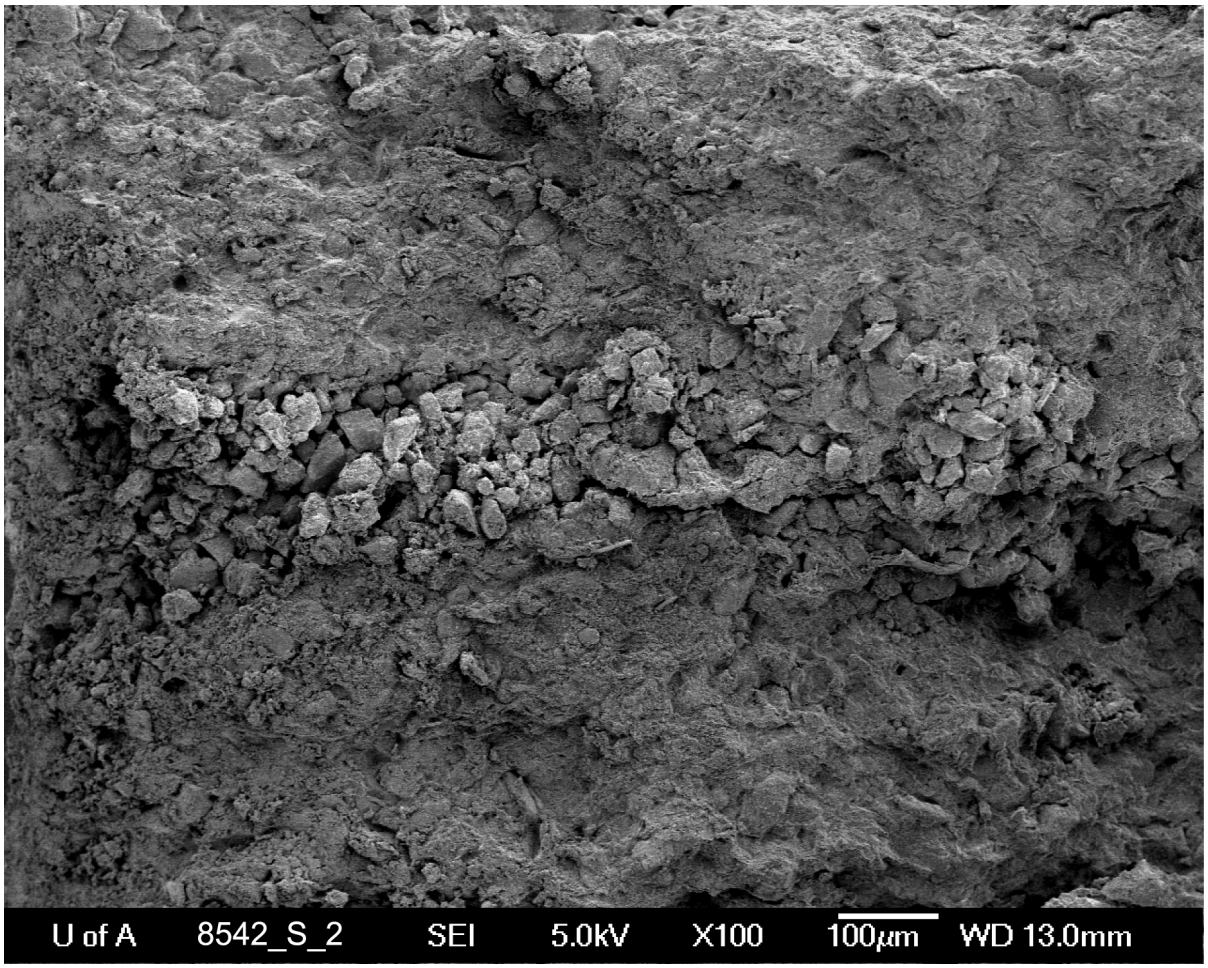
Image	Magnification
8542_S_1	20×



Cross-sectional view of bedding, showing two silt layers identified by the yellow and red arrows. The silt layers are separated by about 1 mm of very silty clay. The upper silt layer is continuous in the sample, while the lower layer appears to be discontinuous, although the lateral continuity of the lower layer is difficult to discern in this image. The top and basal contact of both layers is sharp and somewhat wavy. Fracturing is linear to curvilinear and parallel to subparallel to bedding; most likely due to core expansion, retrieval and handling. At this scale of view, the silt layers exhibit fairly high porosity.

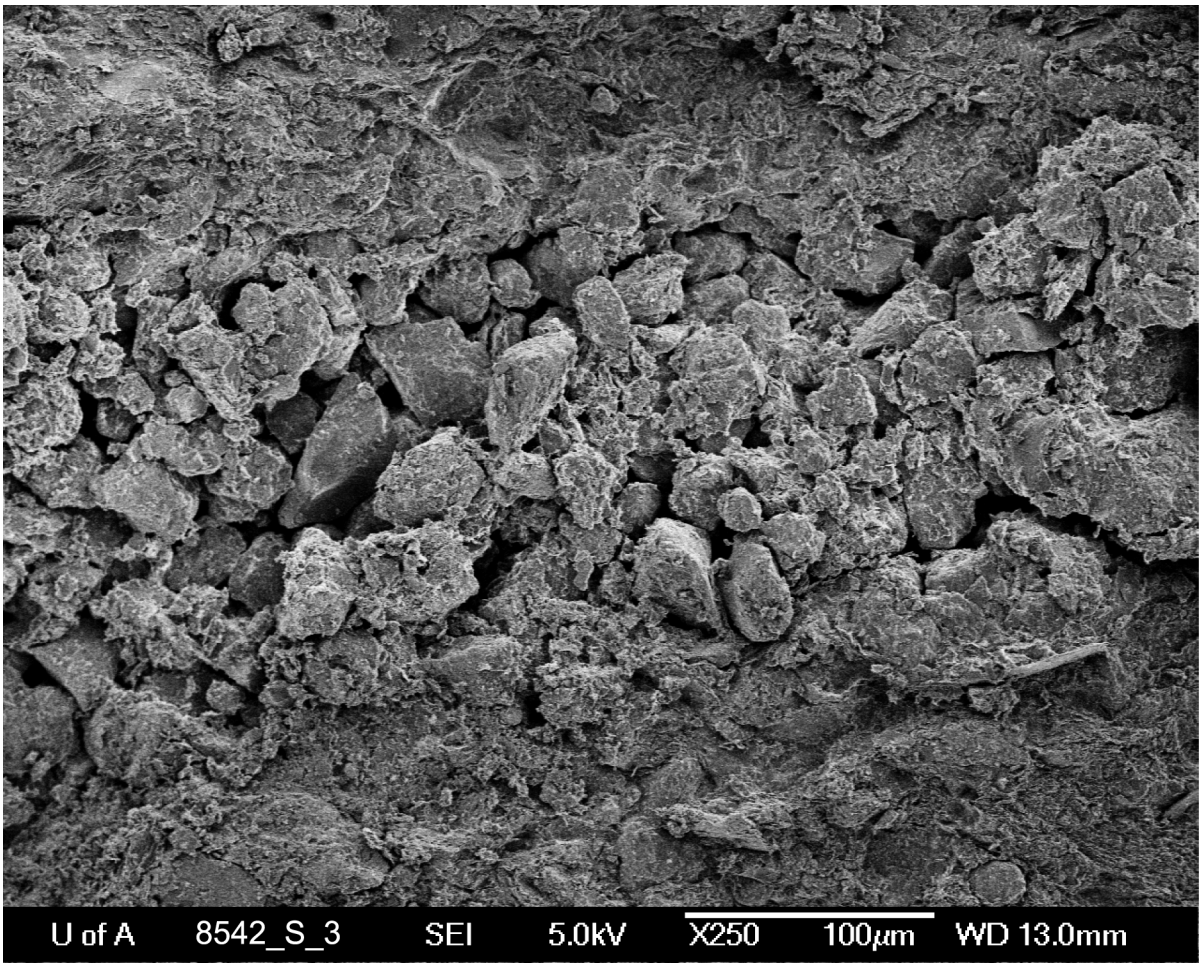
b)

Image	Magnification
8542_S_2	100×



In this image, taken near the tip of the red arrow in image 8542_2_1, the mudstone overlying and underlying the silt layer appears to be exceptionally silty, although porosity is low relative to the silt layer. The silt layer is poorly cemented, has a high degree of permeability and appears to be fairly well sorted. The thickness of the layer appears to vary from about 100 to 200 μm (microns). The upper and lower contacts are fairly sharp and wavy. EDX analysis overview (EDX AS_001) of this image indicates high silicon, moderate aluminum and oxygen, and smaller amounts of potassium, calcium and iron.

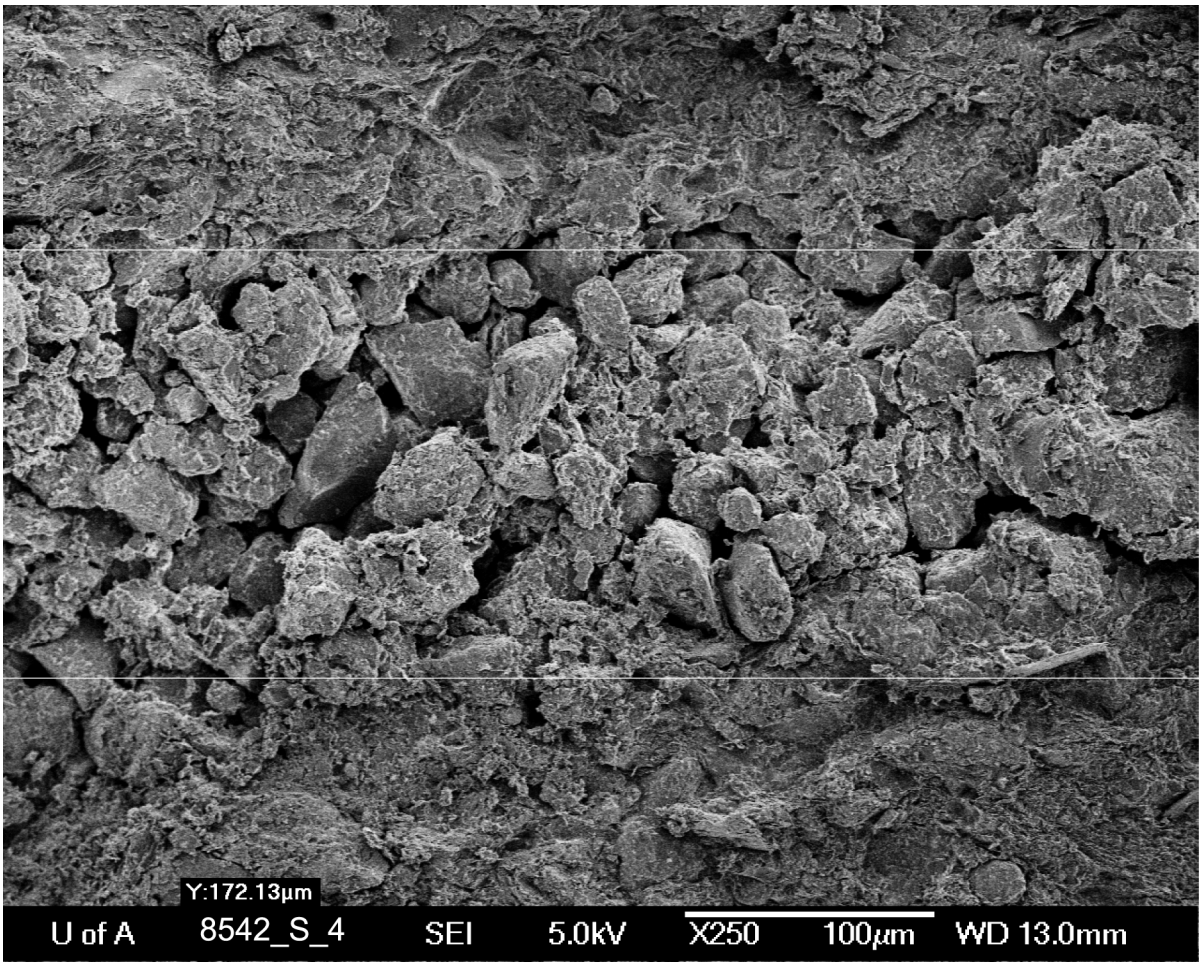
Image	Magnification
8542_S_3	250×



This view is taken near the centre of the previous image (8542_S_2). The size of the grains varies from about 20 to 70 µm, with a visually estimated mode in the area of 30–40 µm (medium to coarse silt). Grains exhibit dominantly angular to subrounded edges and a few rounded particle edges. Sphericity is generally poor to moderate. At least half the particles appear to be coated with clay-sized minerals, and some of the grains on the extreme right side of the image appear fractured. There is very good inter-granular porosity and exceptionally high permeability, as the layer is poorly cemented. A visual estimate of porosity yielded greater than 15%. The laminae viewed in these images would make very good conduits for shale gas diffusion.

c)

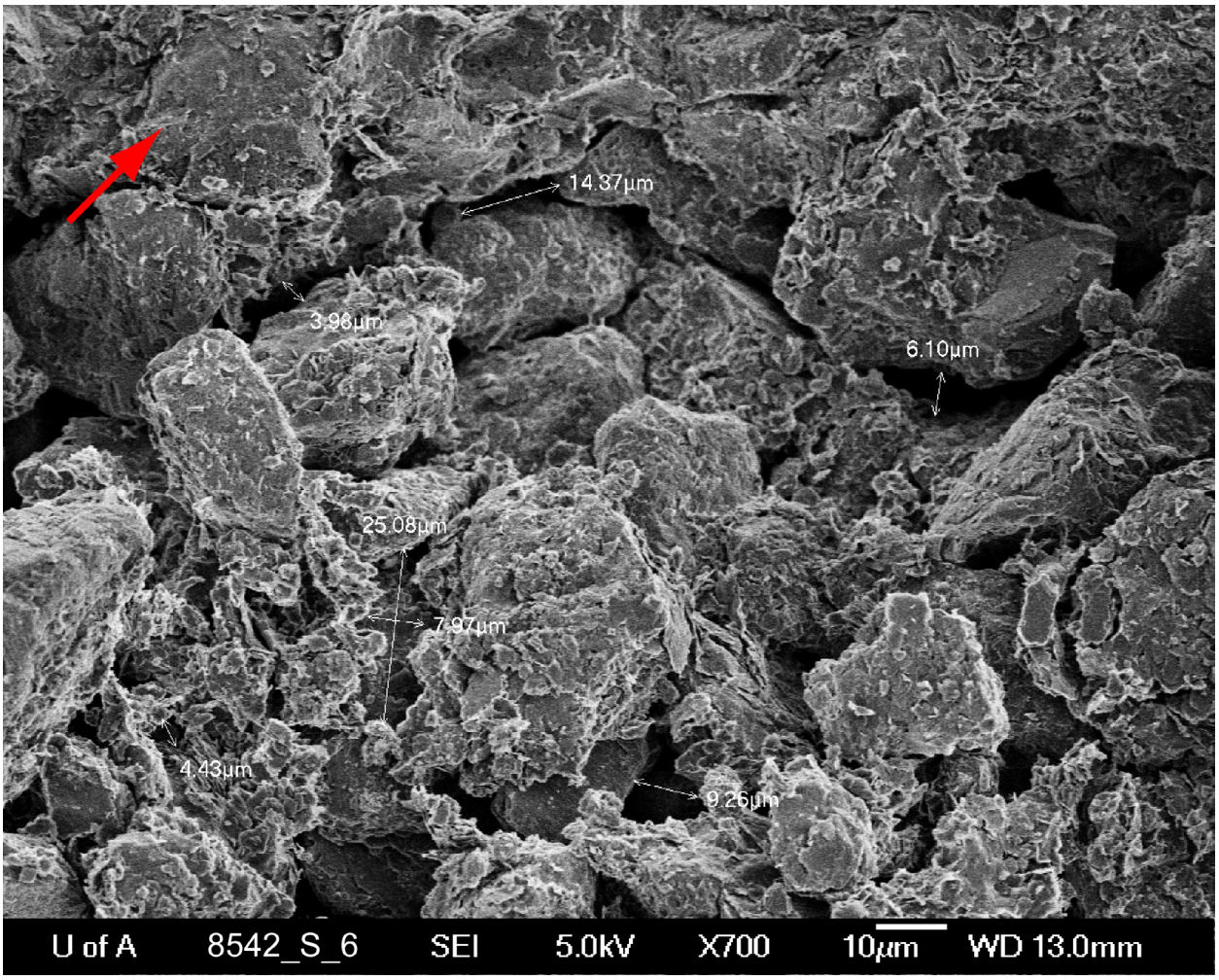
Image	Magnification
8542_S_4	250×



This is same image as 8542_S_3 with the addition of a measuring tool that indicates the thickness of the lamination to be about 172 µm. There are about 5–6 silt grains that typically span the width of this layer. An interesting comparison is that the average thickness of this layer is the same size of a single grain of fine sand on an Udden-Wentworth grain-size scale.

d)

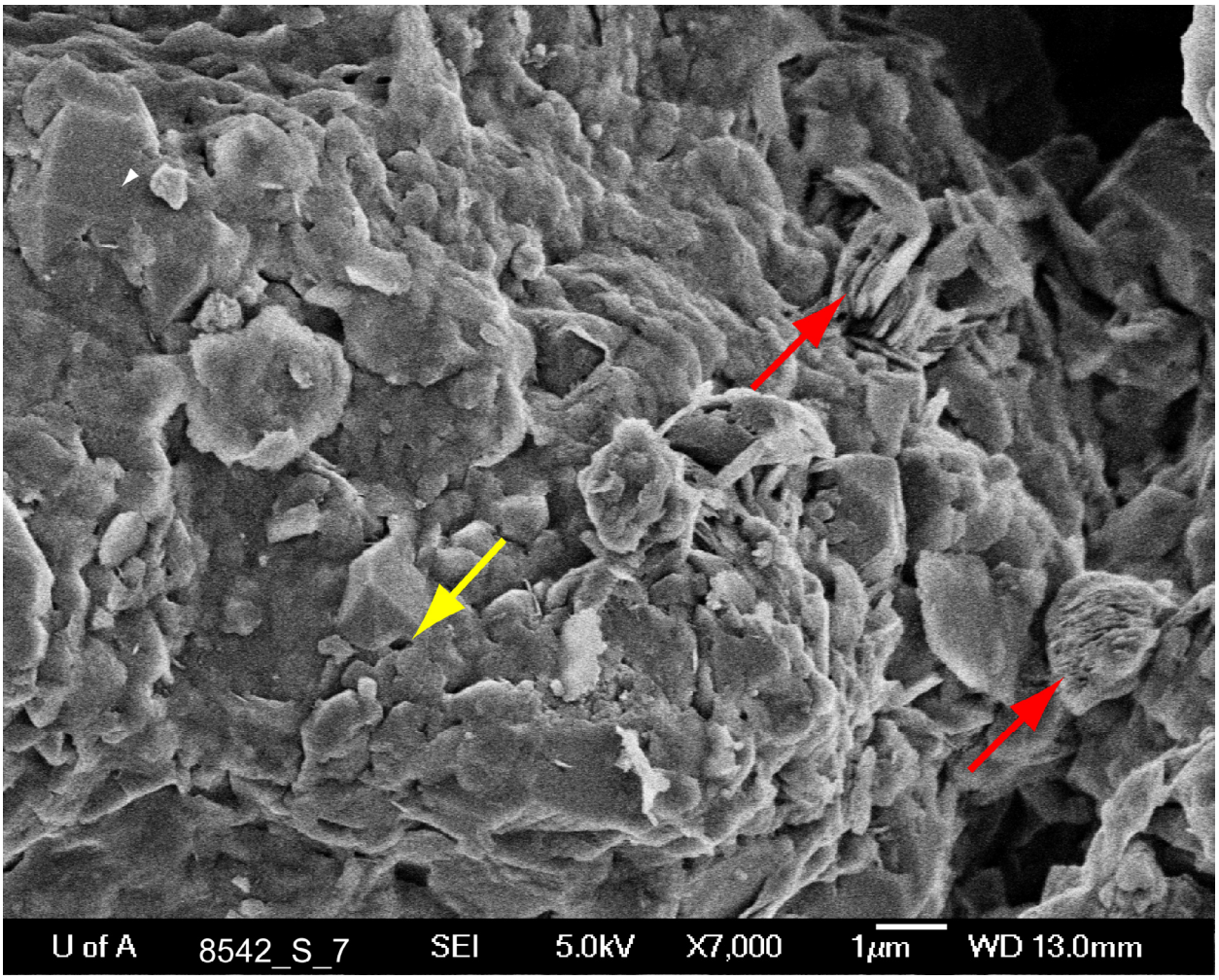
Image	Magnification
8542_S_6	700×



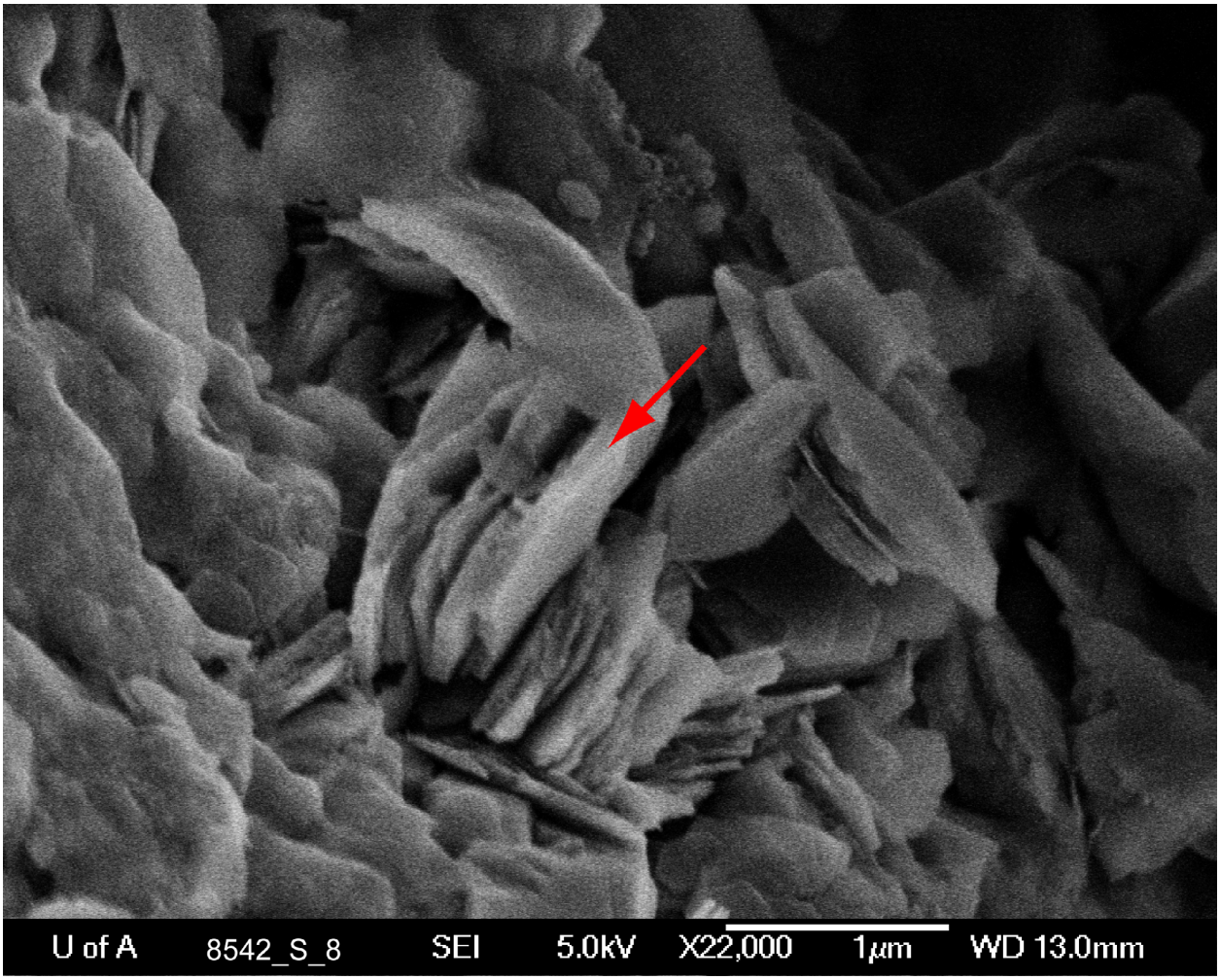
High-magnification view showing the size of some of the pore throats of the silt layer and the coating of many of the grains. The measured throats range from 3.96 to 25.08 µm, with a visually estimated mode of about 5–15 µm. EDX analysis overview of 8542_S_5 (EDX AS_002) indicates dominantly quartz with sodium feldspar and clays. EDX analysis of the coating on the grains shows dominantly quartz overgrowth with authigenic clay and some detrital clay also present. The coating appears to bridge some of the grains, as seen in the upper right of the image. The red arrow shows the location of the lower half of image 8542_S_11 (section 1g).

e)

Image	Magnification
8542_S_7	7000×
8542_S_8	22000×
8542_S_9	19000×
8542_S_10	9000×



The next four images show a higher magnification view of the coating. Image 8542 _S_7 shows quartz overgrowth covering a grain, along with two detrital clay domains (red arrows) on the right side of the image. There appears to be a poor to moderate degree of microporosity associated with the quartz overgrowth, although the effectiveness of the porosity is questionable. Porosity is evident between clay sheets in the detrital clay particles (see red arrows). The next image is taken near the upper right red arrow.



An EDX analysis of the clay in image 8542 _S_8 indicates the detrital particle to be kaolinite/dickite. The clay particle seen near the lower red arrow of image 8542 _S_7 may also be kaolinite/dickite.

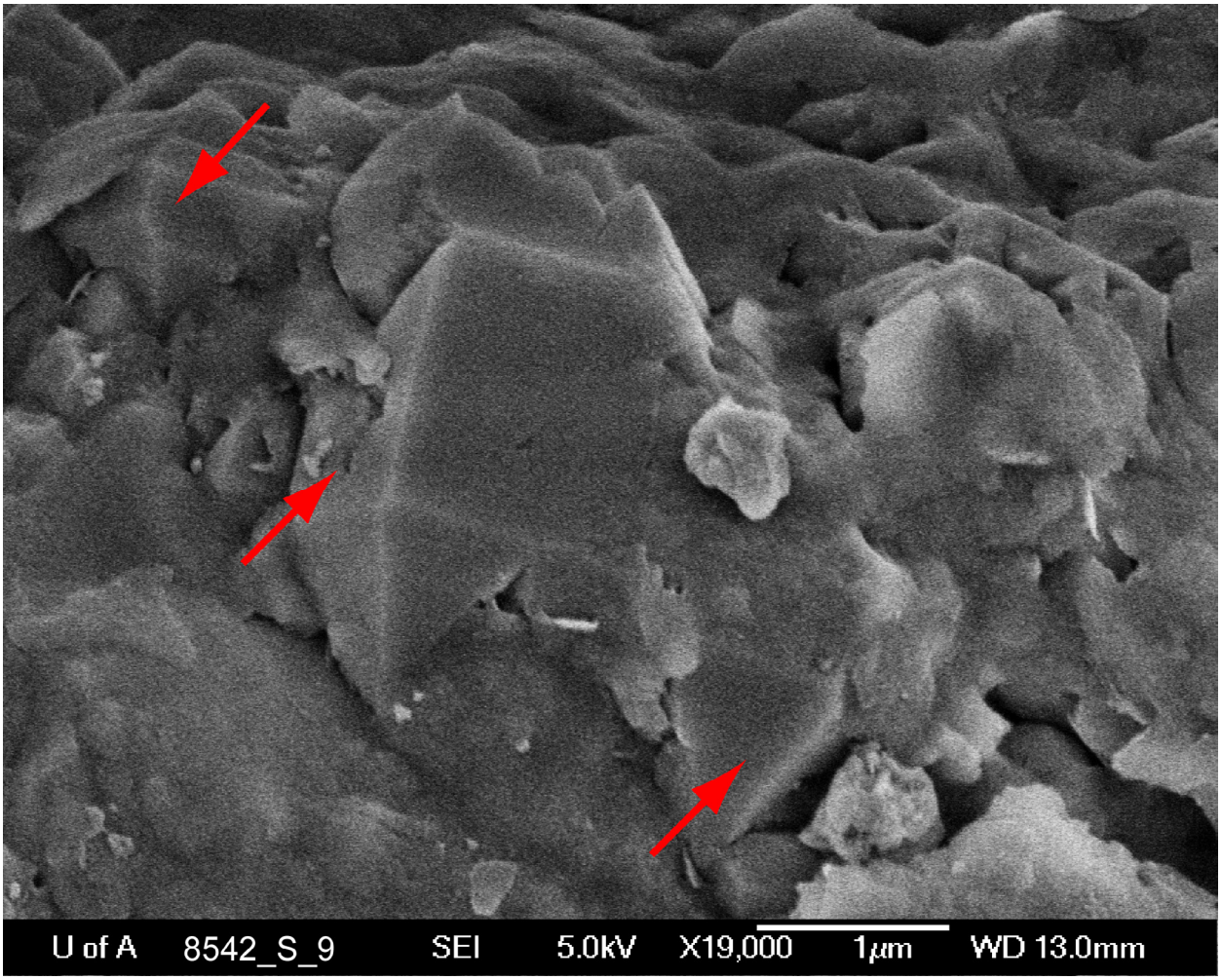
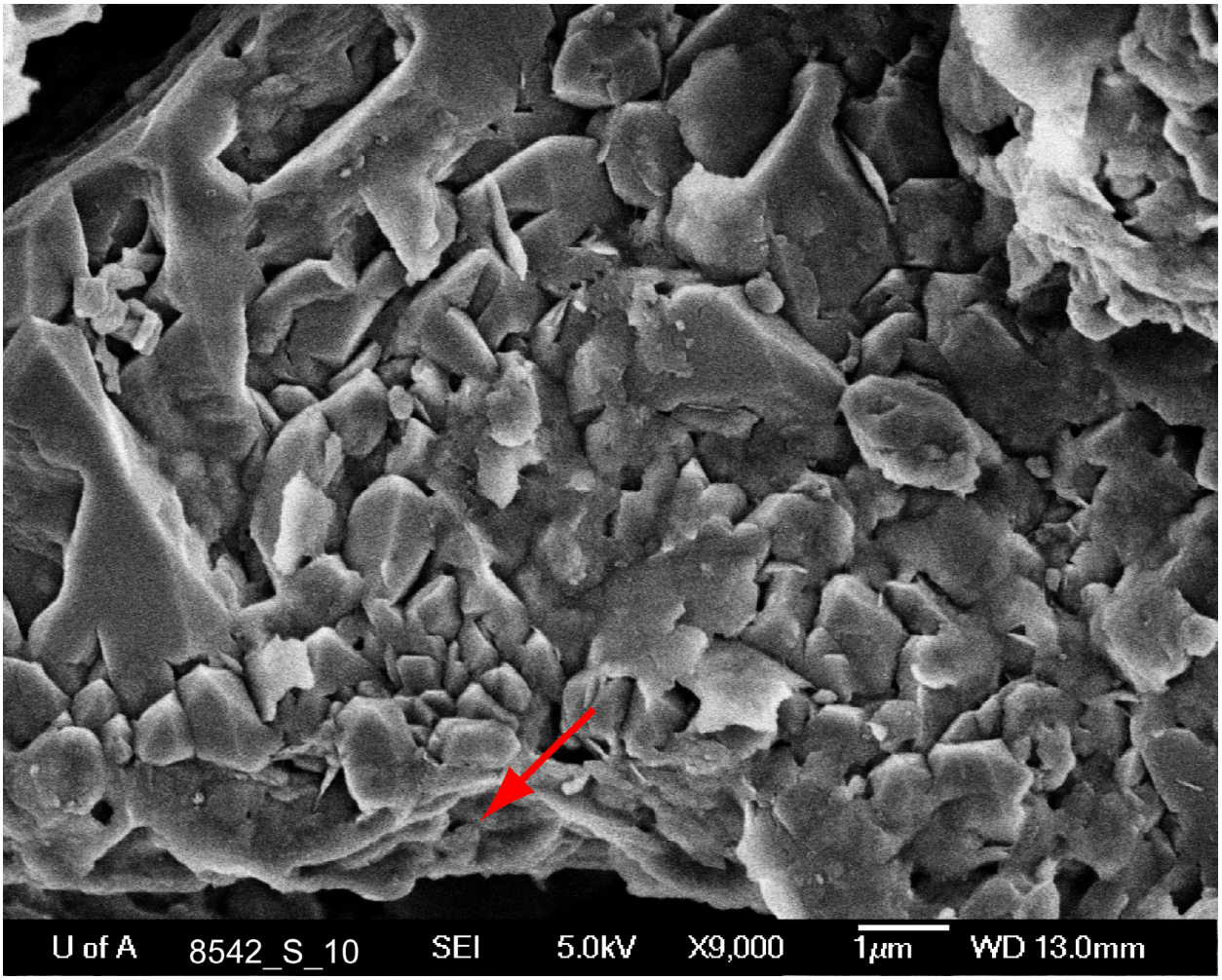


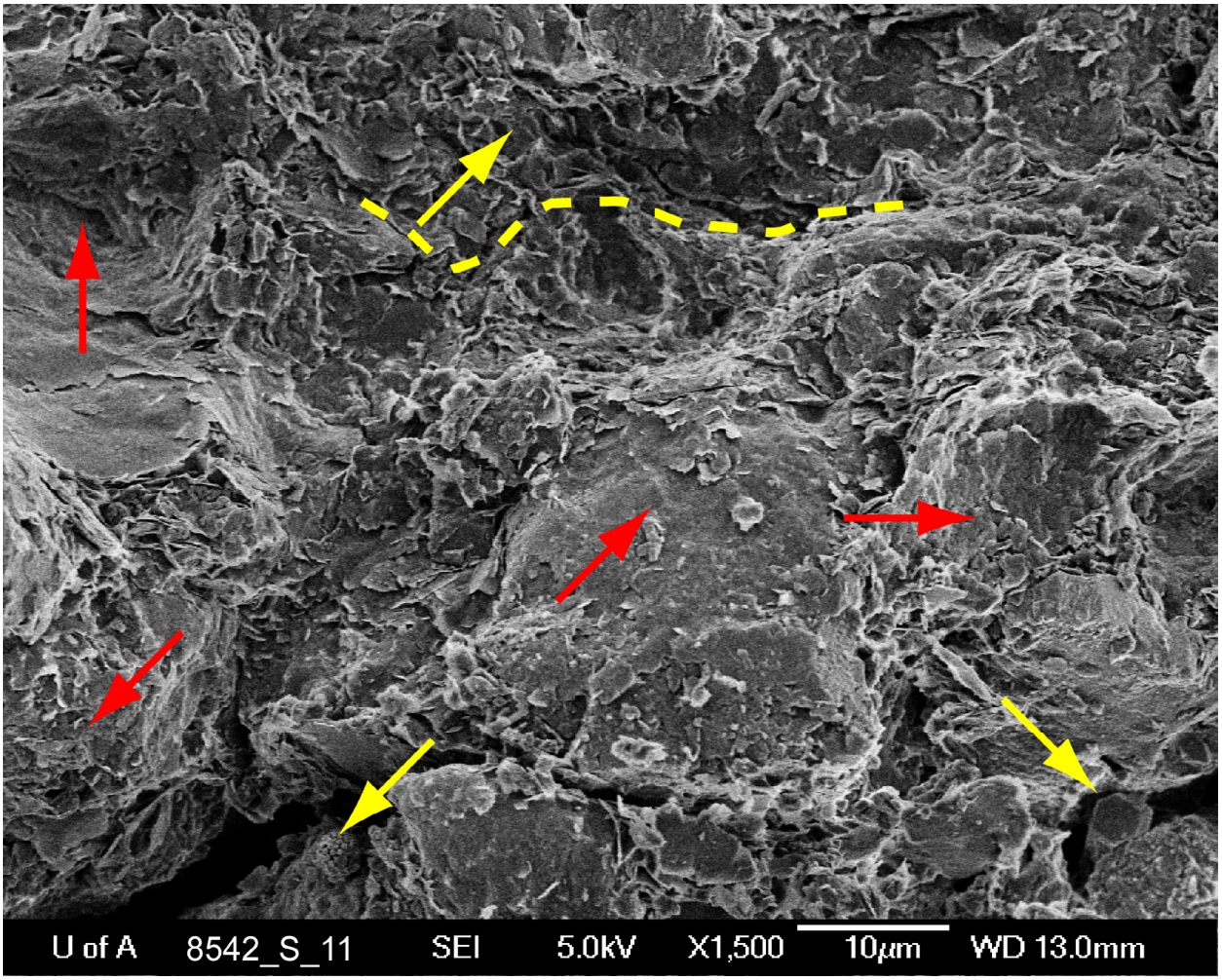
Image 8542_S_9 was taken near the upper right quadrant of image 8542_S_7 and shows fairly well developed quartz overgrowth crystals and a coating of very fine grained quartz overgrowth over much of the image. A very moderate degree of microporosity is associated with overgrowth and clay (white particles) in the bottom right of the image. Intraparticle porosity can be seen near the top of the middle red arrow.



The final image (8542_S_10) in this set shows a variety of quartz overgrowth crystals with a fairly high degree of intercrystalline porosity where the overgrowth crystals are less than 1 μm in diameter; intercrystalline pore throats are much less than 1 μm. The basal layers in this photo (clay, red arrow) also exhibit porosity between individual sheets. Note that the sheets are somewhat crenulated and curvilinear.

f)

Image	Magnification
8542_S_11	1500×
8542_S_12	15000×
8542_S_13	8000×



This set of images was taken at the upper interface between the silt and clay layers. The large grain in the middle of image 8542_S_11 (middle red arrow) corresponds to the grain identified by the red arrow in the upper left quadrant of image 8542_S_5. The dotted yellow line on image 8542_S_11 approximates the contact between the upper silt layer and the clay-rich zone. The base of this image shows silt-sized grains in the middle and left (red arrows), and the former positions of plucked grains on the right and upper left (red arrows). The grains appear to be well coated with clay, which itself exhibits a degree of porosity; clay sheets drape over and bridge silt grains. The upper yellow arrow points to what appears to be chaotic clay fabric (Davies et al., 1991; fabric refers to the orientation of the clay plates; O'Brien, 1985). Here, porosity and permeability are enhanced, relative to flat-lying clay sheets. The yellow arrows on the bottom right and left show the positions of the next two images, respectively.

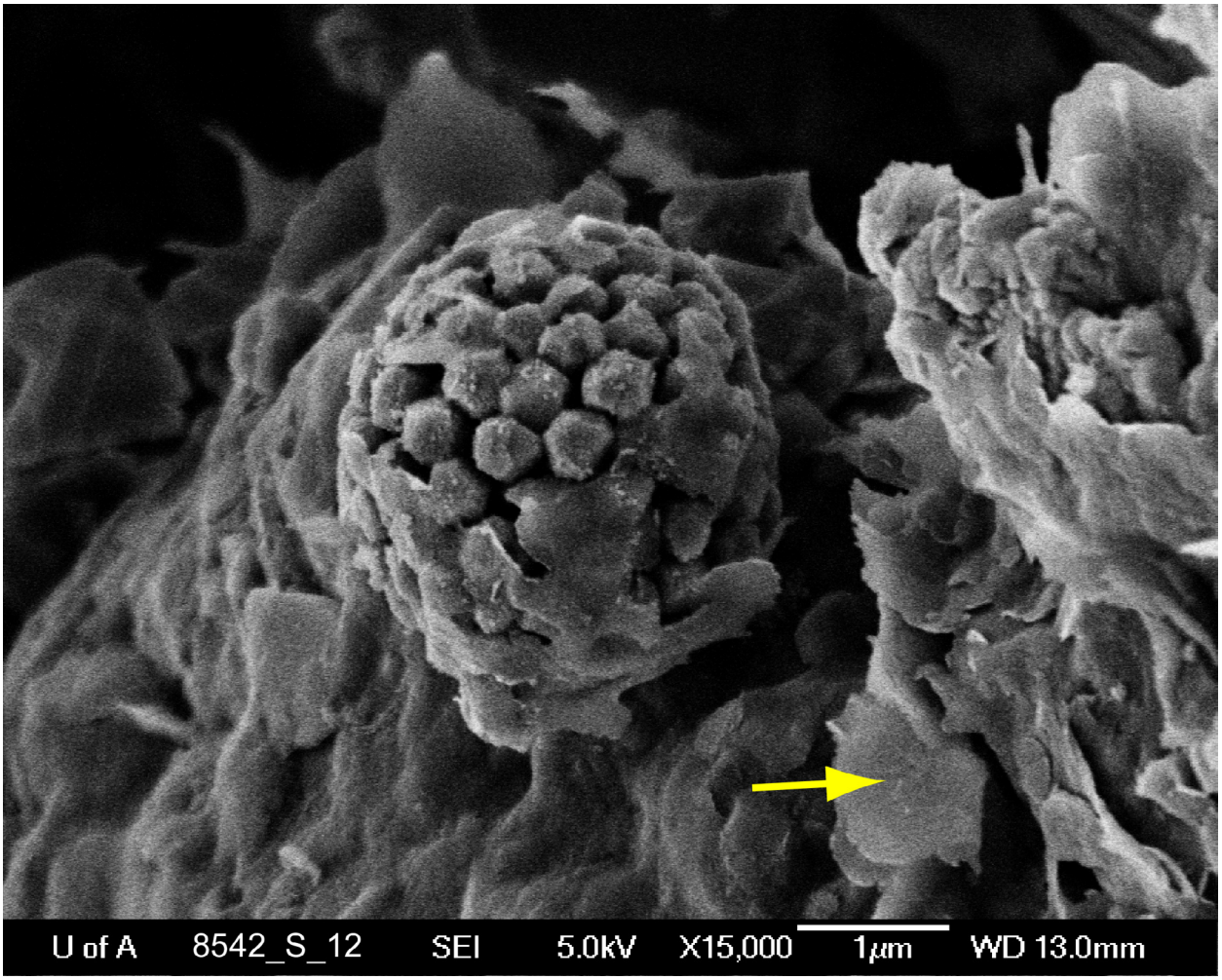


Image 8542_S_12 shows framboidal pyrite on top of a grain covered with quartz overgrowth. The spacing between pyrite crystals is in the order of 100 nm (nanometres). The pyrite is 'coated' with clay mineral. The yellow arrow in the bottom right of the image points to a kaolinite sheet identified by EDX analysis. Note the microporosity associated with clay 'flower' to the right of the pyrite.

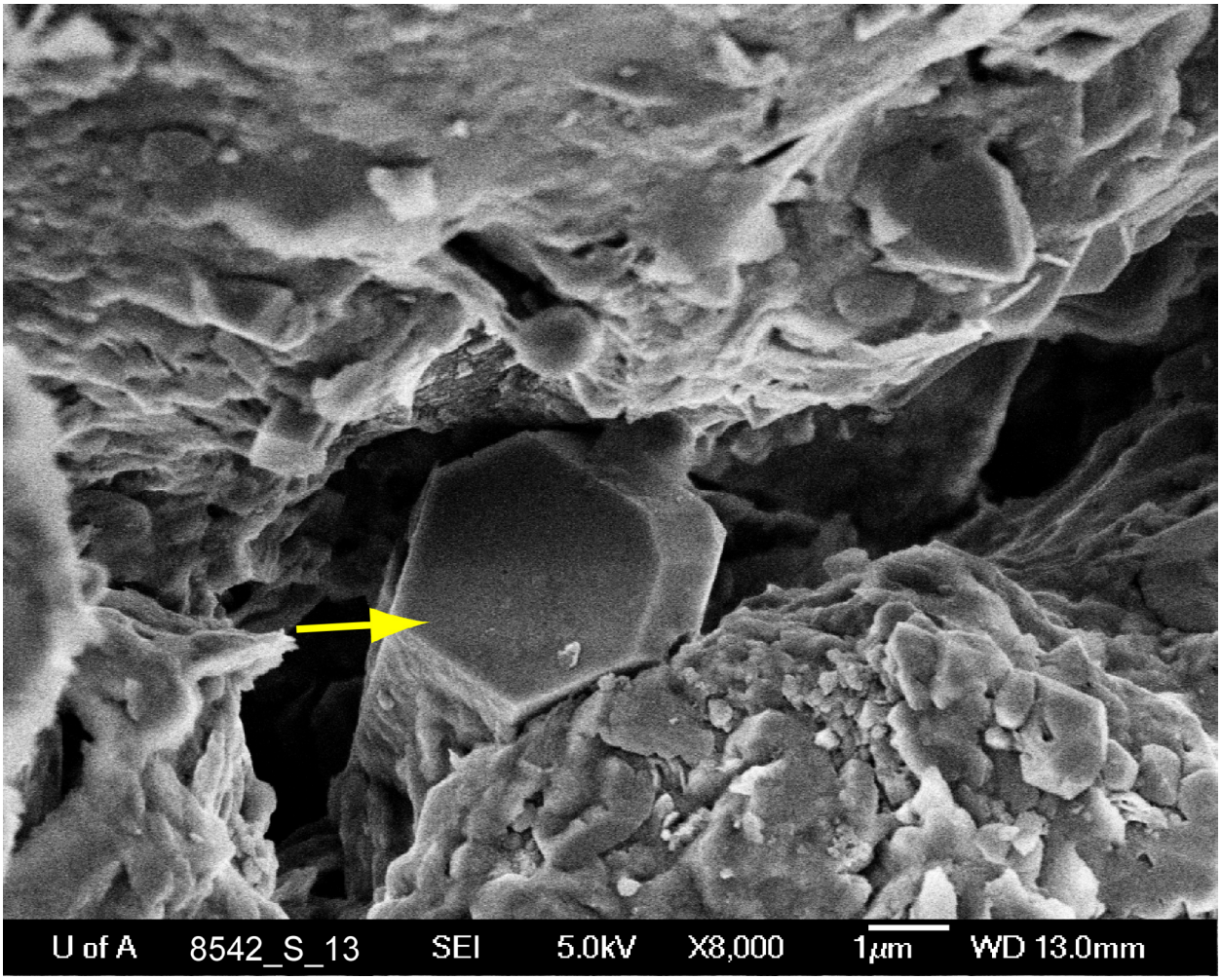
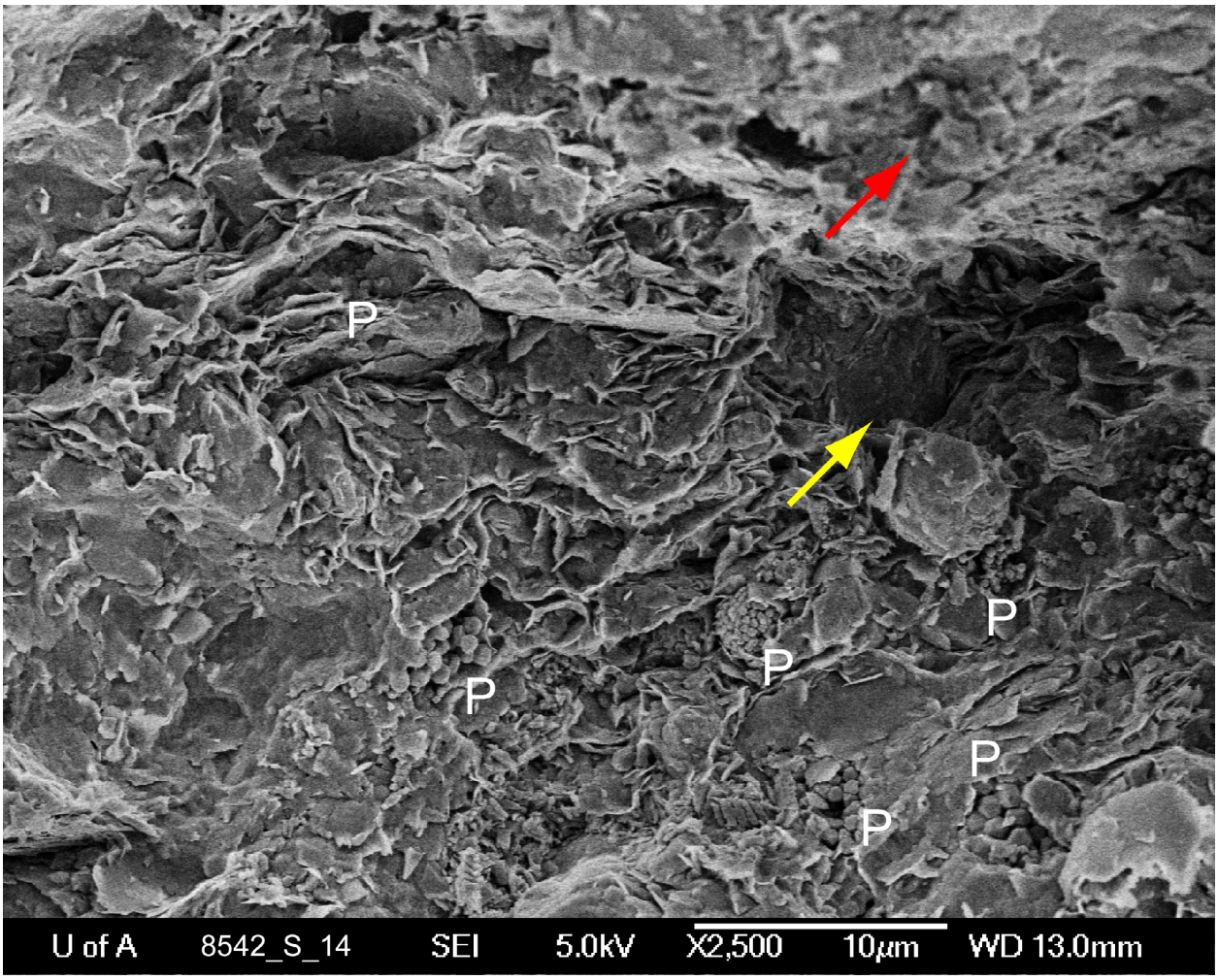


Image 8542_S_13 identifies a very well developed quartz crystal (yellow arrow) that has significantly occluded porosity and disrupts permeability in the sample. Other smaller crystals of quartz projecting into the pore are also in view. The width of the pore between the grains is >2 μm. Porosity is observable on top of the grain in the bottom right of the image between quartz overgrowth crystals.

g)

Image	Magnification
8542_S_14	2500×
8542_S_15	10000×
8542_S_16	10000×
8542_S_17	12000×



This set of images shows the clay fabric above the upper silt layer. The three yellow arrows in the middle of the 8542_S_14 trend along basal clay sheets that surround pyrite clusters. Observe the open clay fabric on the right side of this image, as opposed to the fabric on the upper and bottom left side. Such an open fabric enhances porosity and permeability of clay mineral–rich rocks and enhances diffusion to silt layers. There is enough effective porosity that both lateral and vertical fluid flow will be enhanced. Vertical and lateral fluid flow associated with the fabric on the left side of the image would be restricted. At the extreme upper right of the image (red arrow) there appears to be microporosity that would allow a degree of vertical fluid flow. Pyrite clusters are noted by the letter 'P'. The yellow arrow may identify the site of a plucked silt grain.

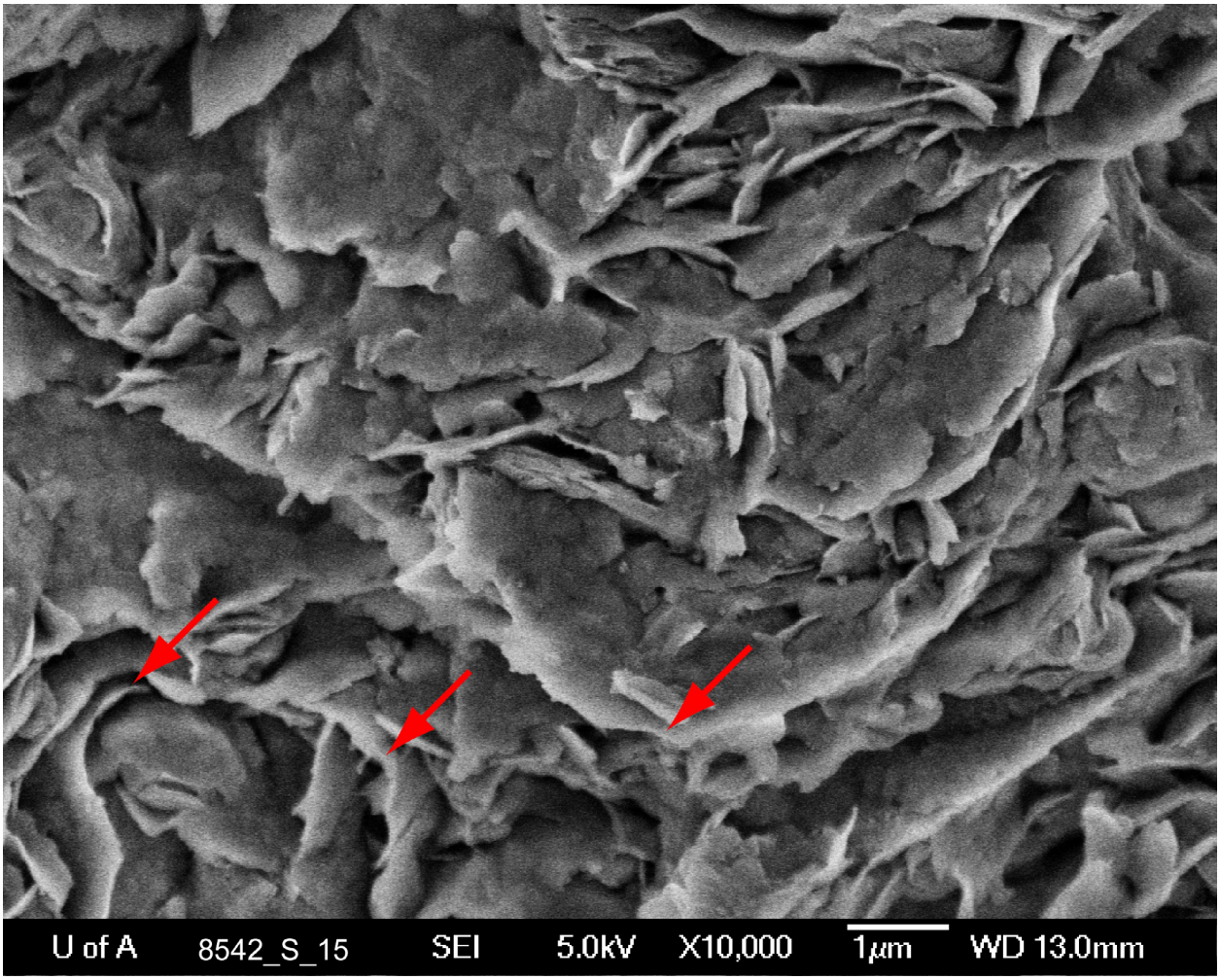
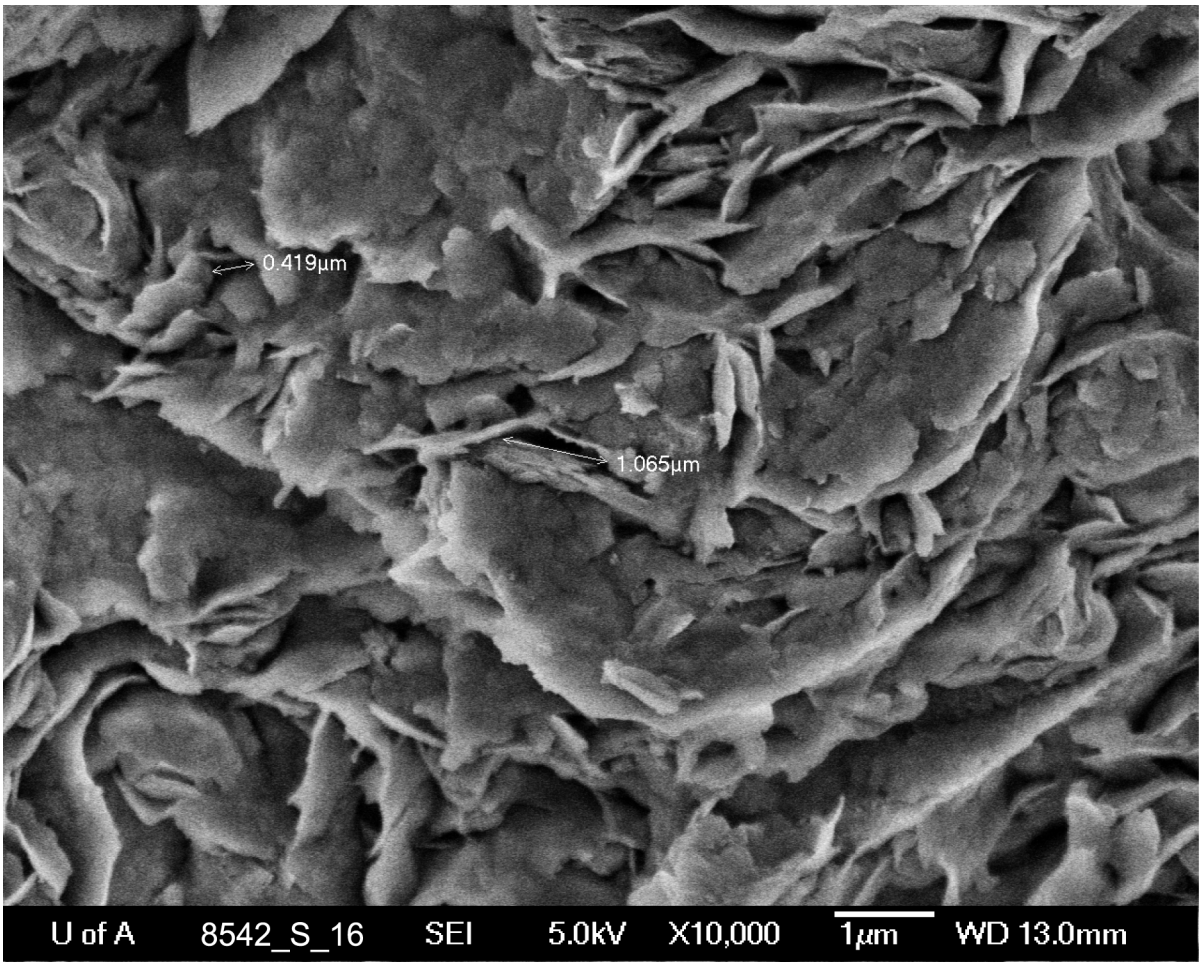


Image 8542_S_15 is a high-magnification view taken in the centre of the previous image, showing a fairly disrupted clay fabric that creates a relatively high degree of porosity and permeability. The fabric is composed of primarily single-domain clay particles (e.g., Moon, 1972; Bennett and Hulbert, 1986; Bennett et al., 1991). Note the curved clay sheets near the bottom of the image (red arrows).



Measurement of pore throats in image 8542_S_16 indicated that the long axis of many of the pore throats is less than 1 µm, although there are some larger pores.

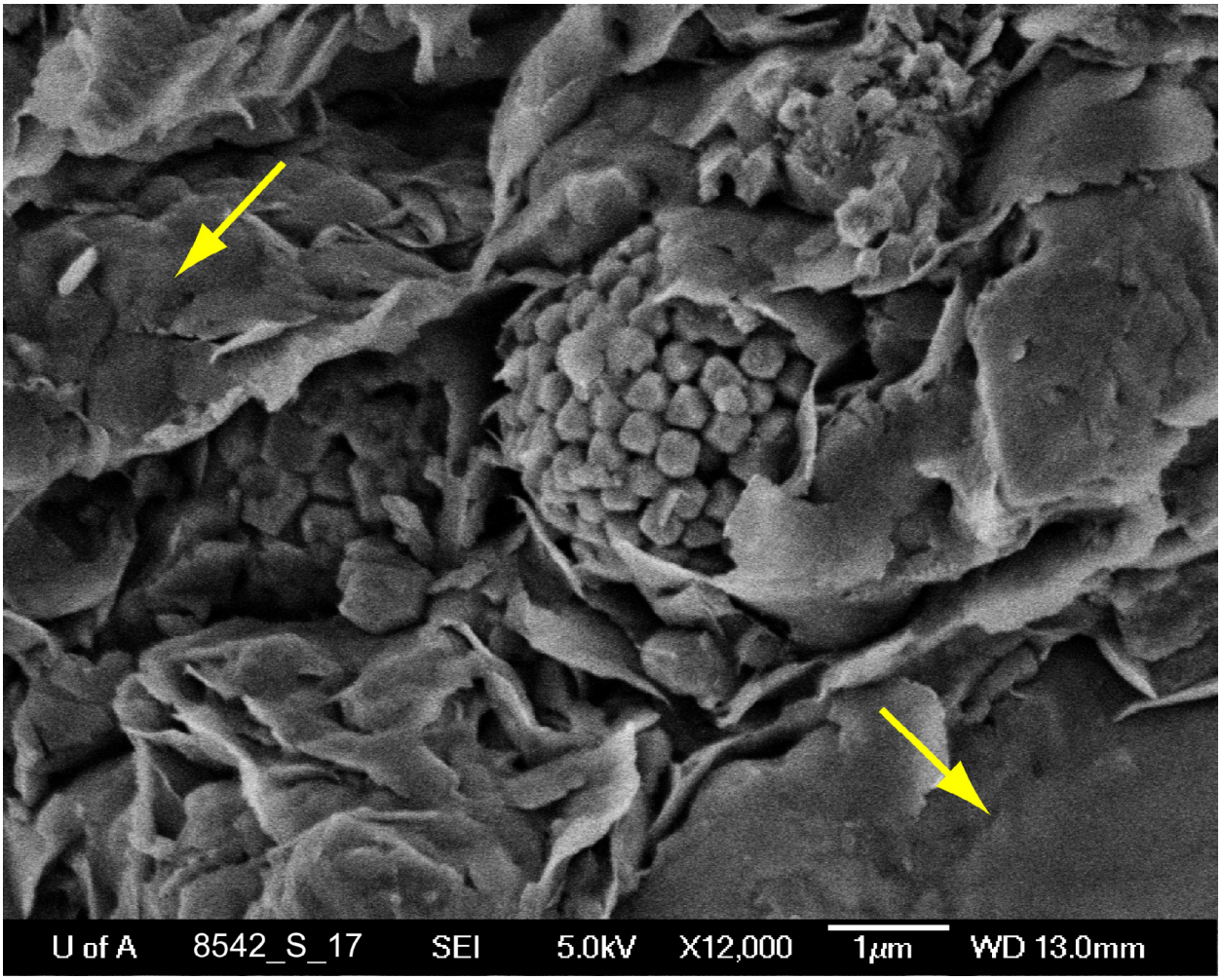


Image 8542_S_17 shows pyrite clusters surrounded by a relatively disrupted clay fabric. The yellow arrows point to clay sheets that are approximately parallel to bedding and appear to have few to no pores penetrating the sheets; hence, vertical migration of hydrocarbons will be retarded, at least locally. The upper left arrow also identifies the overlapping structure of clay plates (Bennett et al., 1990).

h)

Image	Magnification
8542_S_18	2500×

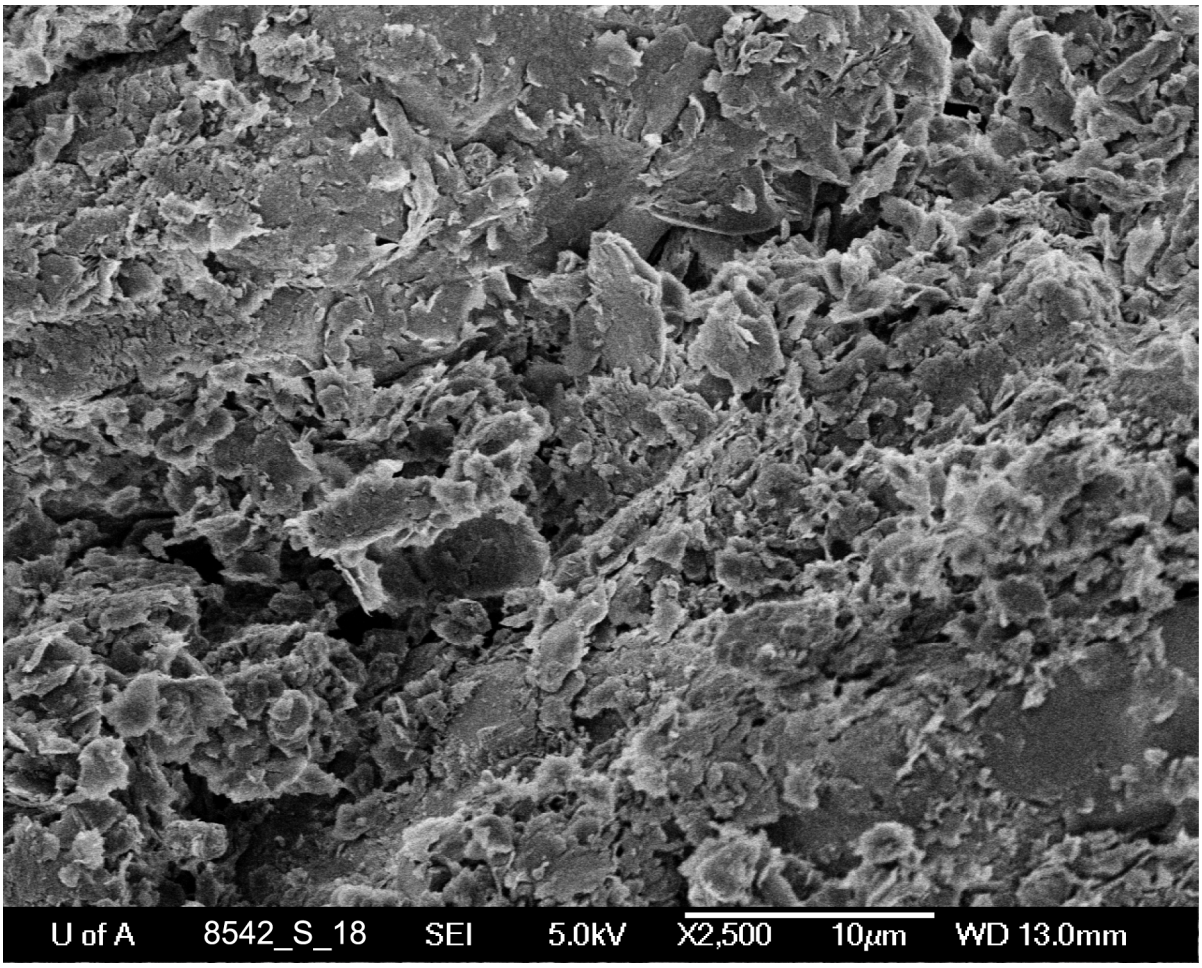
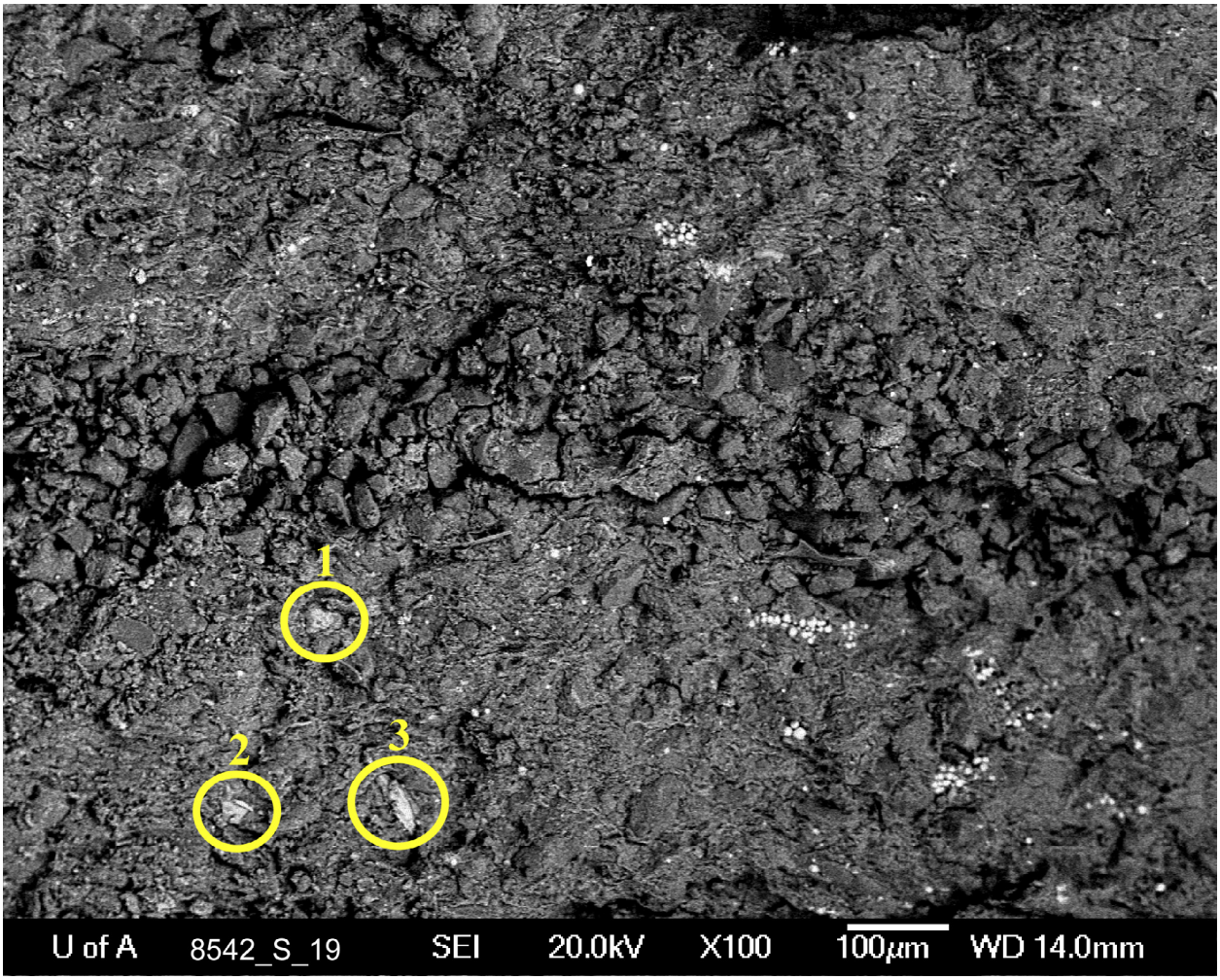


Image 5442_S_18 is a similar view of clay fabric but was taken below the corresponding silt layer and indicates relative continuity of the type of fabric above and below the silt layer.

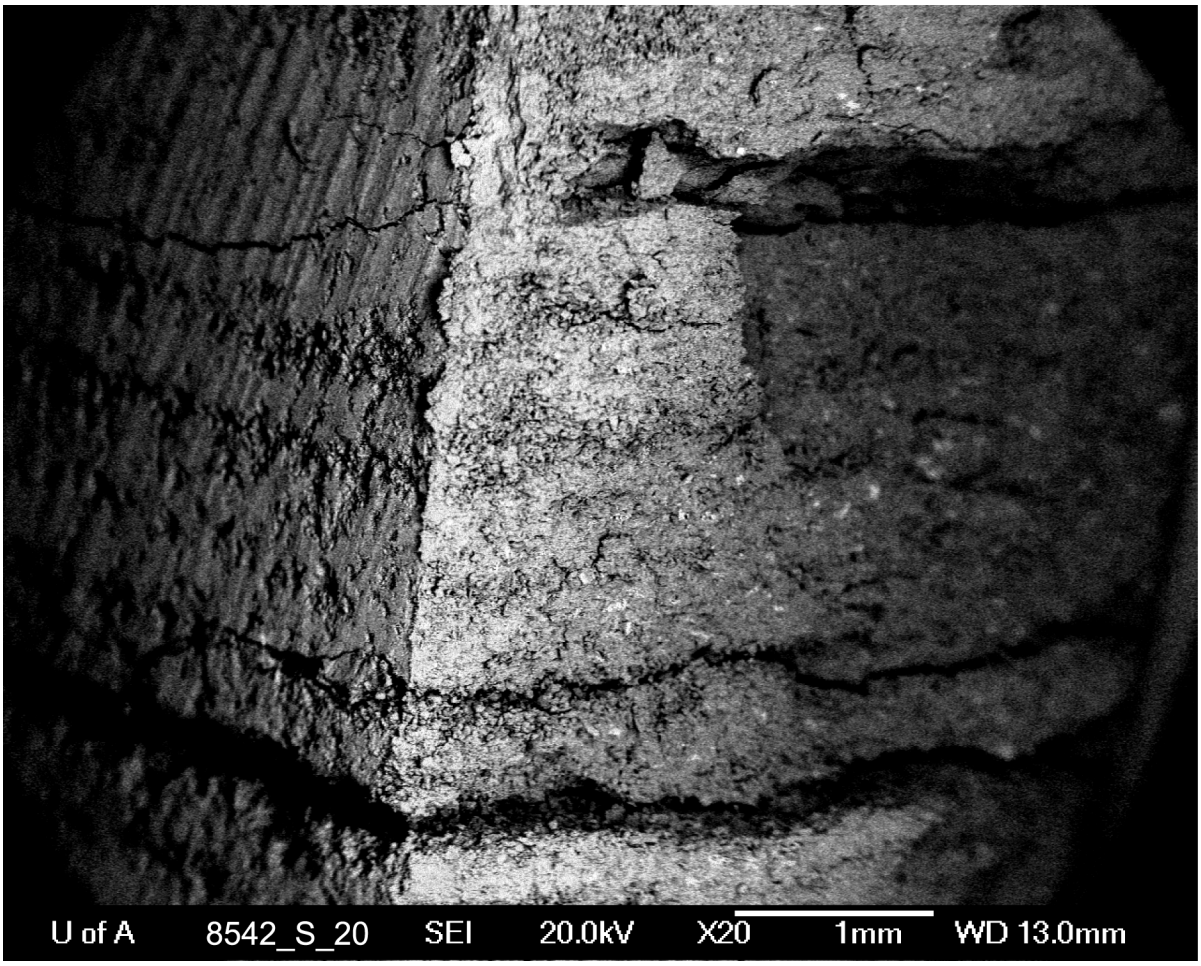
i)

Image	Magnification
8542_S_19	100×
8542_S_20	20×
8542_S_21	22×

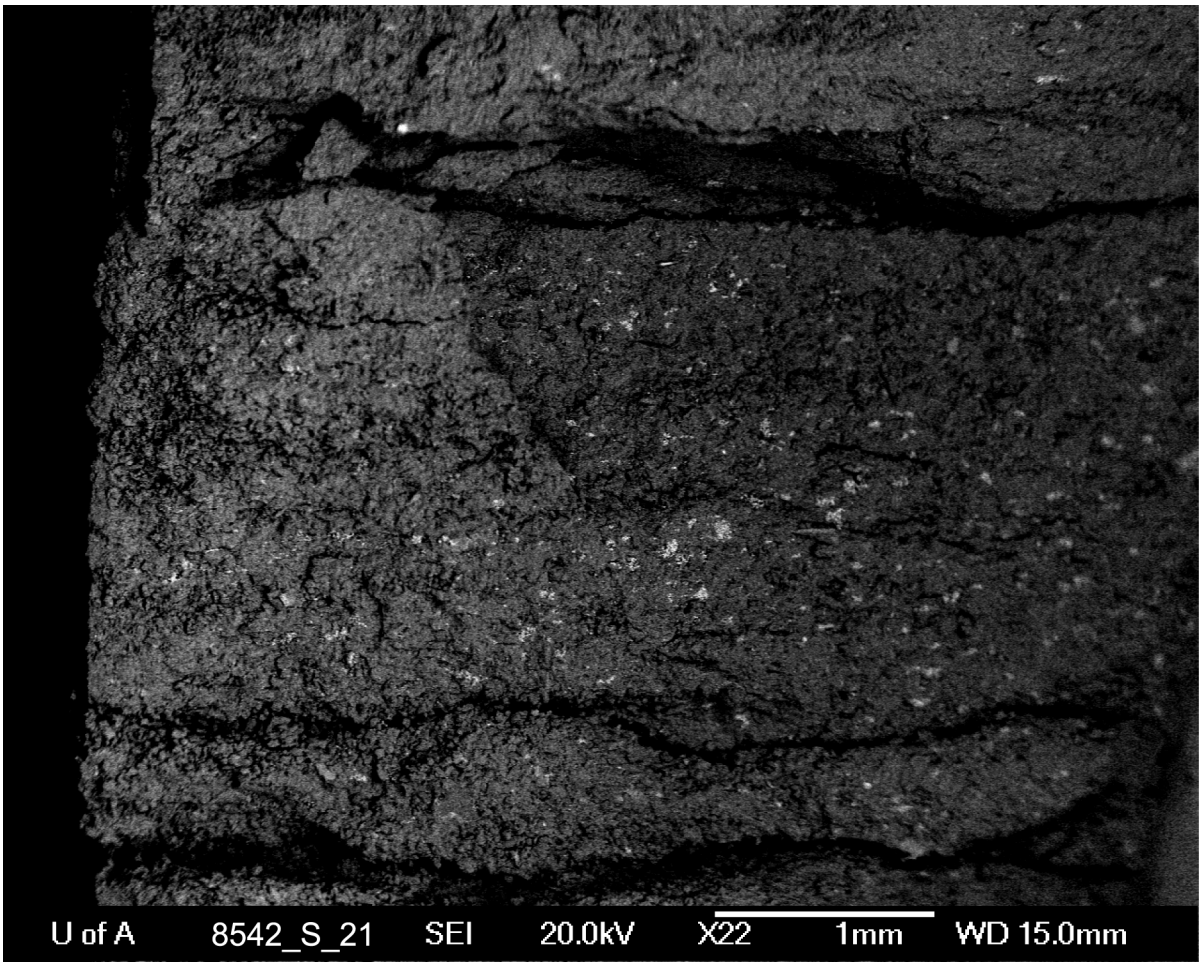
This is a set of three backscattered images. White areas in the photos indicate heavy minerals, or more often pyrite. Pyrite clusters in these images occur mainly in clay-rich layers, often where the fabric is open. Porosity shows up as black or dark areas, while the intermediate colours represent light minerals. Results of EDX analysis of the minerals identified by the circles are listed in the table below the image.



Composition	**Image**	**ID on Image**
titanium oxide (EDX AS_011)	8542_S_19	1
calcium phosphate (EDX AS_012)	8542_S_19	2
iron sulphide with calcium (EDX AS_013)	8542_S_19	3



An interesting observation in image 8542_S_20 is that the cluster of 5–6 silt layers, similar to the layers described above, occurs within a sample thickness about 2–2.5 mm.



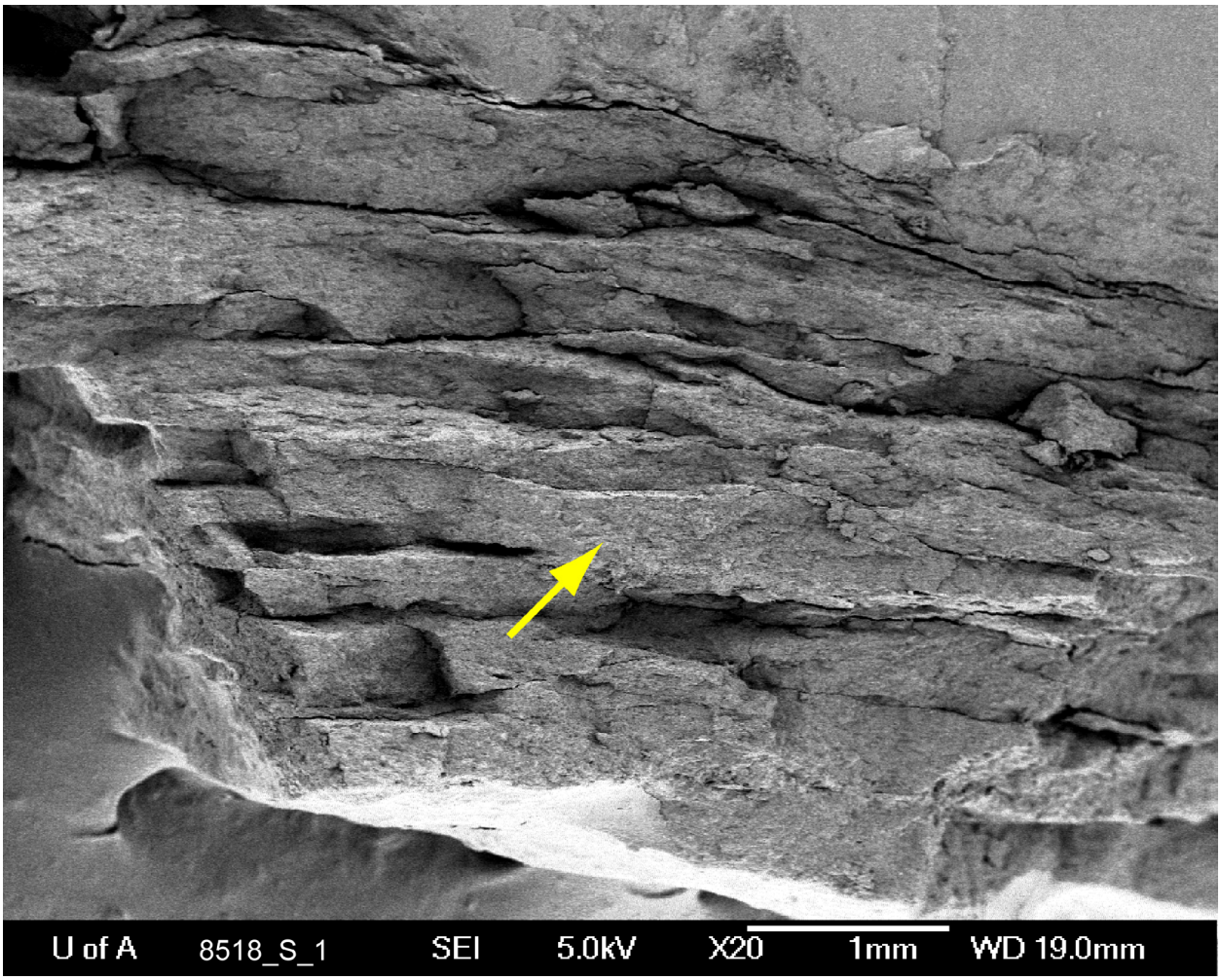
This is a back scattering image of sample 8542. The bright white spots are mostly pyrite.

2) Upper Colorado Group; First Yellow Speckled Shale Formation; Sample 8518; 02/03-14-018-11W4/00; 407.5 m core depth.

The sample is dark grey, slightly silty shale. The bedding planes trend east in all images, and up is northward. This set of four samples represents an overview of the texture of the sample.

a)

Image	Magnification
8518_S_1	20×
8518_S_2	100×
8518_S_3	250×



The first image (8518_S_1) shows a fairly homogeneous texture with a lack of silt or sand laminae. Fracturing is linear to curvilinear and parallel to subparallel to bedding. Much of the bedding-parallel fracturing is relatively evenly spaced at about 0.5 mm. A few fractures that crosscut bedding are evident. The yellow arrow points to the general location of the next image.

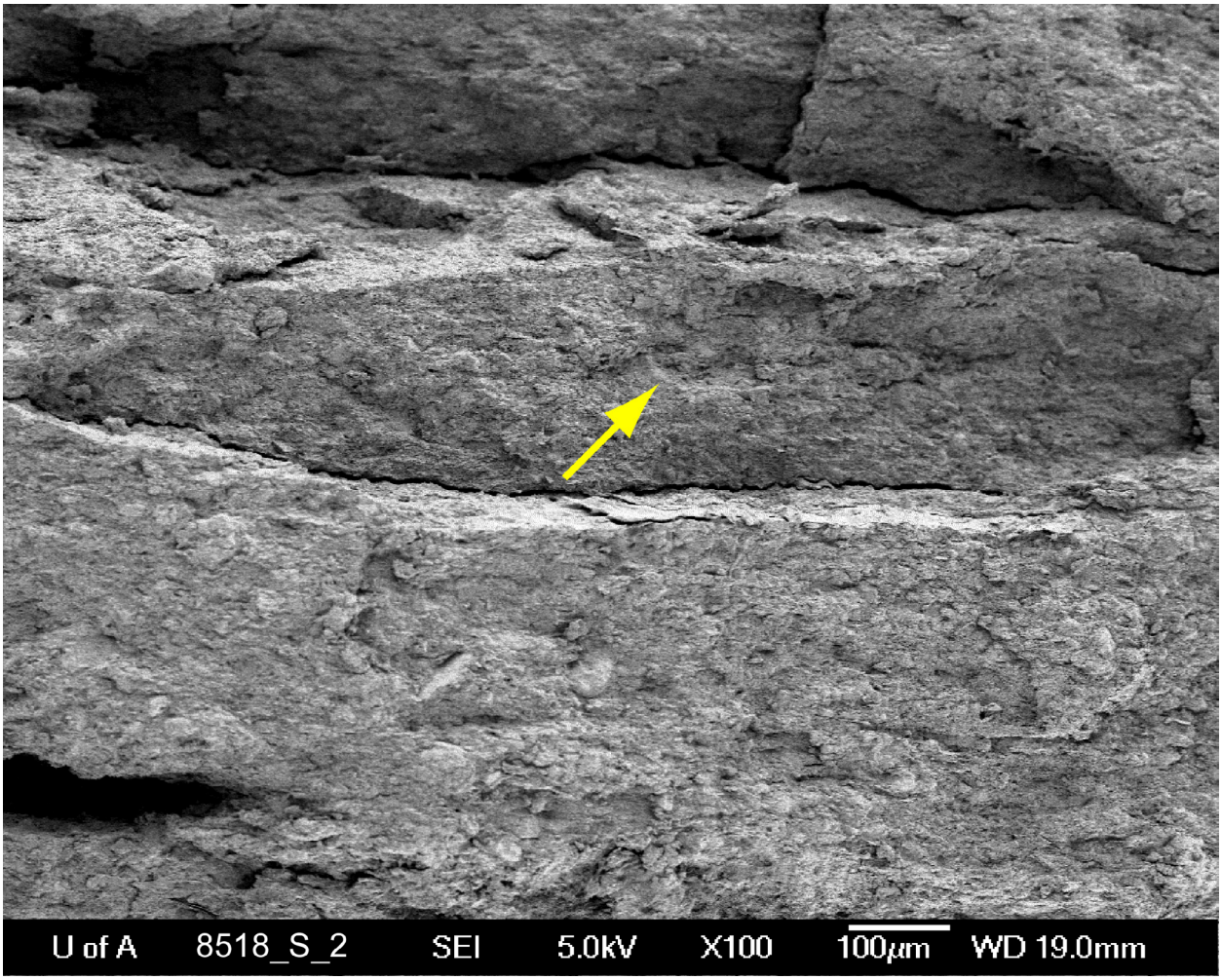


Image 8518_S_2 is taken near the centre left of image 8518_S_1. Here, the texture is fairly rough and 'bumpy', suggesting the presence of silt or sand grains. The yellow arrow points to the location of the next image.

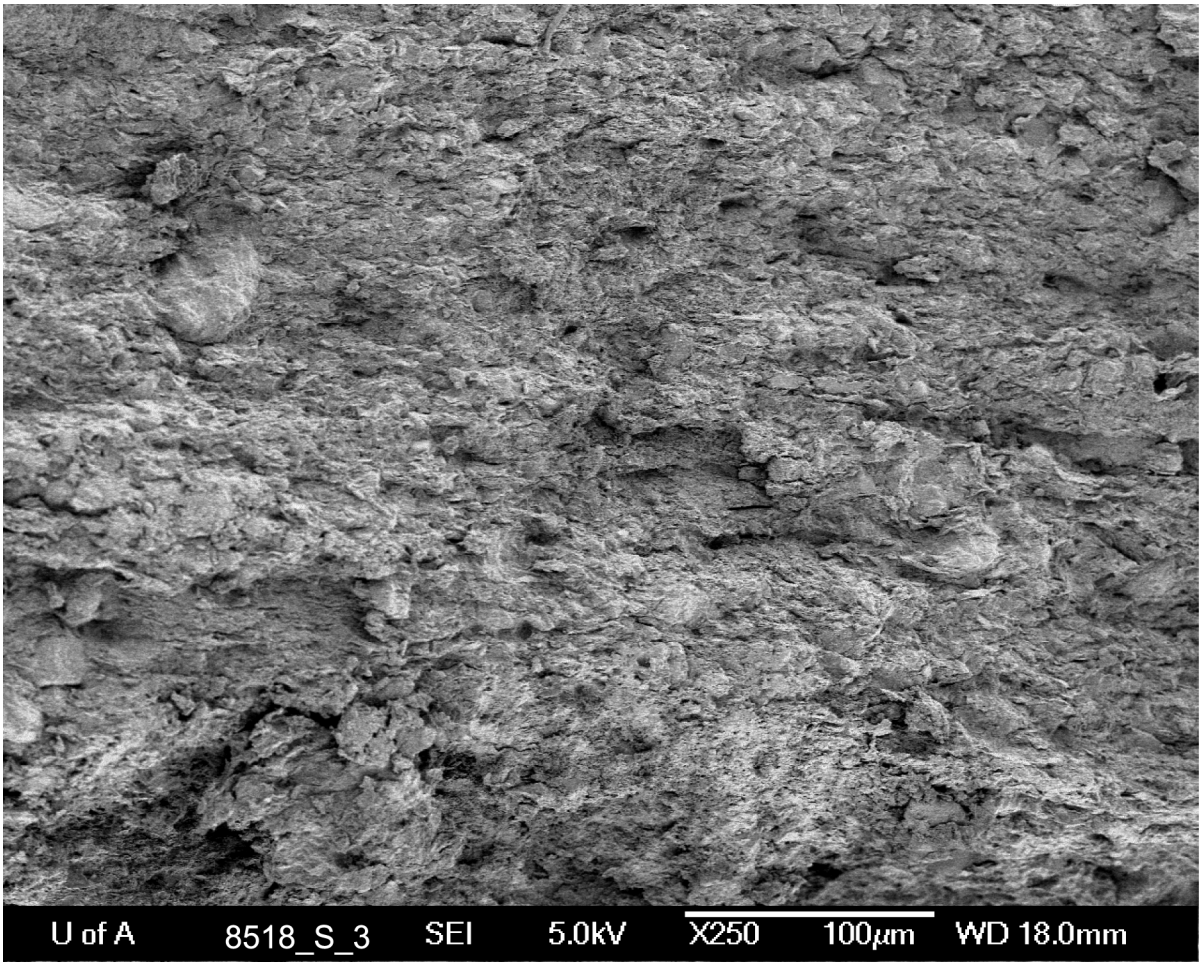


Image 8518_S_3 is a 250× magnification and still looks fairly homogeneous, although the texture is again rough with fairly angular edges in some areas. At this scale of observation, the rough texture suggests the presence of silt.

b)

Image	Magnification
8518_S_4	700×
8518_S_5	2500×
8518_S_6	22000×
8518_S_7	2500×

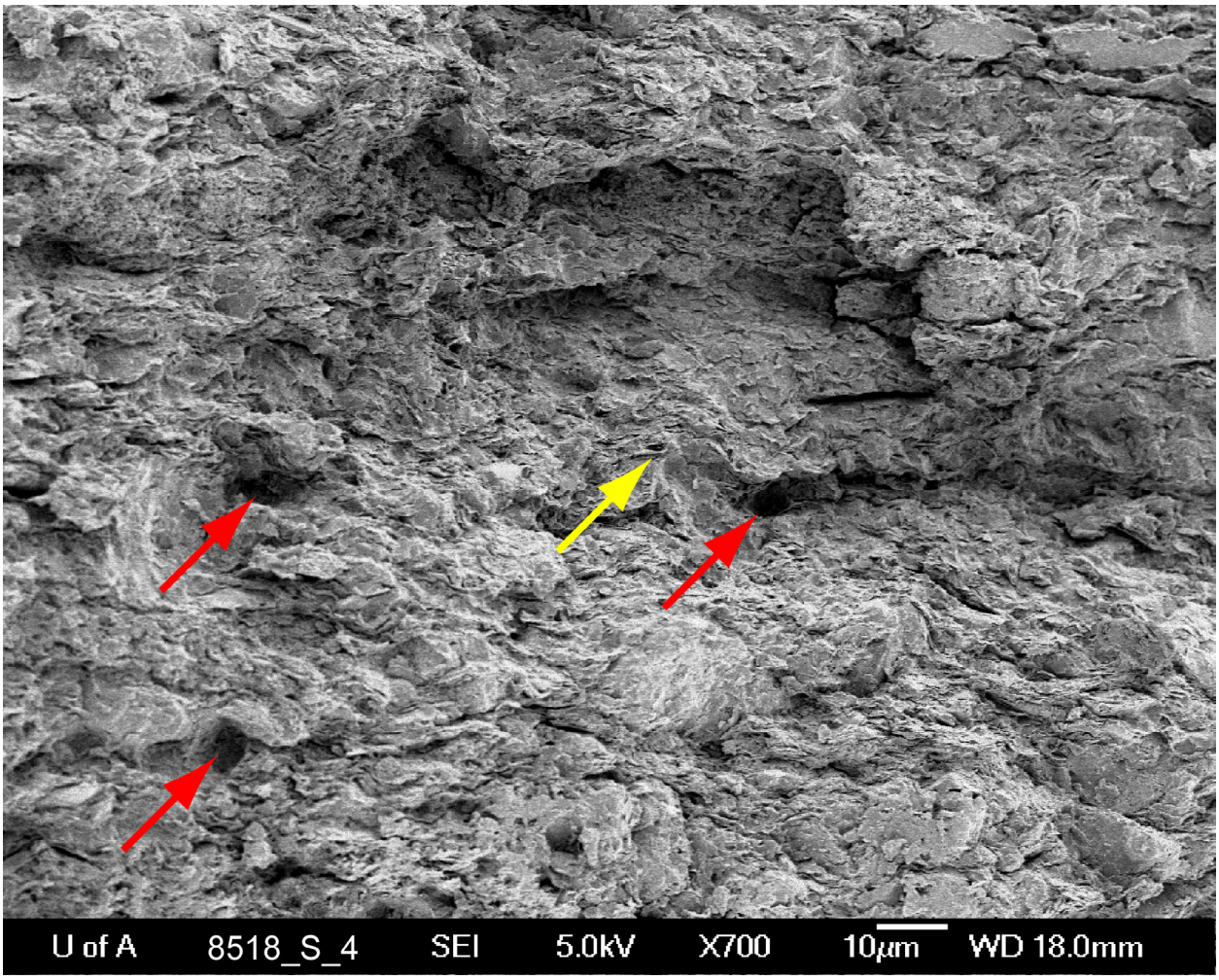
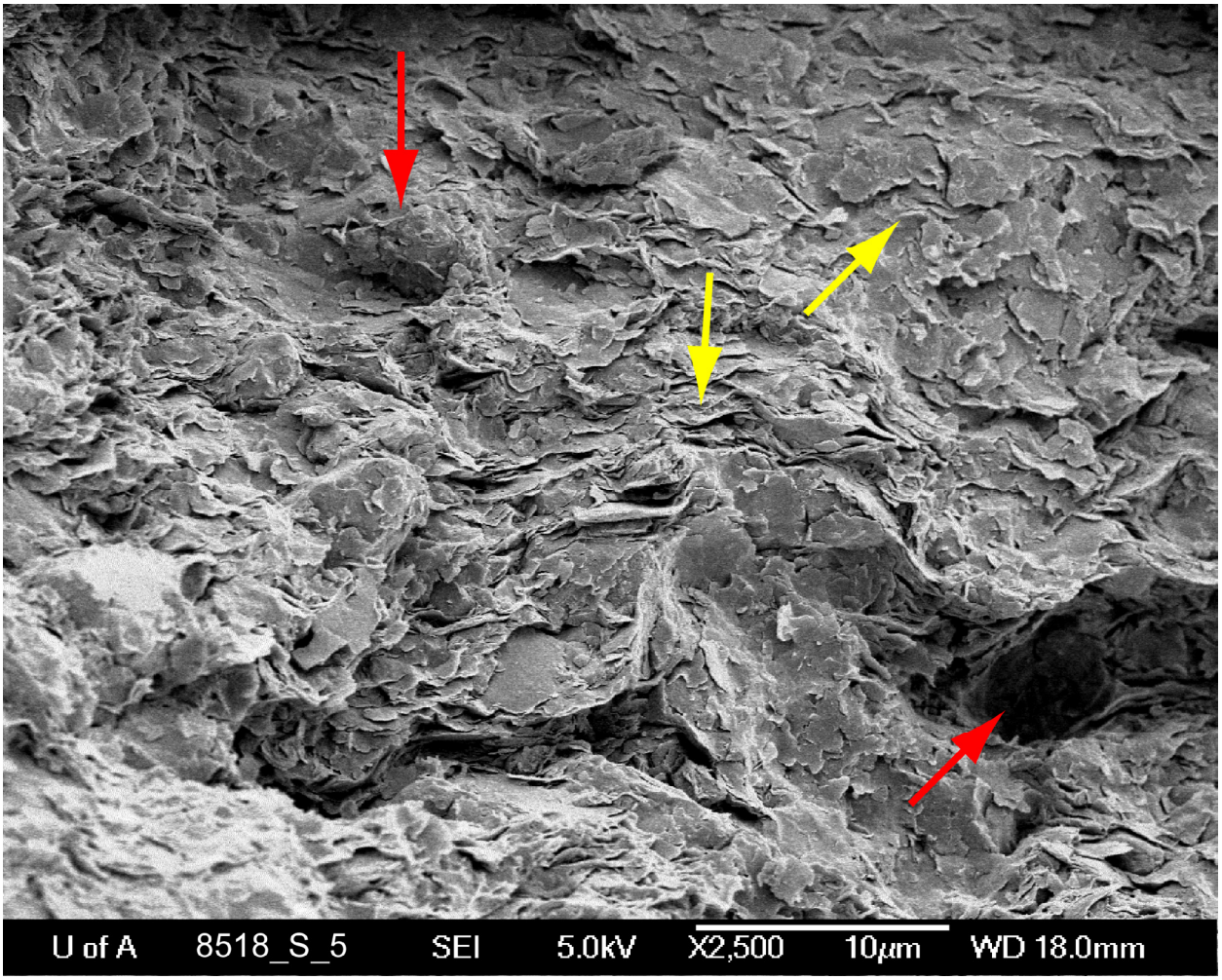


Image 8518_S_4 is taken at the centre of the previous image. The central area of this photo is a good location to view the micromorphology of the sample. The red arrows indicate where 'plucked' gains (<10 µm diameter) may have resided. The yellow arrow identifies the location of the next image.



The red arrow in the lower right quadrant of image 8518_S_5 identifies the 'plucked' grain feature located in the previous image. The red arrow pointing downward in the upper left quadrant of the image indicates a fairly bumpy surface that may identify the location of silt grains that have been coated with clay. This sample, however, is dominated by single-domain clay sheets that appear to have an overlapping or 'offset arrangement of plates' ('cardhouse' fabric; e.g., Bennett et al., 1991), as seen near the yellow arrow. There appears to be microporosity near the sheet edges, especially the front edge and perhaps along the side of the individual clay sheets. The tops of the sheets are fairly homogeneous and appear unbroken and void of porosity; hydrocarbon migration would therefore be dominated by lateral rather than vertical movement. The next image is taken near the tip of the downward-pointing yellow arrow near the centre of the photo.

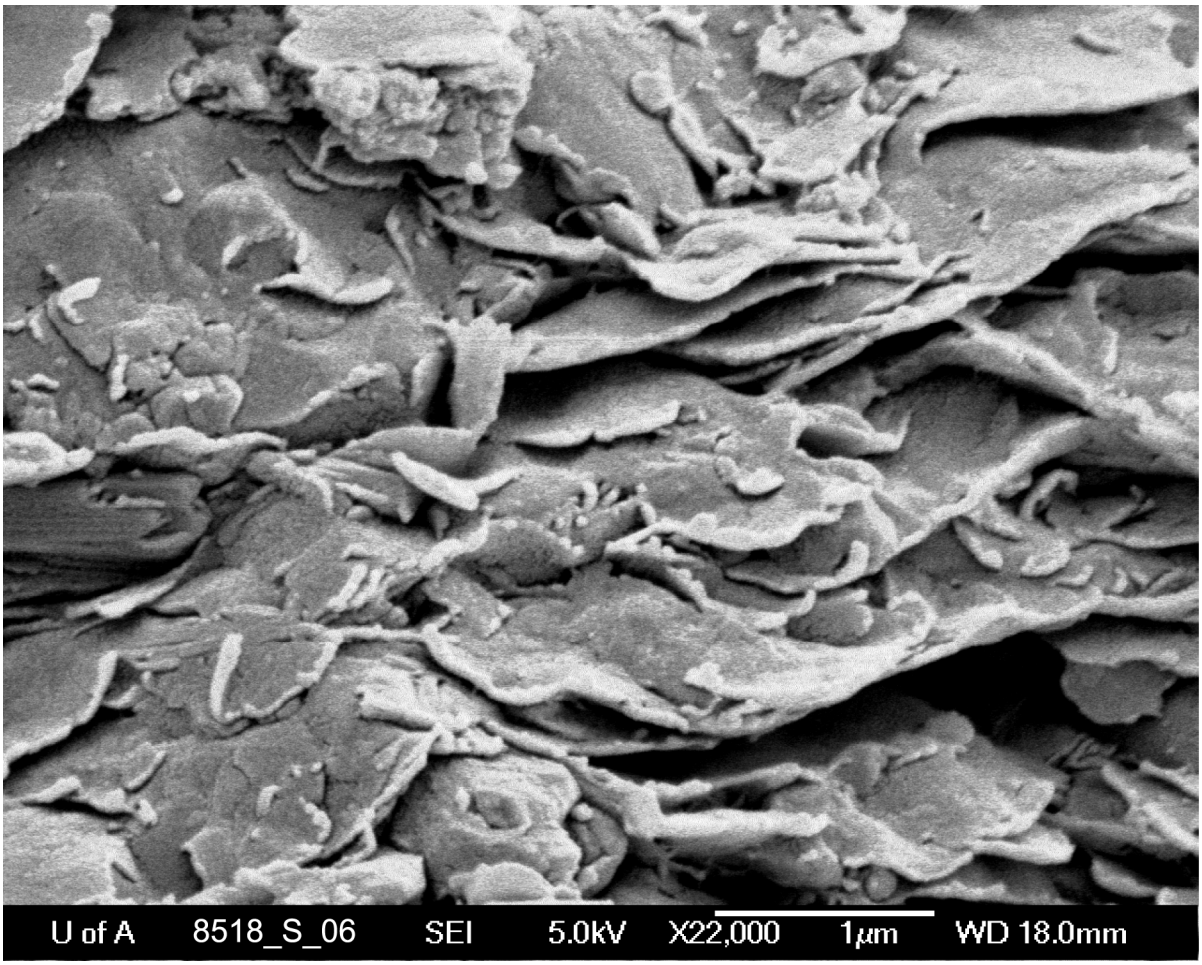


Image 8518_S_6 shows overlapping single-domain clay sheets, many with a curvilinear upturned edge. The tops of the sheets show very few pores, so vertical fluid migration is limited relative to lateral migration but may still occur through a relatively tortuous pathway. Contrast this view of clay fabric with the more open fabric of images 8542_S_15, 14 and 16.

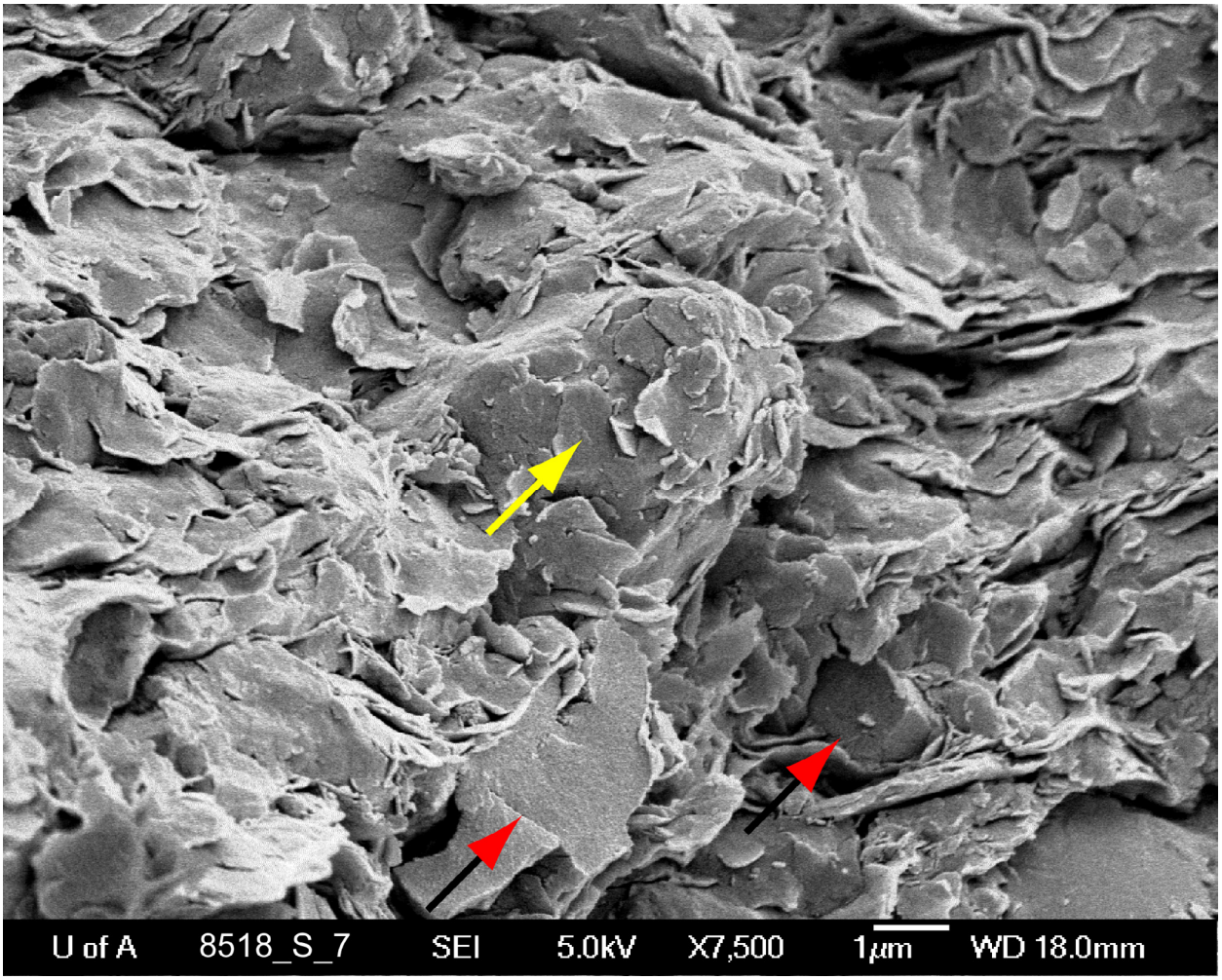


Image 8518_S_7 shows a ‘cardhouse’ structure with many overlapping clay plates and microporosity largely at plate edges. Quartz crystals with relatively fresh fracture faces are shown by the red arrows. The large bulge in the centre (yellow arrow) may identify a silt grain covered with clay.

c)

Image	Magnification
8518_S_8	2500×
8518_S_9	15000×

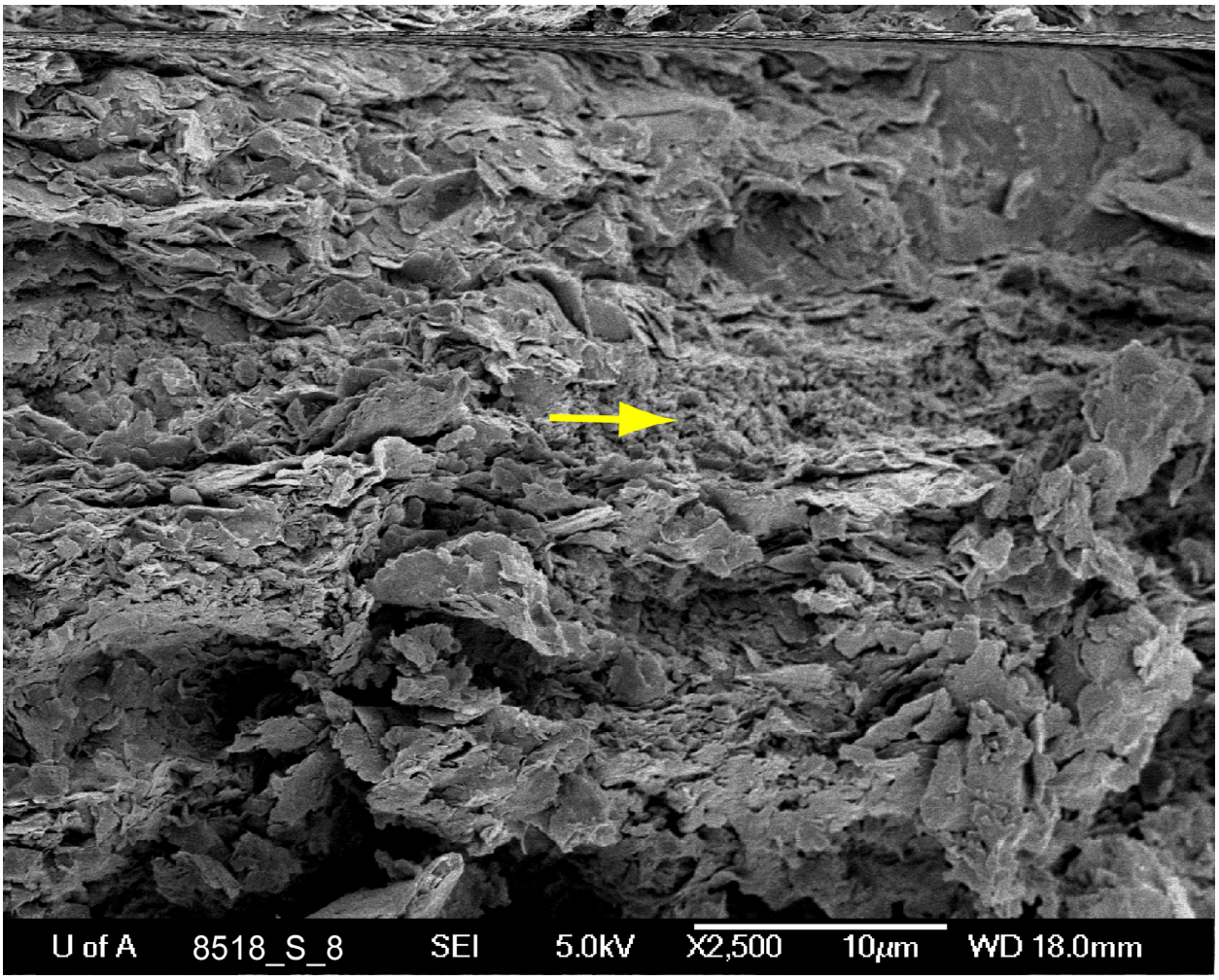


Image 8542_S_8 exhibits similar features to the previous three images but has a lamina with a curious texture (yellow arrow). There is an abundance of loose clay sheets in the foreground of the image.

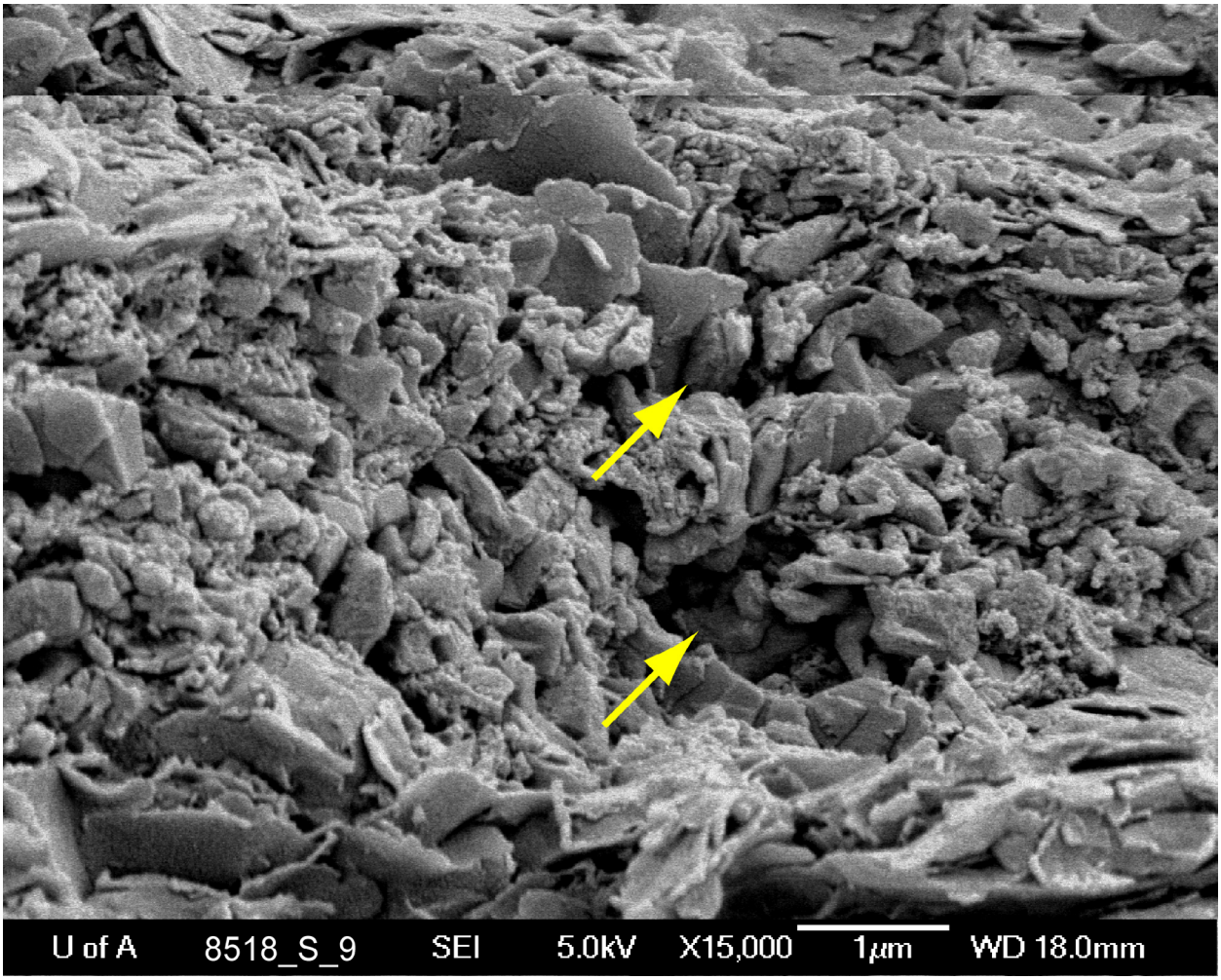


Image 8518_S_9, a high-magnification view of the previous image near the yellow arrow, shows what appear to be coarse and fine crystals of quartz overgrowth. There are hints of clay- to fine silt–sized grains, as seen near the tips of the yellow arrows. It is tempting to suggest that this is a porous lamina of very fine silt with an abundance of quartz overgrowth crystals; however, we cannot be certain of the texture or mineralogy of the particles underlying the surface features. The thickness of the layer is 2–3 μm.

d)

Image	Magnification
8518_S_10	700×
8518_S_11	2700×
8518_S_12	7500×

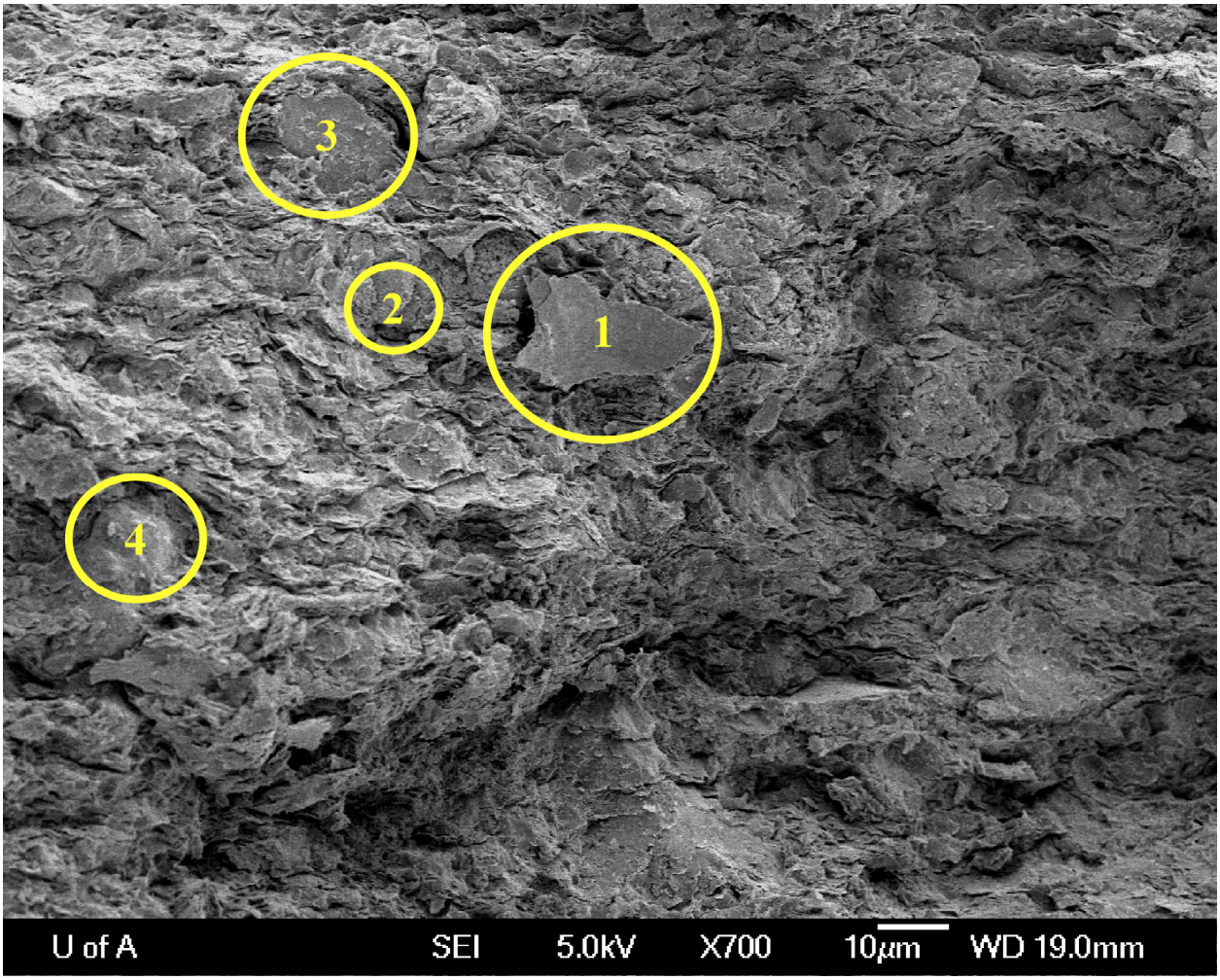


Image 8518_S_10 shows a moderate degree of porosity in a slightly silty clay-rich sample. An EDX analysis of the thin plated, 'arrowhead shaped' mineral (also shown in image 8518_S_11) suggests that it is mica, although the EDX analysis was not definitive. The depth of penetration of the EDX beam is about 2 µm, which is much thicker than the thin plated mineral; hence, the analysis picks up chemical elements of the underlying sediment.

Composition	**Image**	**ID on Image**
mica? (EDX 3S_002)	8518_S_10	1
dolomite (EDX 3S_003)	8518_S_10	2
aluminum silicate (EDX 3S_006)	8518_S_10	3
potassium feldspar (EDX 3S_007)	8518_S_10	4

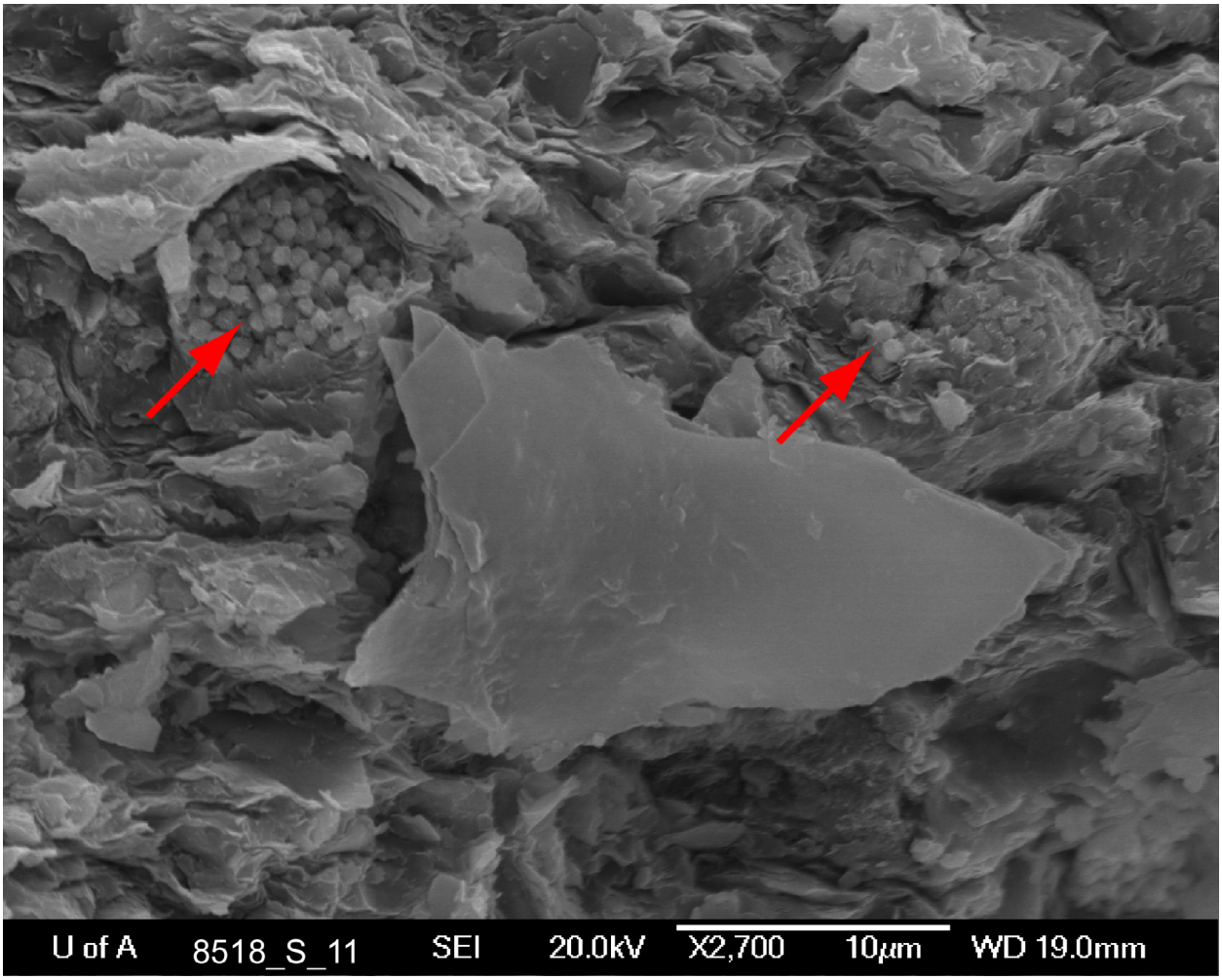


Image 8518_S_11 is a close-up view of the ‘mica’ in the previous image. Framboidal pyrite is clearly visible in the upper left and right quadrants (red arrows).

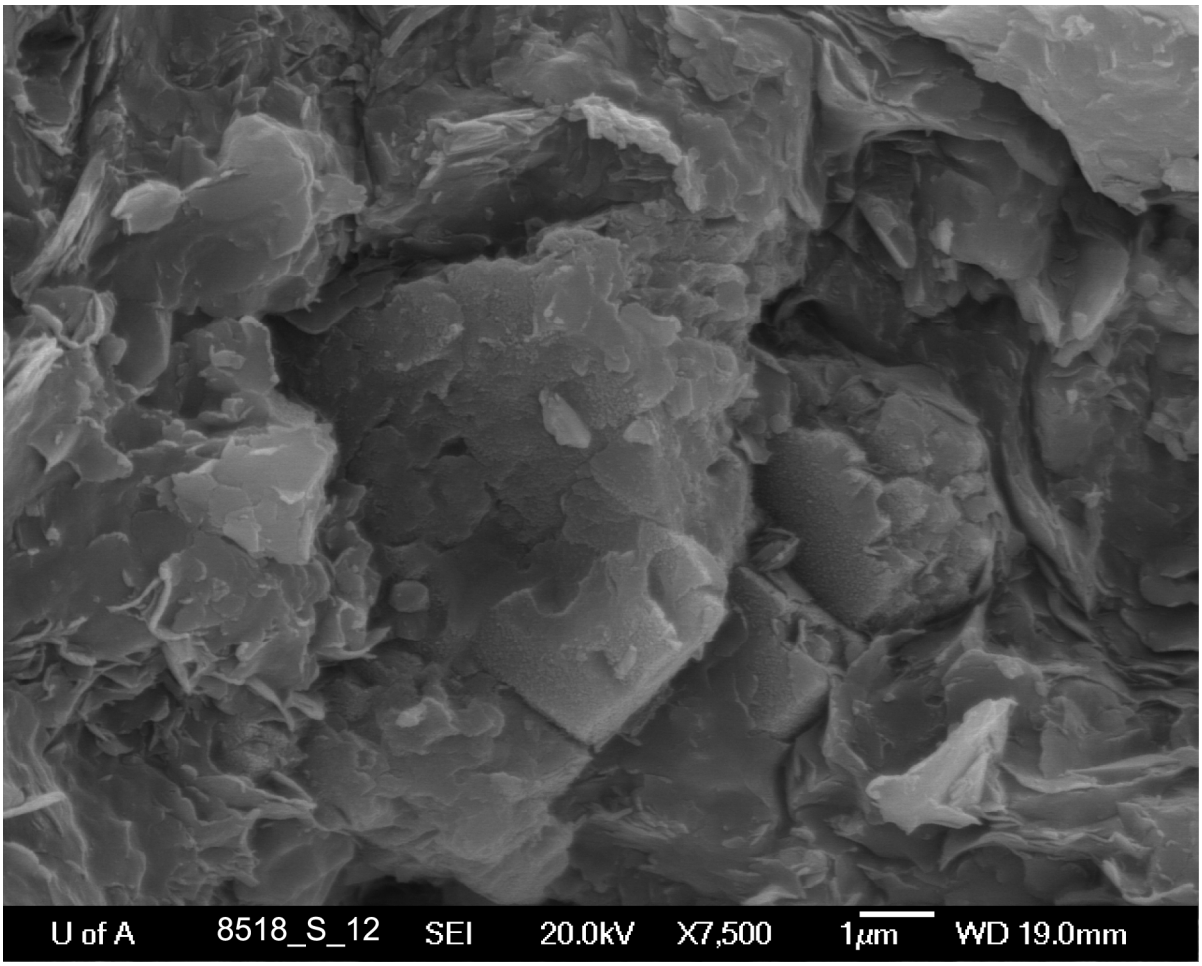


Image 8518_S_12 was taken just off the left edge of the previous image. The grain near the centre with euhedral edges is dolomite, according to EDX analysis (3S_003). The clay particles here have a multidomain character, as defined by Bennett et al. (1990). The sample reflects an agglomeration of multidomain clay minerals. The particles appear to be silt-sized grains composed dominantly of clay minerals, although a few silt particles and dolomite crystals may be observed along with the clay. The sample may represent redeposition of mudstone particles or grains from shelf to basin.

e)

Image	Magnification
8518_S_13	750×
8518_S_14	40000×
8518_S_15	30000×

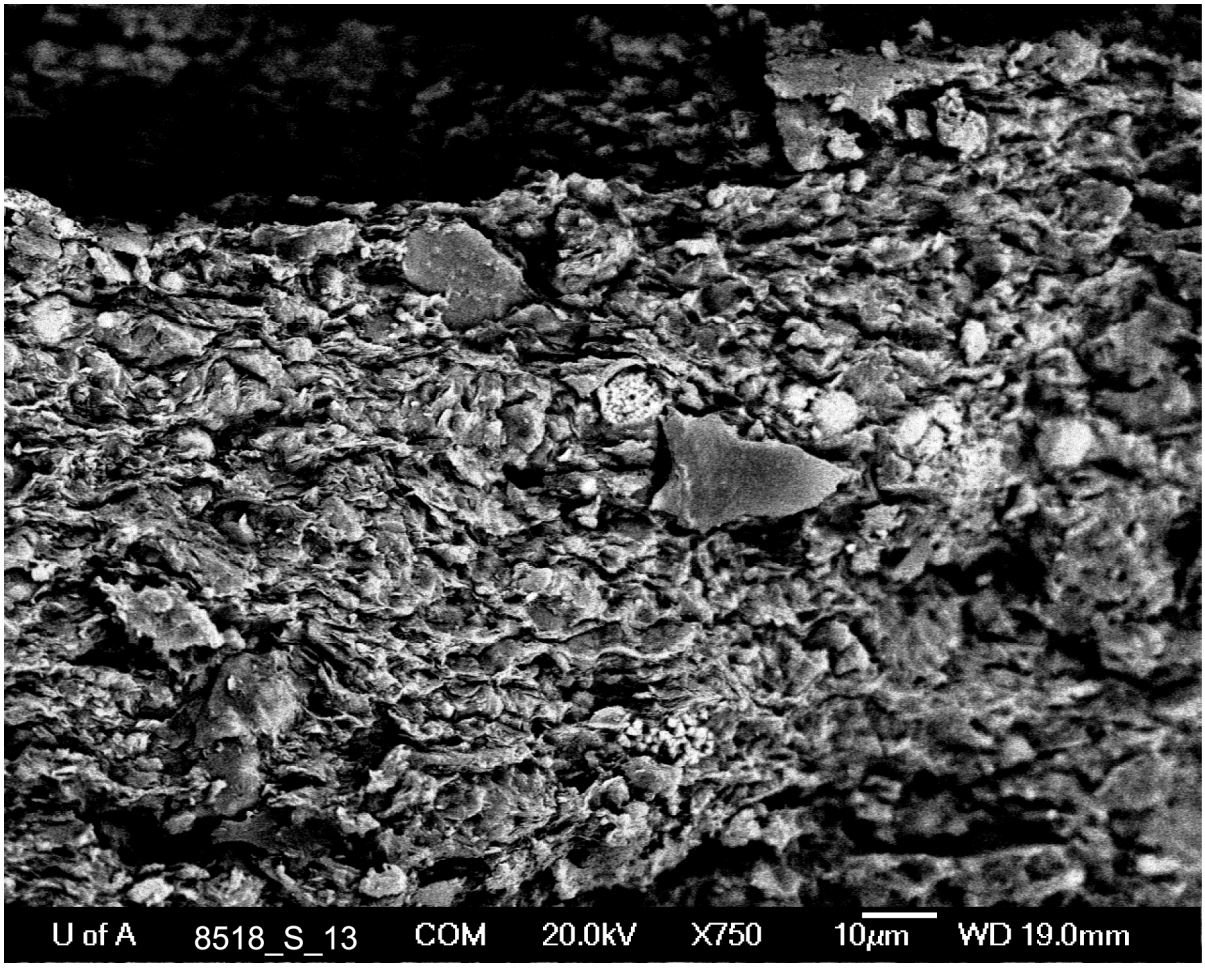
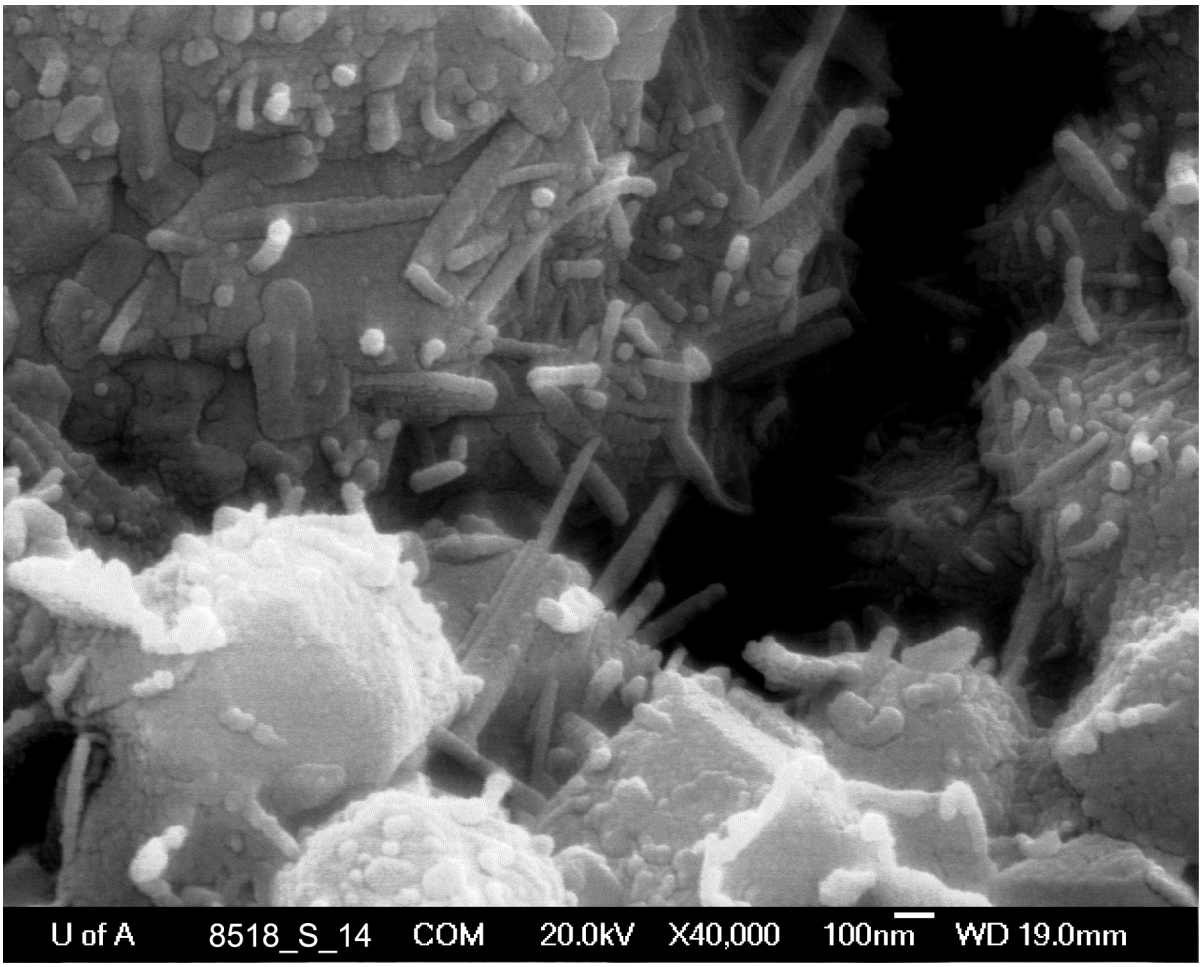
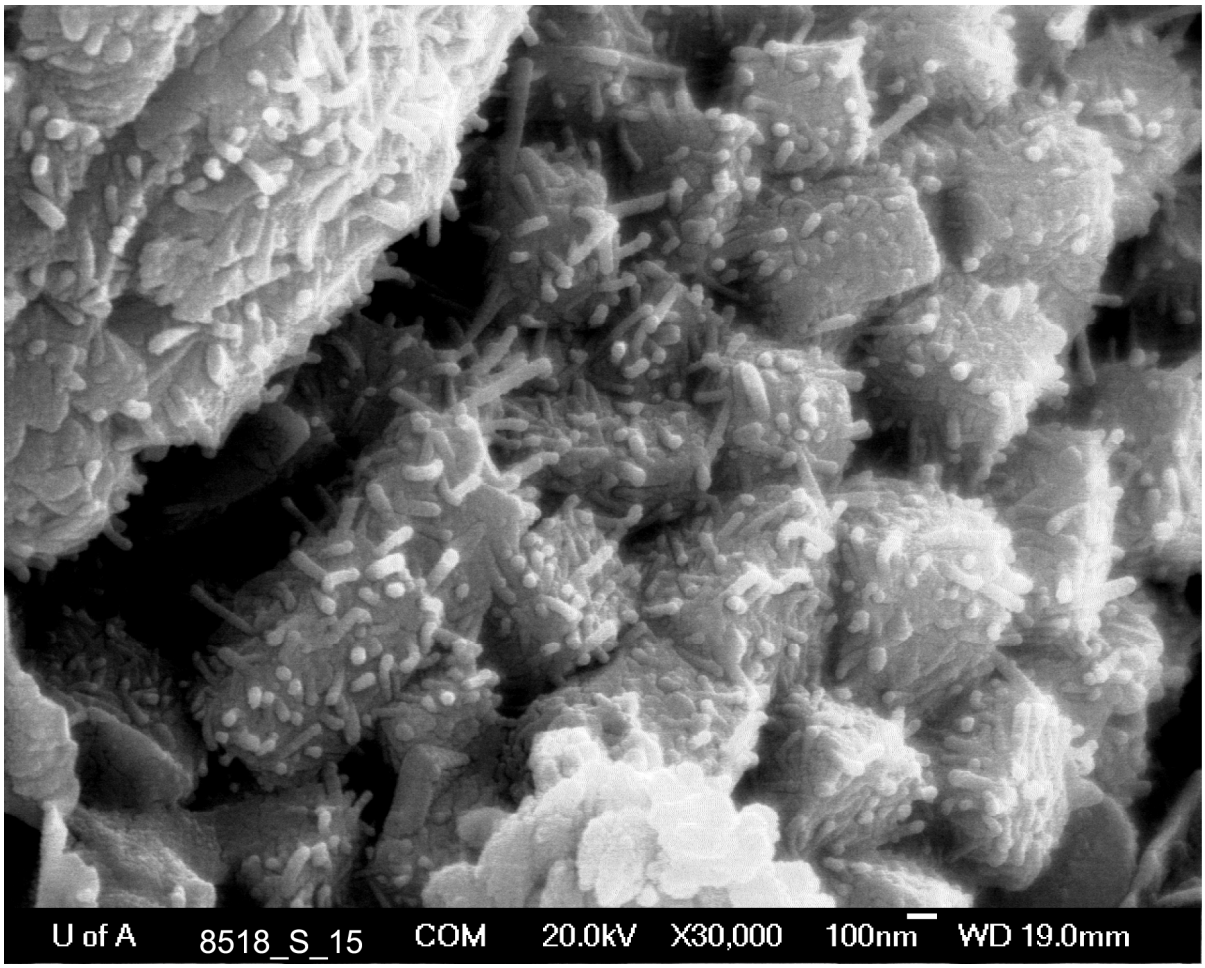


Photo 8518_S_13 is a backscattered image of 8518_S_10, showing the proportion of heavy (white areas) to light (dark areas) minerals; however, the sample was double coated with gold prior to SEM analysis, so the contrast is not as effective as with one coating. Nonetheless, large clusters of pyrite (most likely) show up quite well as bright white areas. The large pyrite cluster seen on the left side of a previous image (8518_S_11) forms the basis of the next two images.

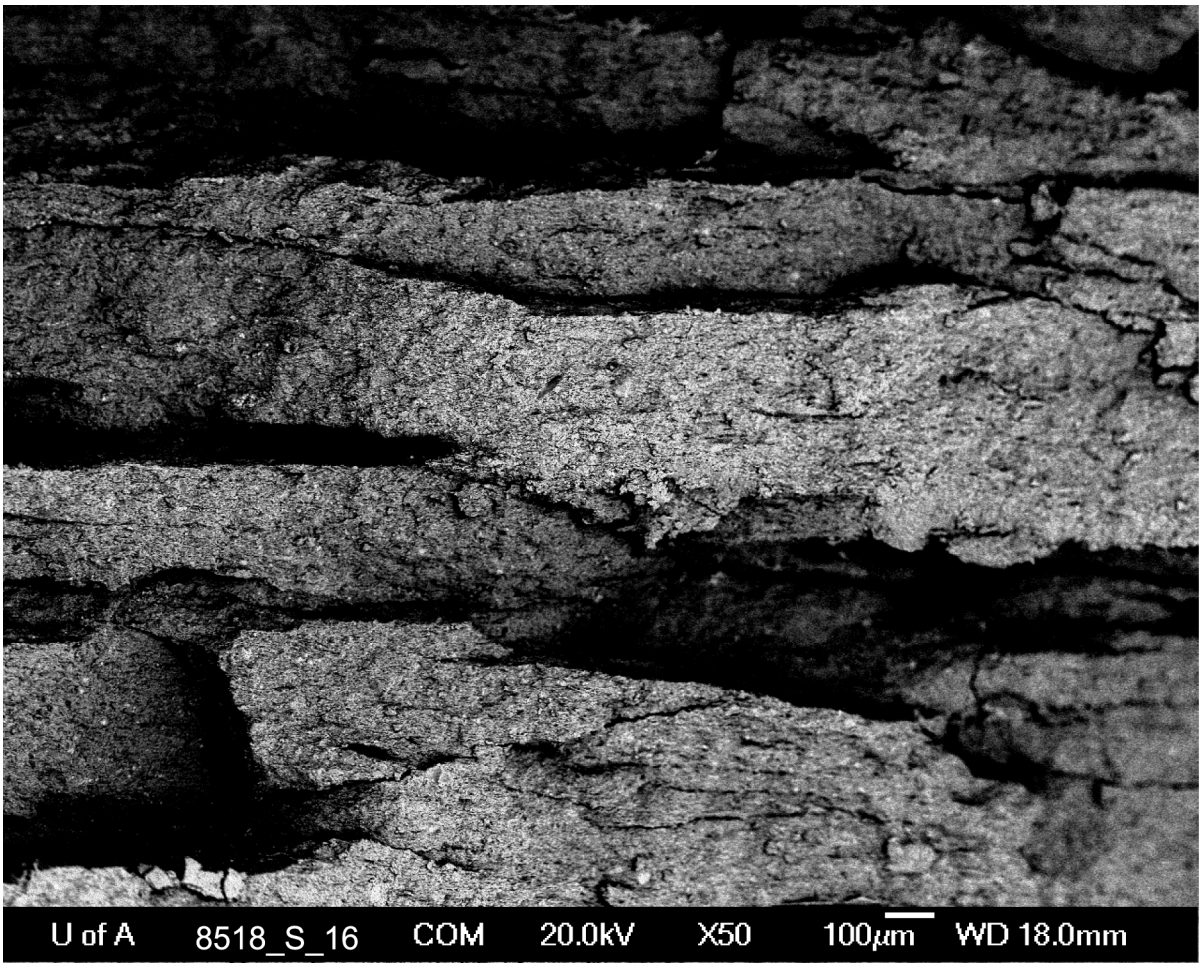
The next two images (8518_S_14, 8518_S_15) are a very high magnification of pyrite clusters. The cylindrical particles that protrude from and lie on top of the pyrite crystals are a few hundred nanometres in length and less than 100 nm in diameter. An EDX analysis (EDX 3S_008) of the particles is swamped by the chemistry of the underlying pyrite, so the mineralogy is unknown. The origin (microbial?) of the particles is also unknown.




U of A 8518_S_15 COM 20.0kV X30,000 100nm WD 19.0mm

f)

Image	Magnification
8518_S_16	50×

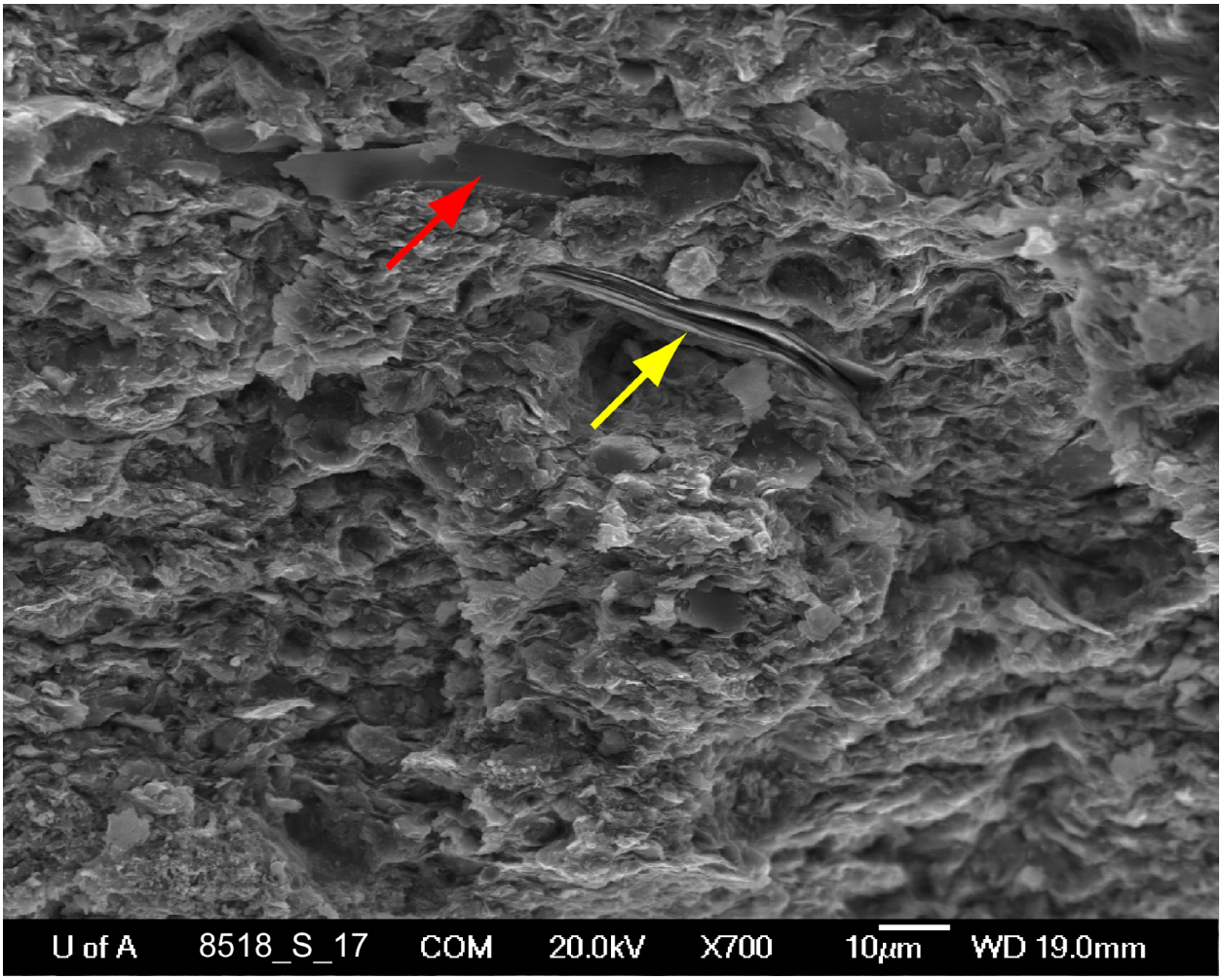


This is a backscattered image of the lower centre of image 8518_S_1, showing an abundance of pyrite and perhaps other heavy minerals, although pyrite is the most likely interpretation.

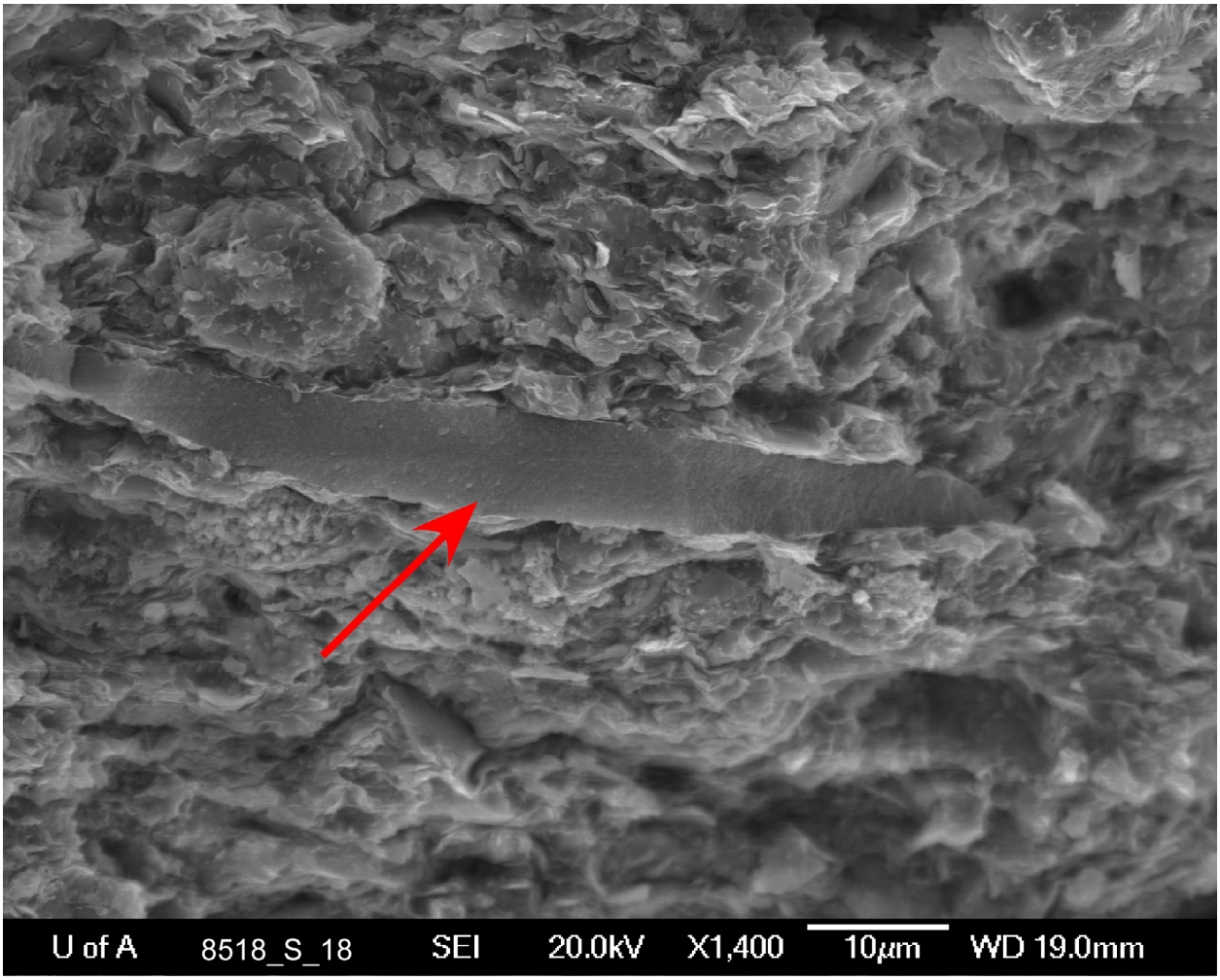
g)

Image	Magnification
8518_S_17	700×
8518_S_18	1400×
8518_S_19	27×
8518_S_20	140×

The last four images of this sample show a few interesting features that were identified as we perused the sample.



The red arrow in image 8518_S_17 is identified as organic material (possibly coal or bitumen), as the EDX analysis suggested that the material is amorphous. The feature identified by the yellow arrow could not be identified using EDX because the orientation of the plates of the material prevented a good reading.



The red arrow in image 8518_S_18 identifies a feature that has a cross-sectional moon shape, suggesting that it may be a fossil of some sort. EDX analysis of the material reveals that it is calcium phosphate (EDX 3S_009).

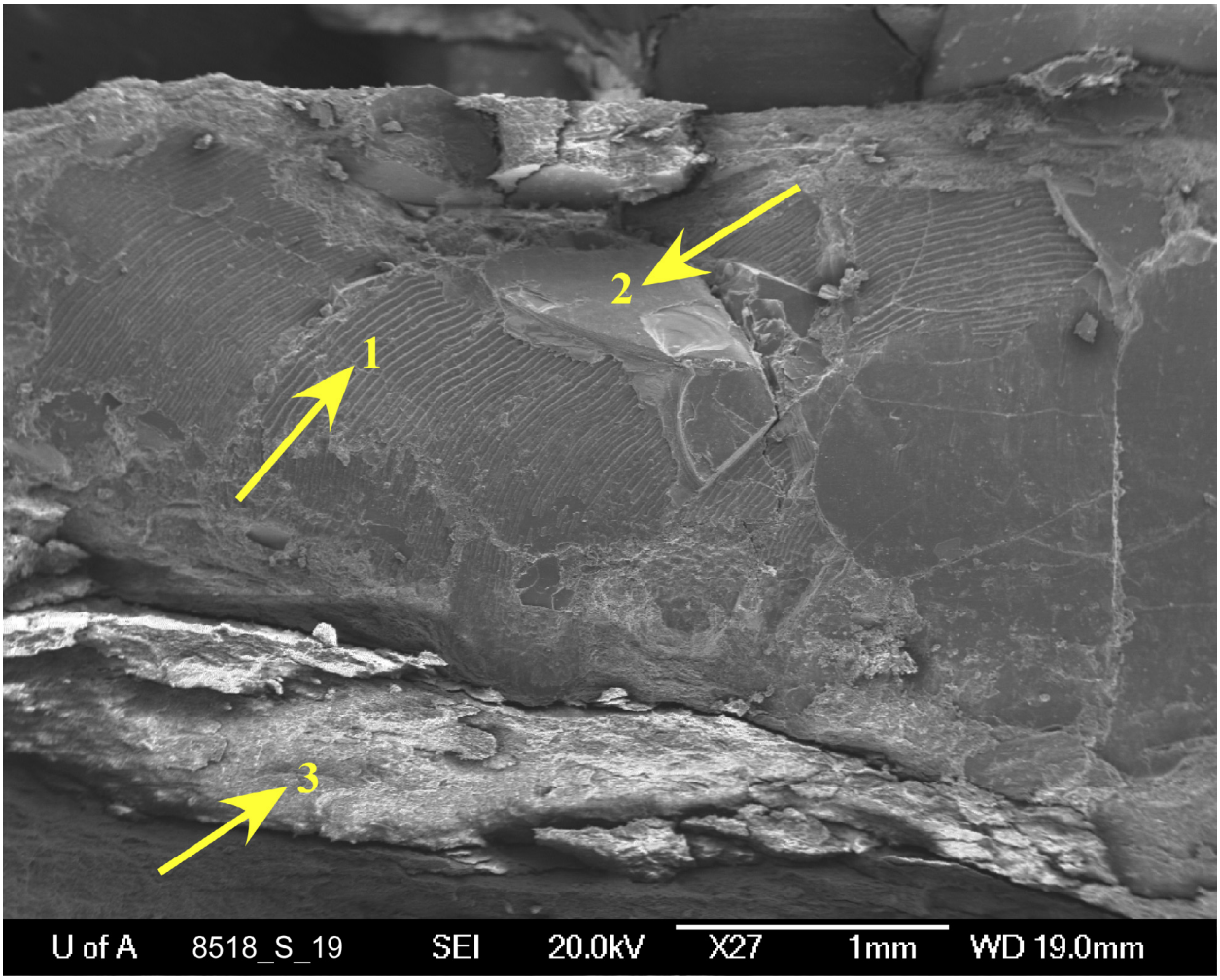
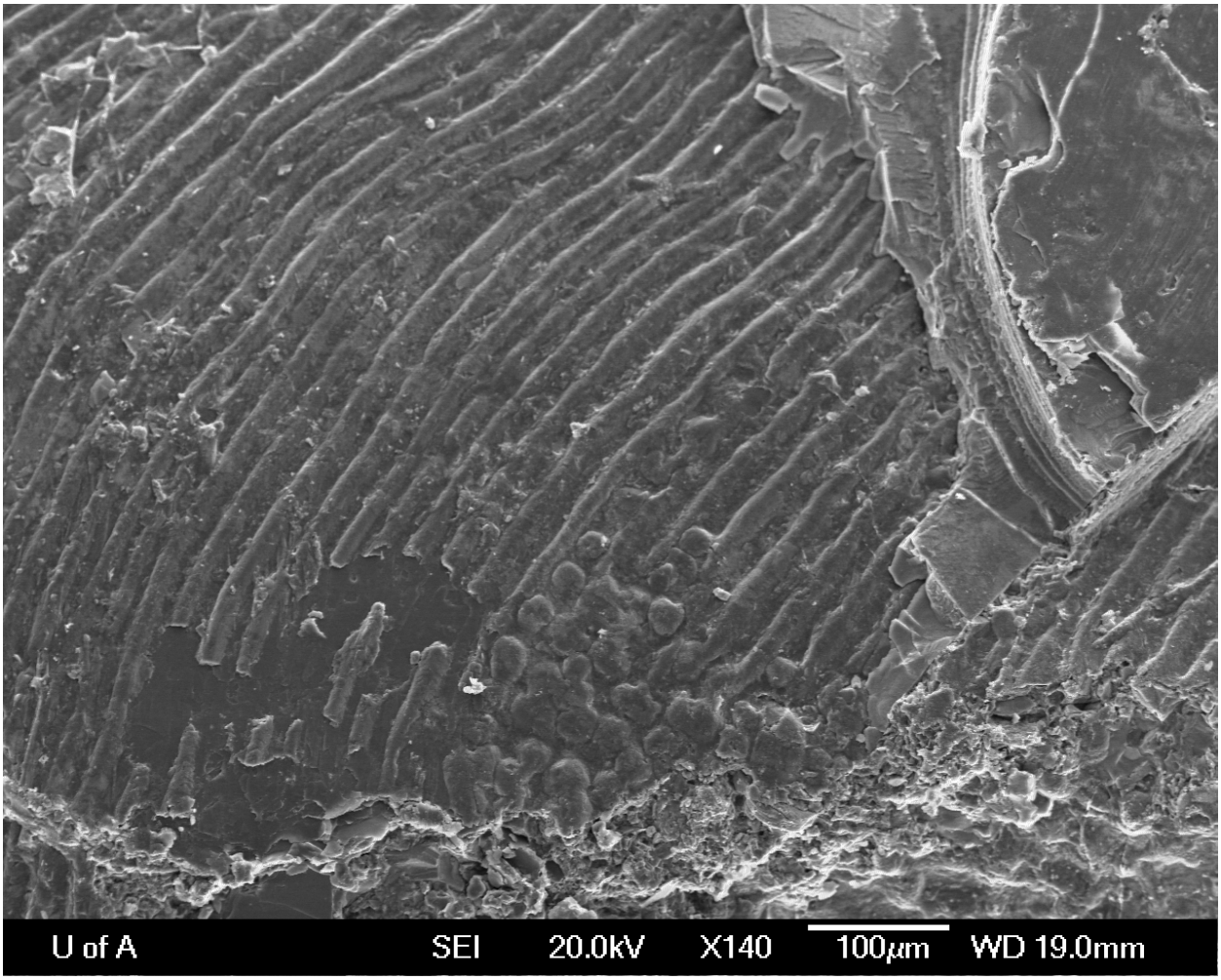


Image 8518_S_19 is a mould of a fossil. The concentric rings in this image and 8518_S_20 resemble growth rings. EDX analysis of 8518_S_19, taken at point 1, indicates calcite (the mould); at point 2, the material is calcium phosphate (remnants of the fossil). Point 3 on the image was found by EDX to be magnesium silicate.

EDX for sample 8519:

Composition	Image	ID on Image
calcite, fossil mould? (EDX 3S_011)	8518_S_19	1
magnesium silicate (EDX 3S_012)	8518_S_19	3
calcium phosphate fossil (EDX 3S_013)	8518_S_19	2



Close-up view of the fossil mold.

Environmental Scanning Electron Microscope (ESEM) Images

3) Upper Colorado Group, possible Cardium Fm. equivalent, Sample 8542; 100/06-36-049-05W4/00, 410 m core depth

a)

Image	Magnification
8542_6	35×

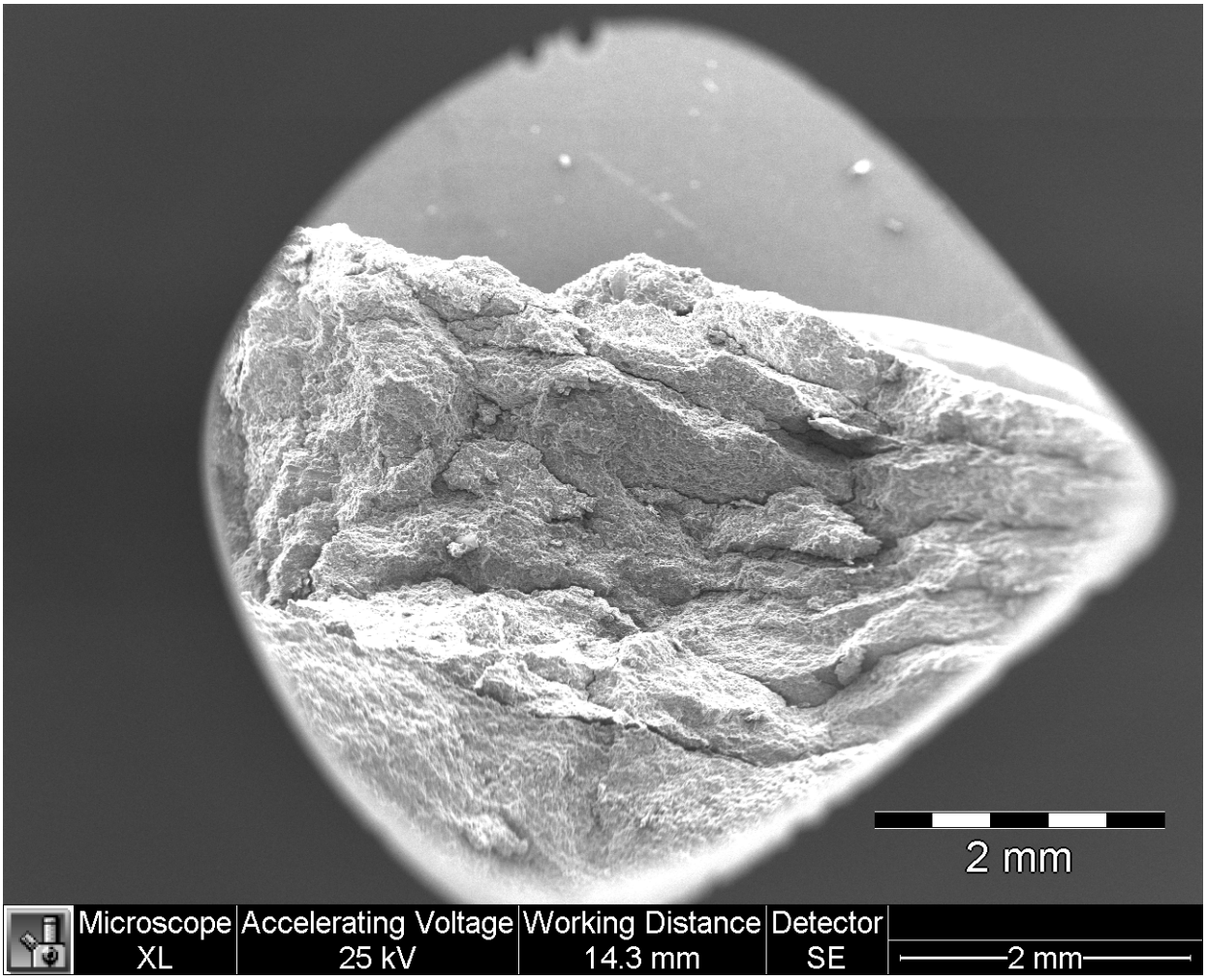


Image 8542_6 is an overview photo of the sample. The next five images that were taken near the centre of the image. The trend of bedding is approximately east-northeast.

b)

Image	Magnification
8542_7	1200×

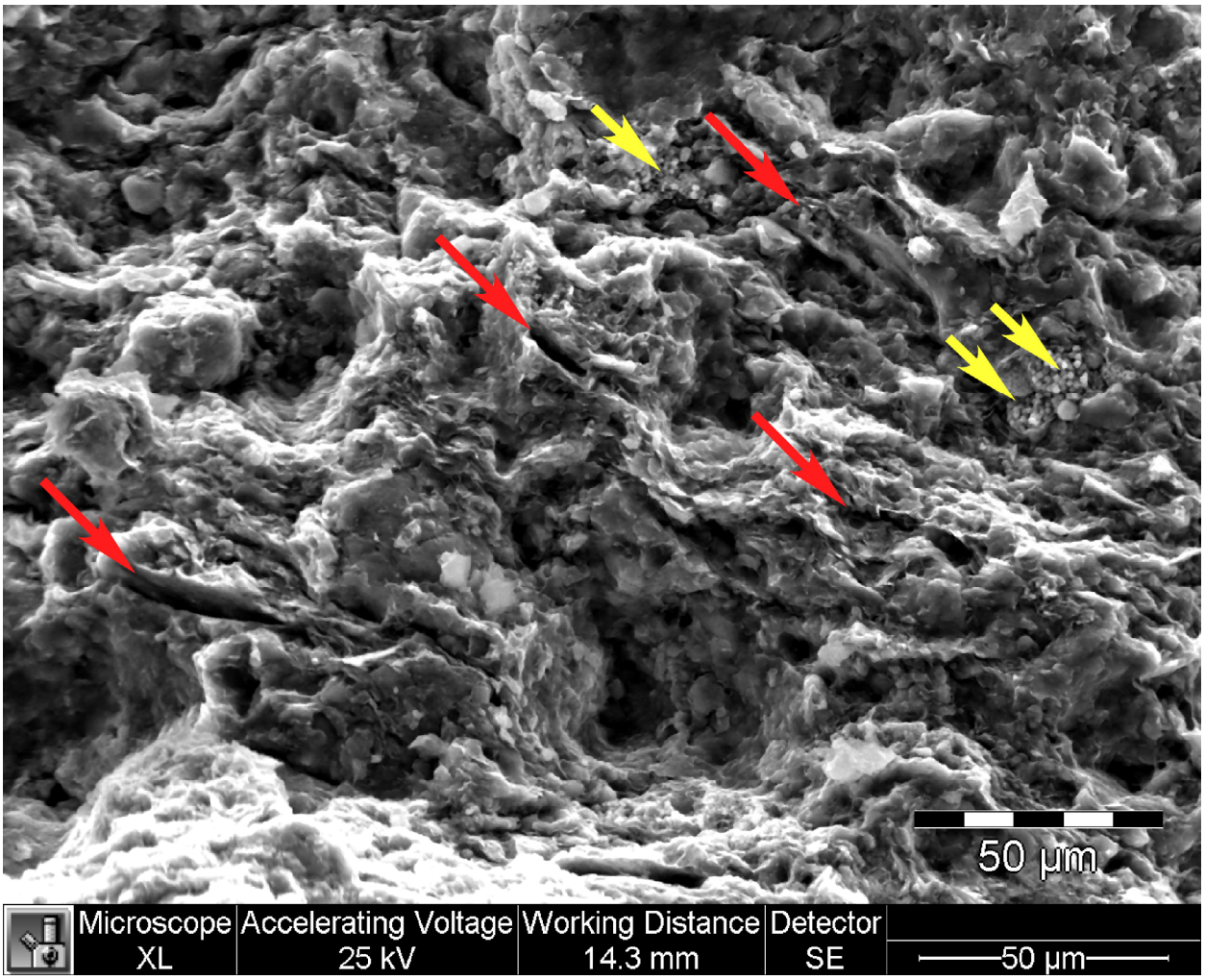
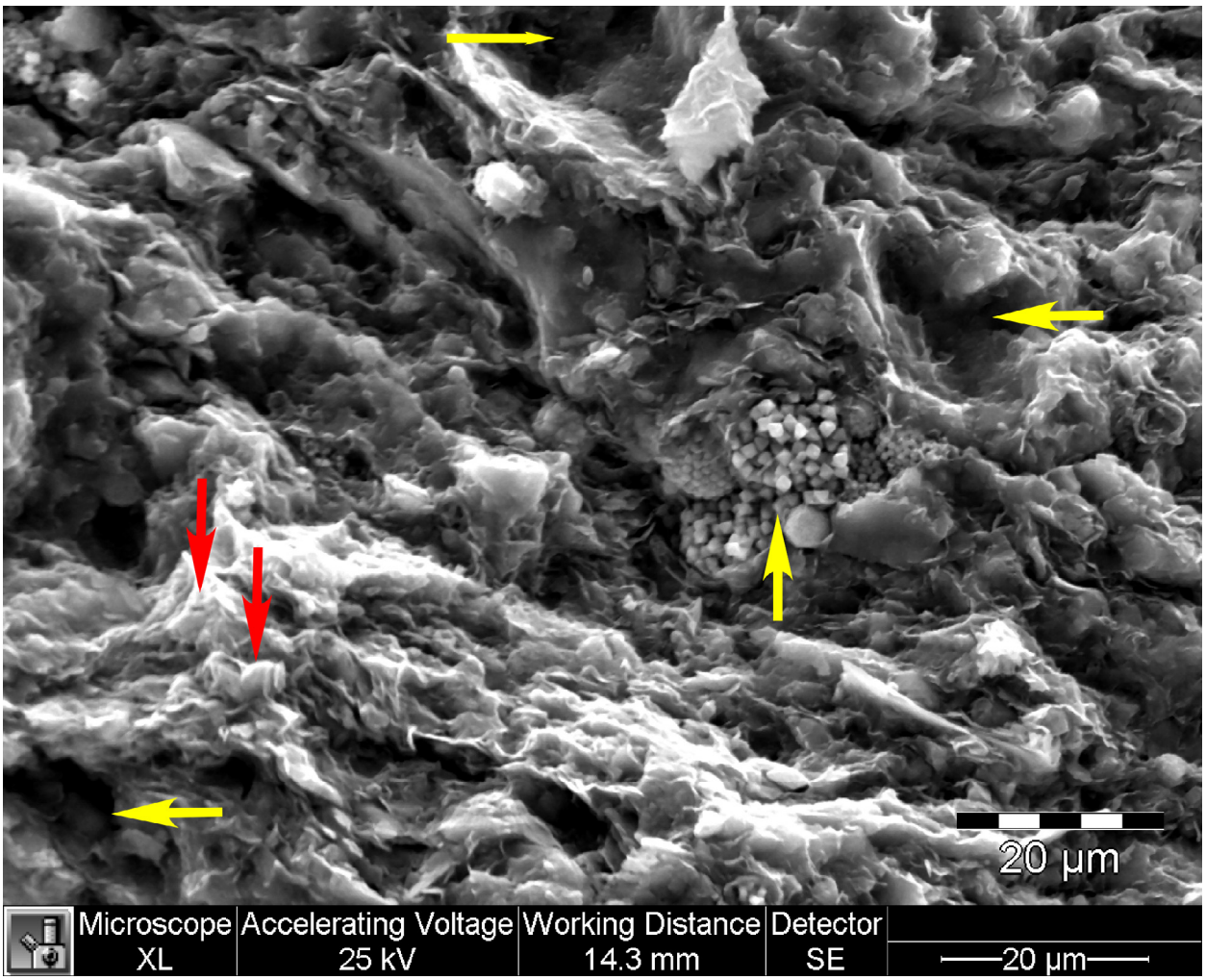


Image 8542_7 shows very silty shale, where the silt is dispersed throughout the bed. There are numerous areas where silt grains appear to have been plucked (see next image). The tabular pores identified by red arrows are curious features. The upper red arrow shows a partially infilled tabular pore. At this level of magnification, the clays have a very weak preferred orientation (approximately southeast). Clay sheets appear to surround pockets of grains (see also next image). Small pyrite framboids are observed based on morphology and identified by yellow arrows. The next photo is taken near the framboidal pyrite in the right centre of the image.

c)

Image	Magnification
8542_8	2500×



The horizontal yellow arrows in image 8542_8 point to possible sites of plucked grains. The tabular pores are largely open, although some infilling can be seen in a few of them. The ESEM that we used is not able to do an EDX analysis, so mineralogical interpretation is based on experience and knowledge gained from other images. The downward-pointing red arrows in the lower left quadrant indicate what appears to be kaolinite booklets (right red arrow) and, likely, illite/smectite (left red arrow), which form the bulk of the clay in the image. The upward-pointing yellow arrow identifies framboidal pyrite that is highlighted in the next image.

d)

Image	Magnification
8542_9	10000×

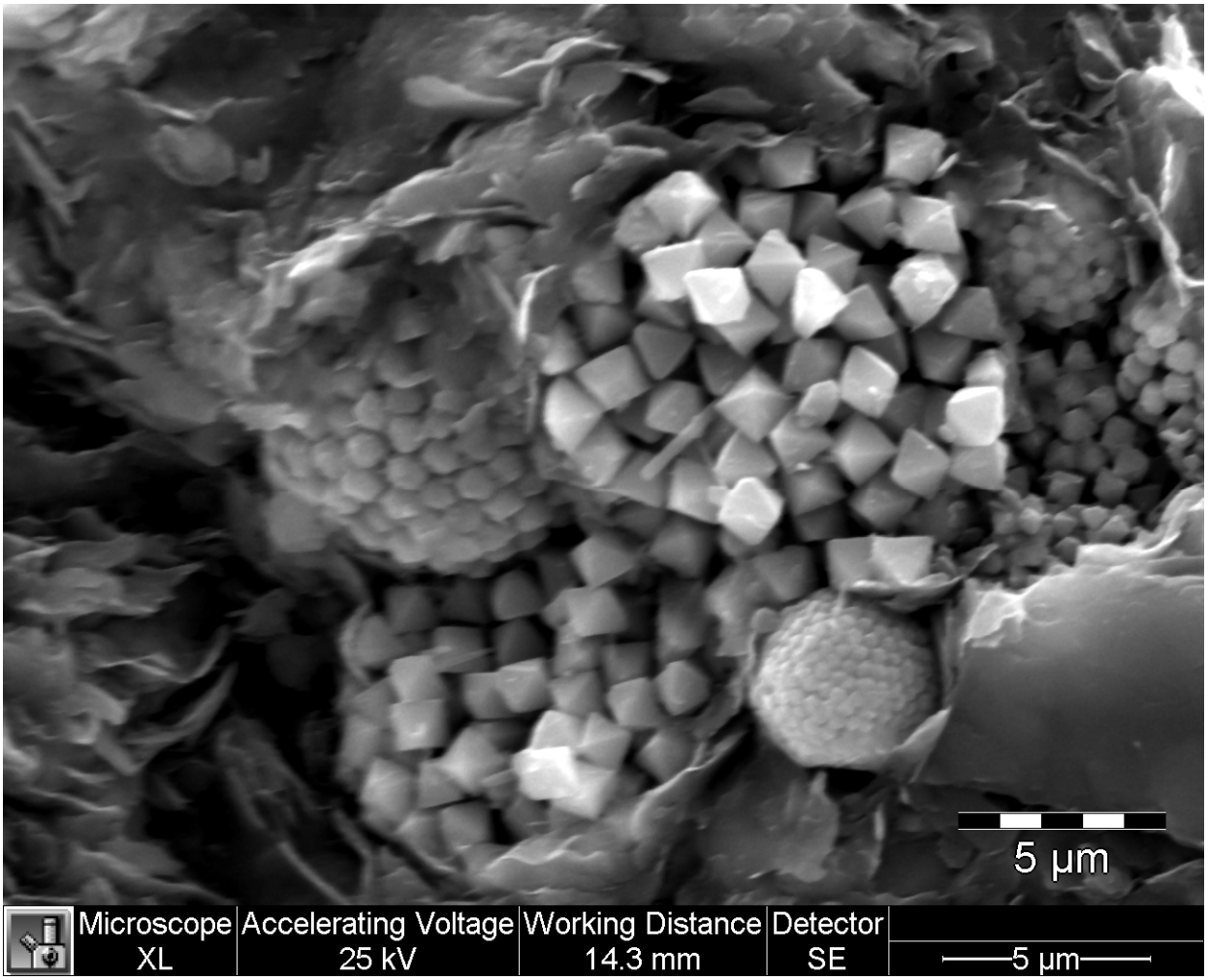


Image 8542_9 shows framboidal pyrite crystals of a variety of sizes, with each cluster wrapped in clay sheets. More important to this study is the fact that the clay to the left and above the pyrite crystals exhibits good porosity between clay sheets. As a general observation, pyrite clusters are most abundant in areas of open clay sheets.

e)

Image	Magnification
8542_10	10000×

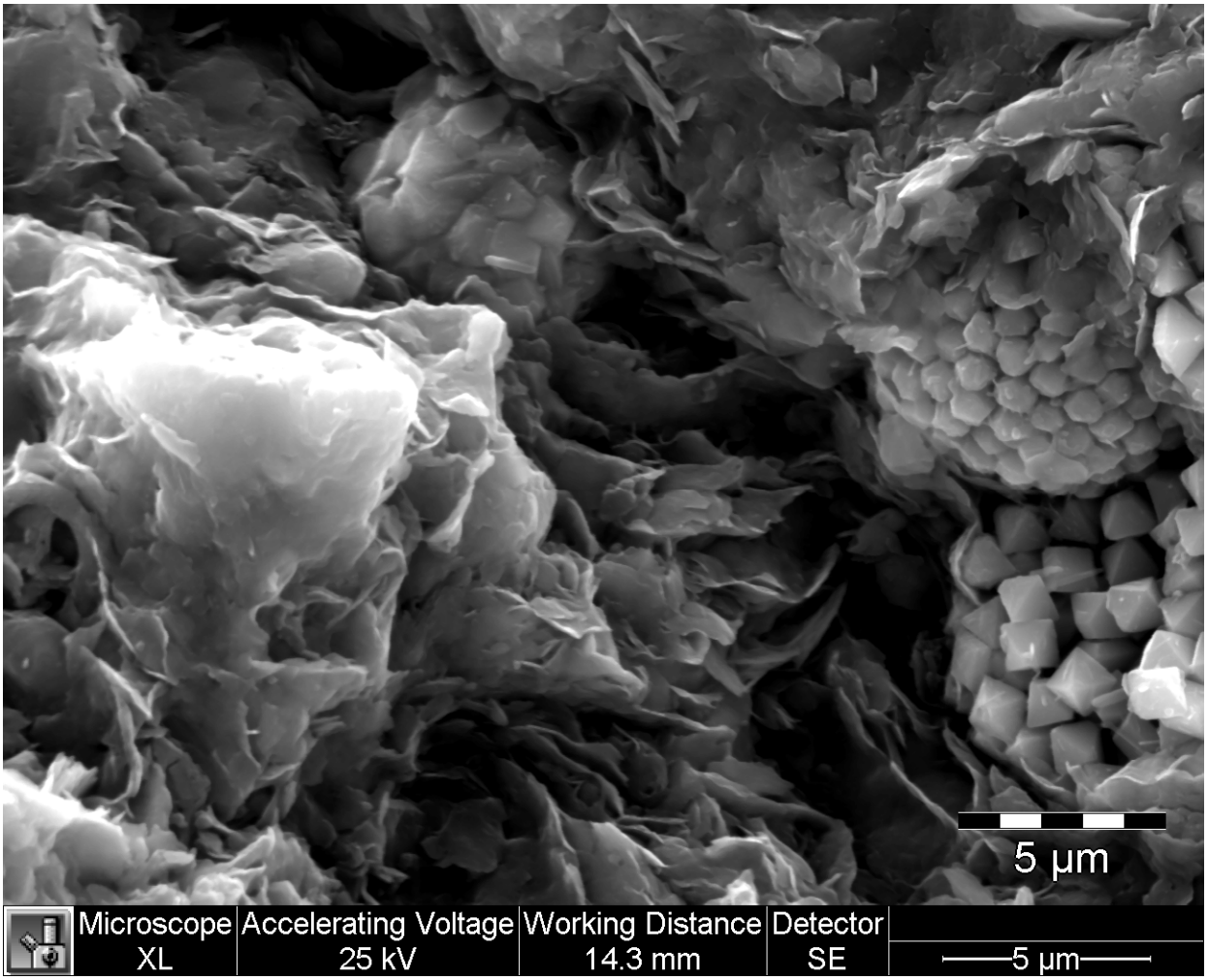


Image 8542_10 was taken just to the left of the framboidal pyrite in the previous image. The clay sheets are open, curvilinear and not stacked, nor do they have a consistent orientation at this scale.

f)

Image	Magnification
8542_11	35000×

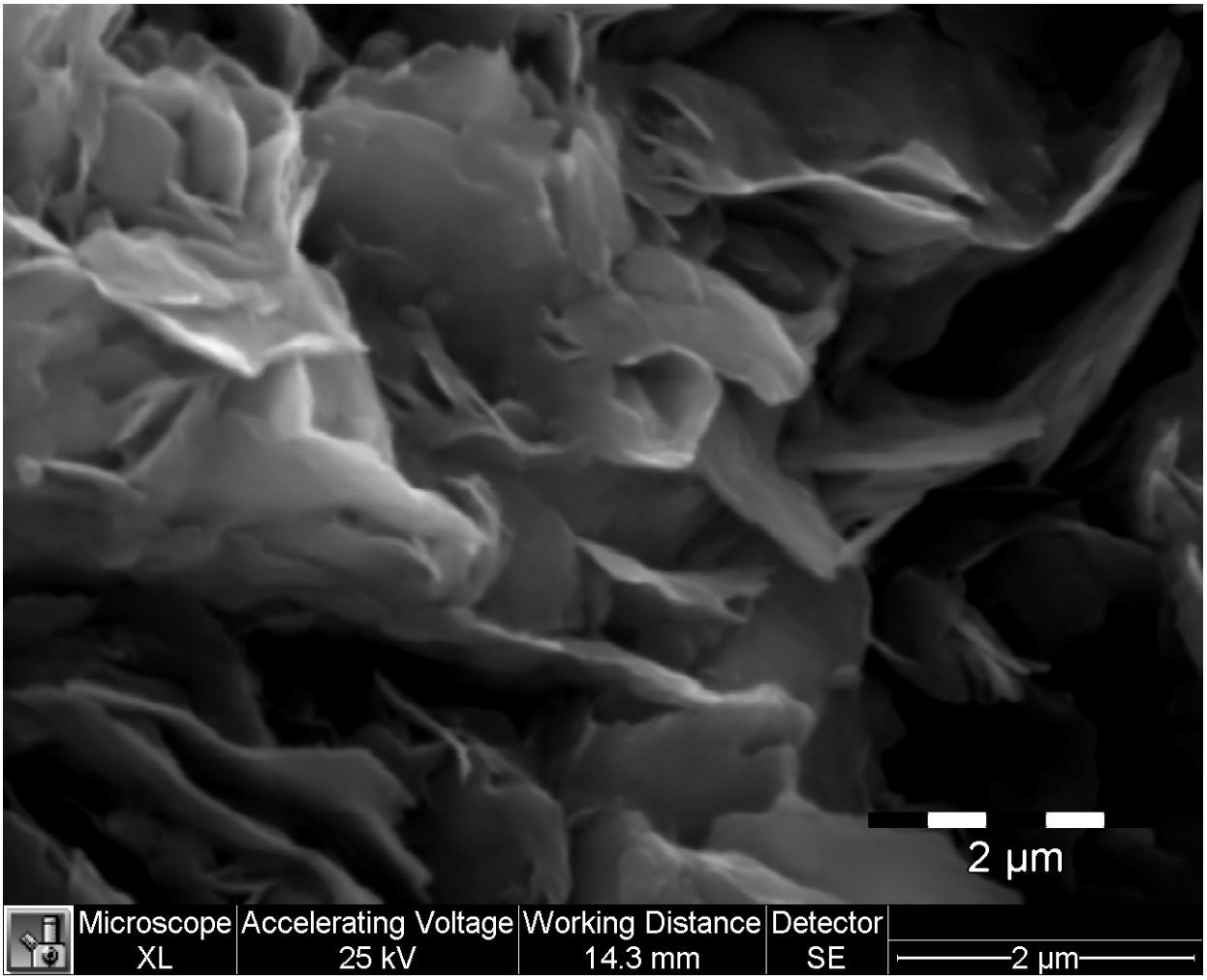


Image 8532_11 is a higher magnification of the porosity in the previous image. At this scale, individual clay plates are visible, with porosity evident between plates. The general trend of the basal axis of the plates is southeast; however, the plates in the northeast quadrant trend in the opposite direction, and many plates exhibit curvature. The clay type may be illite/smectite, although we cannot be absolutely certain.

g)

Image	Magnification
8542_1	est. 50×

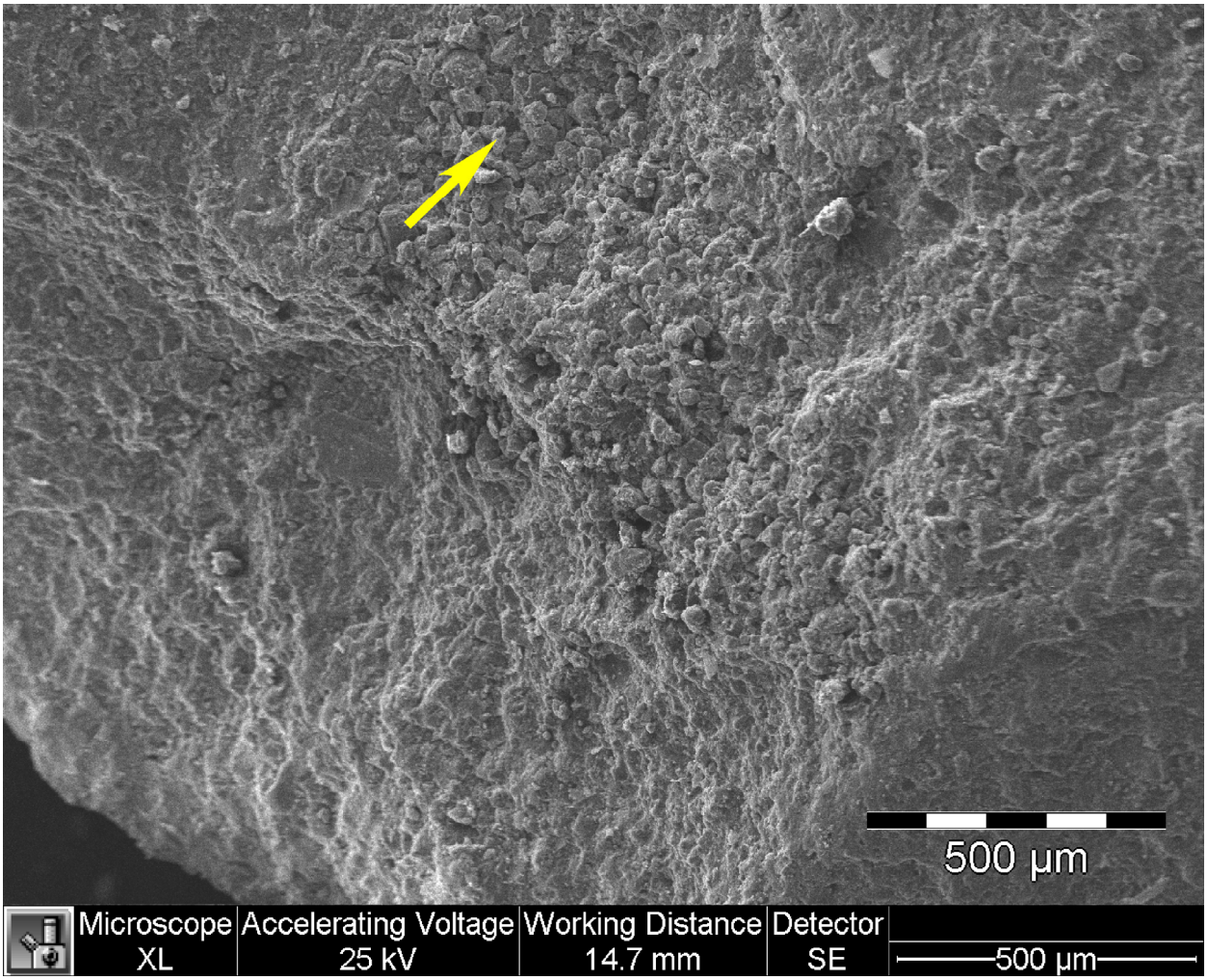


Image 8542_1, which was taken in a different area of the sample from the previous images, shows a discontinuous silt layer. The length of the layer in the image along a southeast axis is about 1.5 mm, and it is about 0.5 mm thick. The location of the next image is indicated by the yellow arrow.

h)

Image	Magnification
8542_3	est. 250×

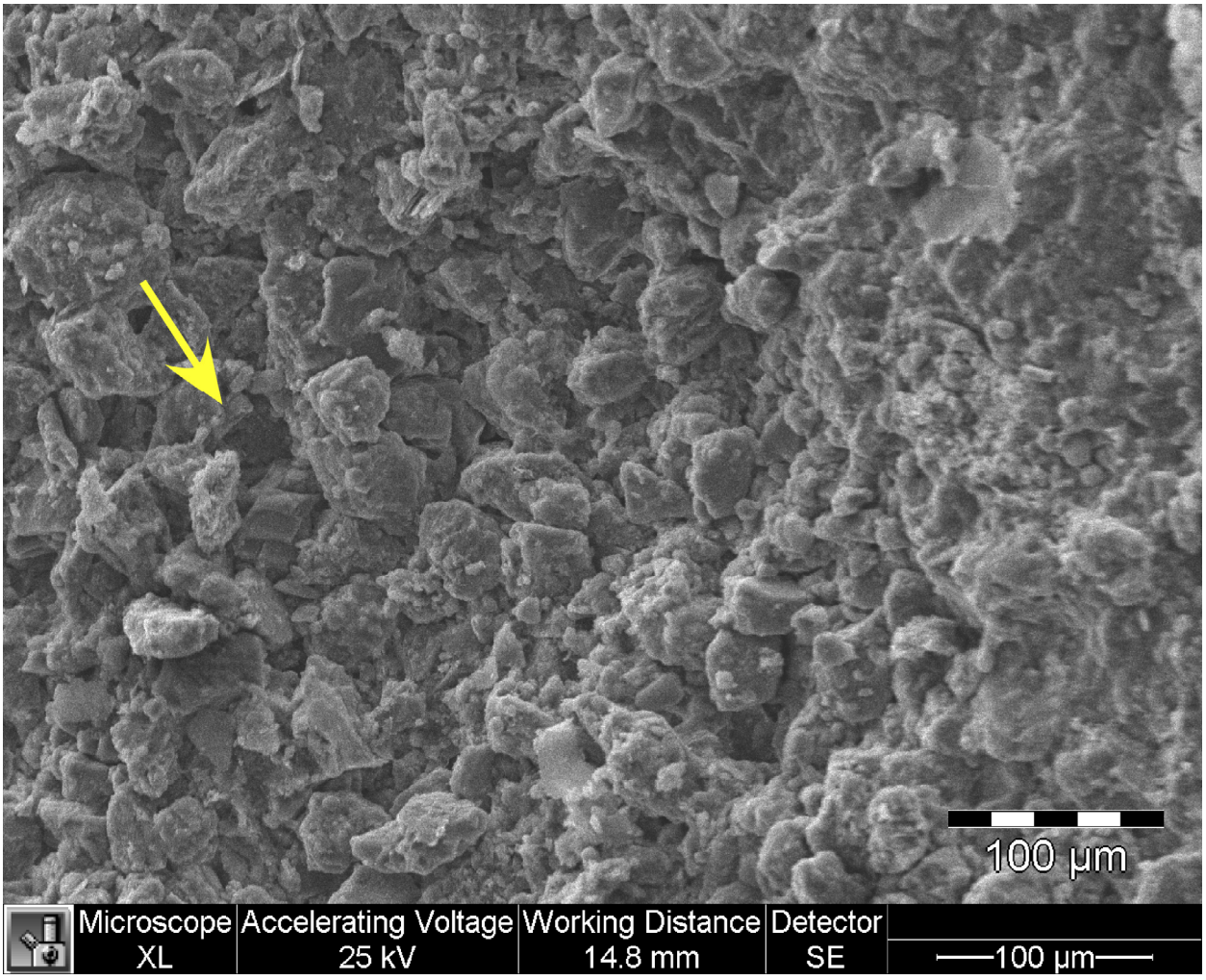


Image 8542_3 is a close-up of the silt layer in the previous image. The silt grains range from ~5 to ~60 µm. The grains are subrounded to subangular and reasonably well sorted. There is a general lack of cement, so the layer is moderately consolidated. Intergranular porosity is visible. The yellow arrow indicates the location of the next image.

i)

Image	Magnification
8542_4	1200×

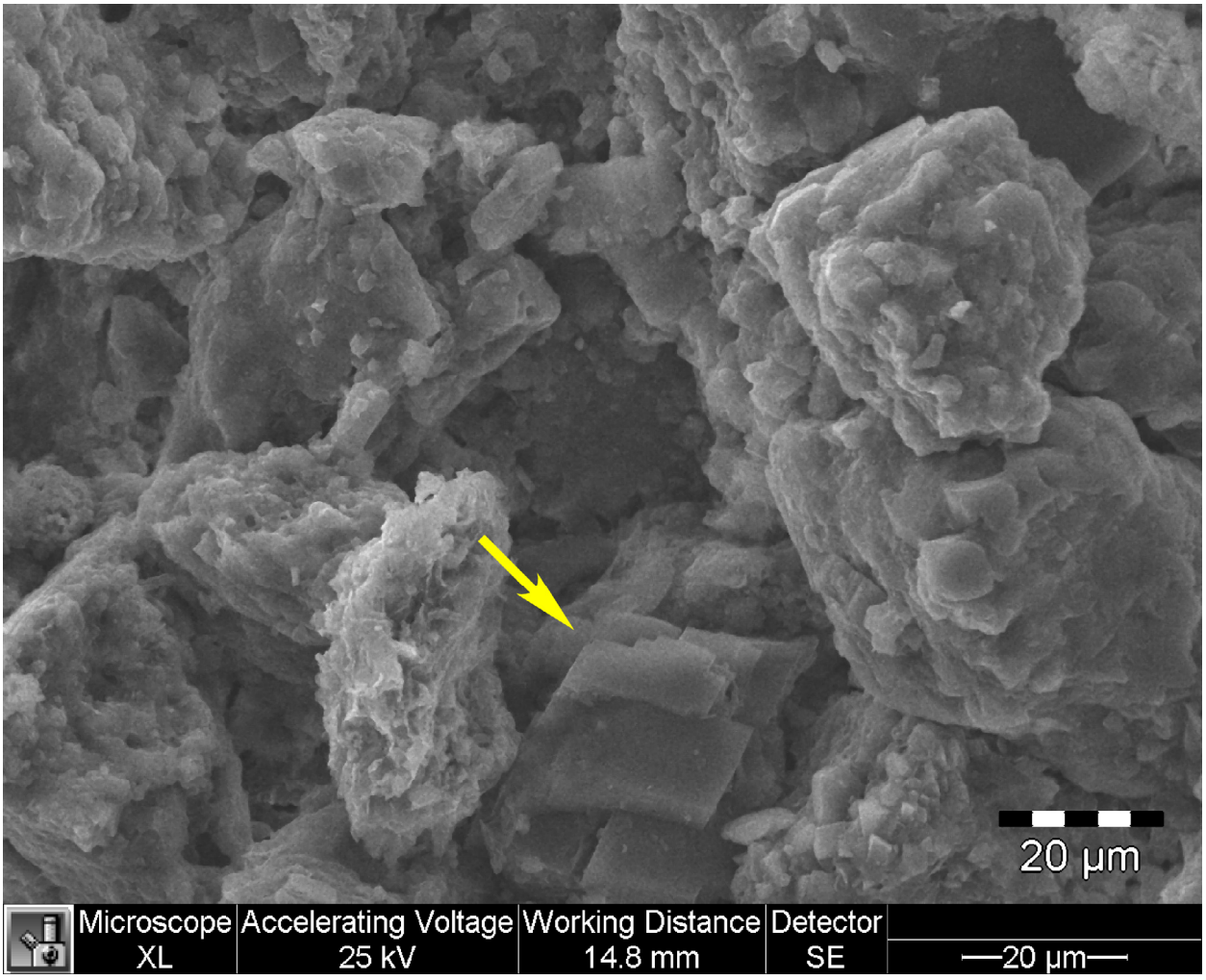


Image 8542_4 is a close-up view of a pore and the surrounding grains. The distinctly shaped crystal in the lower centre is ‘calcite’ (yellow arrow). The remainder of the large particles appear to be silt-sized grains that are partially coated with clay, quartz overgrowth and calcite. It is possible that some of these grains are an agglomeration of smaller particles rather than a single coated grain (see also the previous image).

4) Upper Colorado Group, Second Yellow Specks, Sample 8565_1-4; 100/13-34-047-20W4/00, 852.4 m core depth;

a)

Image	Magnification
8565_4	400×

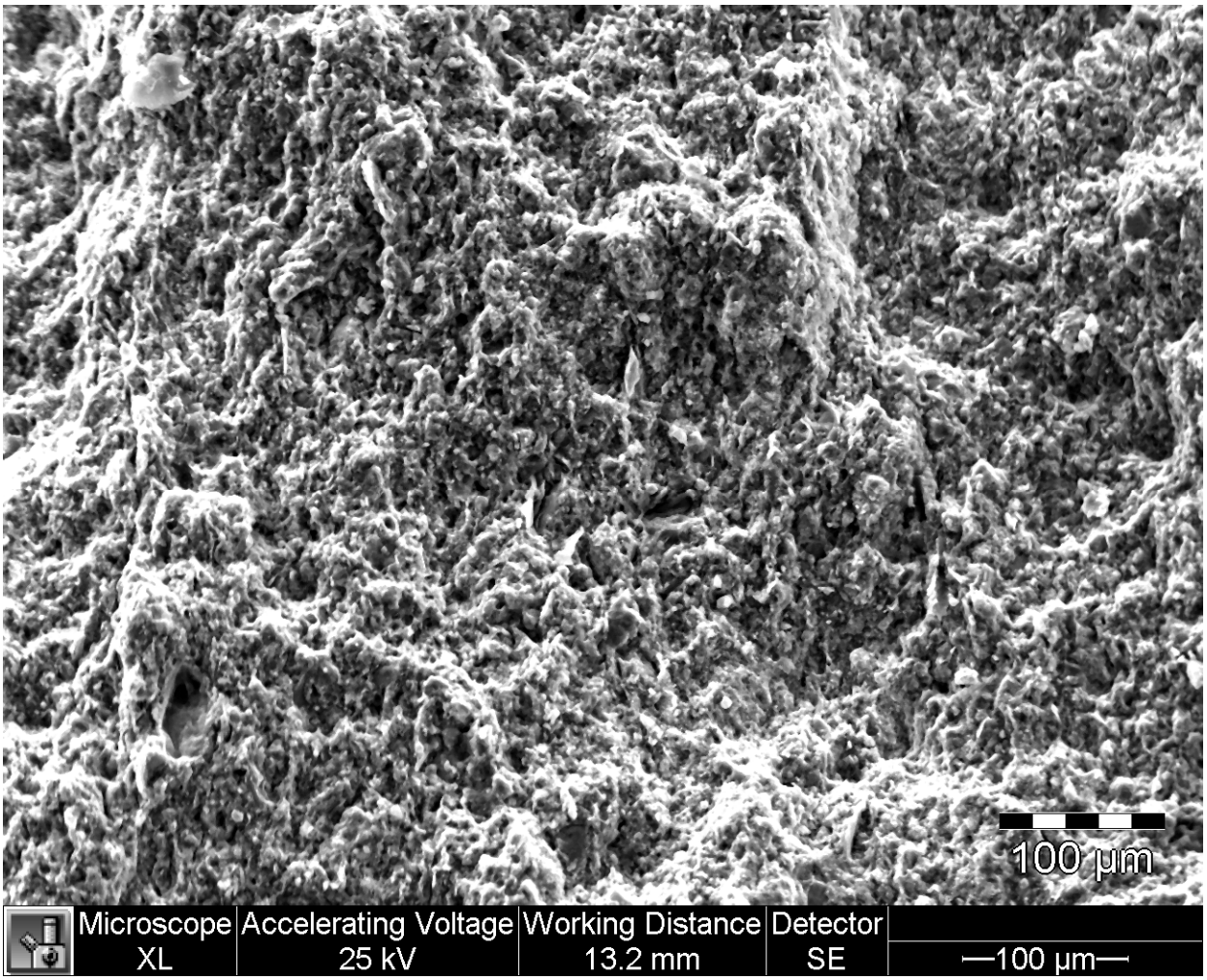


Image 8565_4 is a textural overview, indicating that there is no apparent bedding or preferred orientation visible at this scale.

b)

Image	Magnification
8565_3	2500×

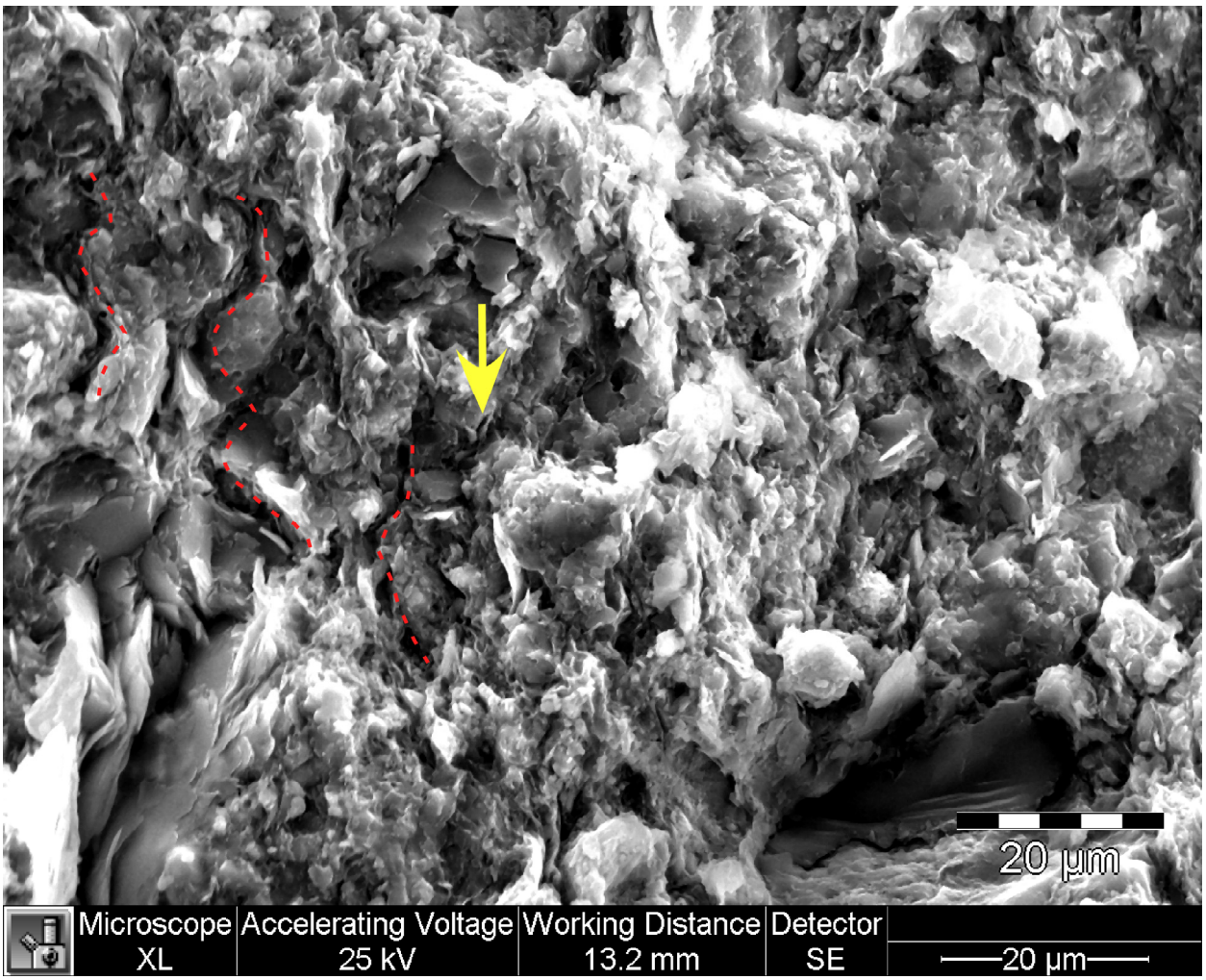
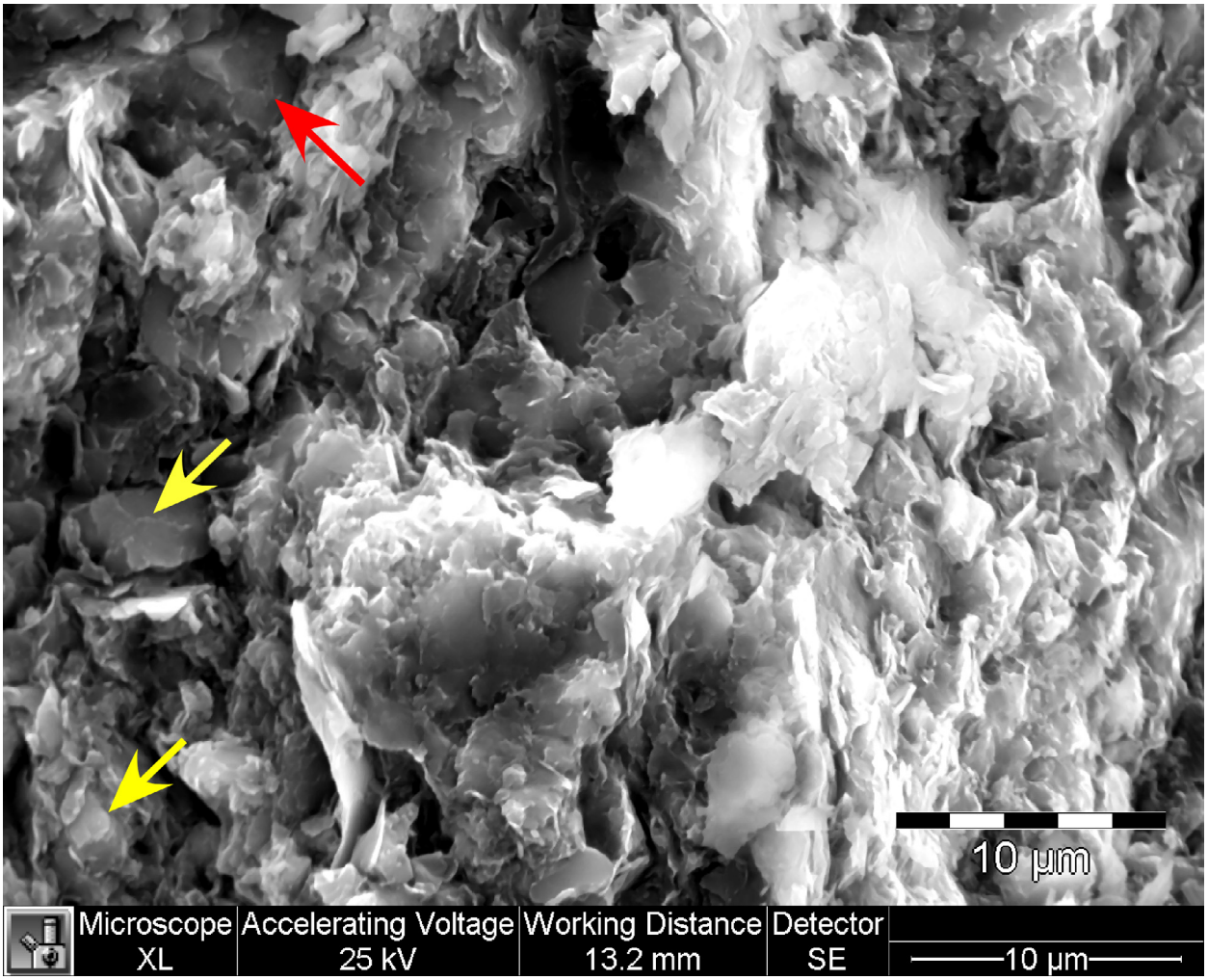


Image 8565_3 shows a chaotic morphology of clay plates with silt grains randomly dispersed throughout the image. Intergranular porosity is evident, with some odd sinuous-shaped porosity (unloading fractures?) indicated by the dashed red lines. The yellow arrow is the location of the next image.

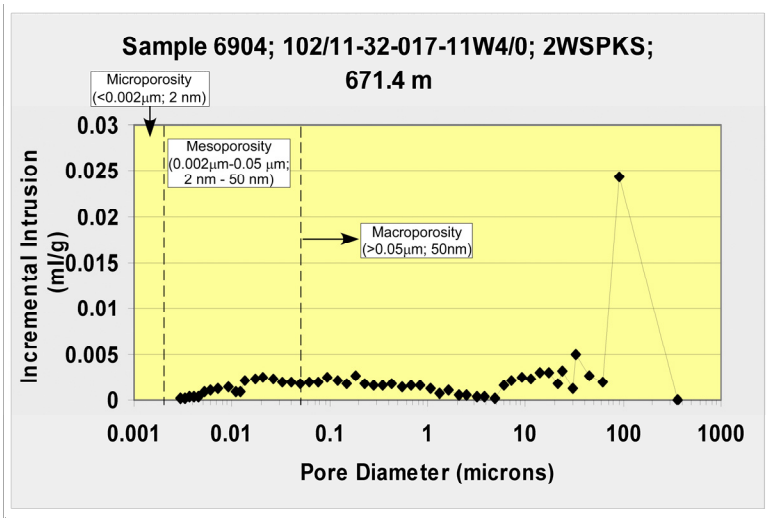
c)

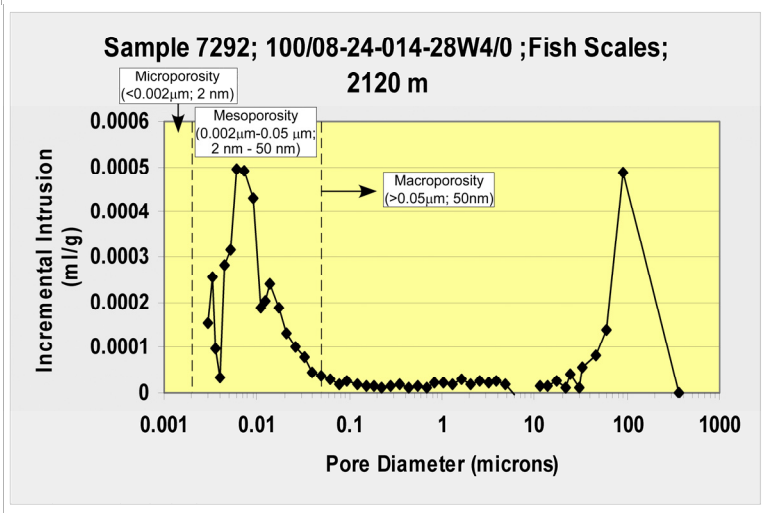
Image	Magnification
8565_2	6500×

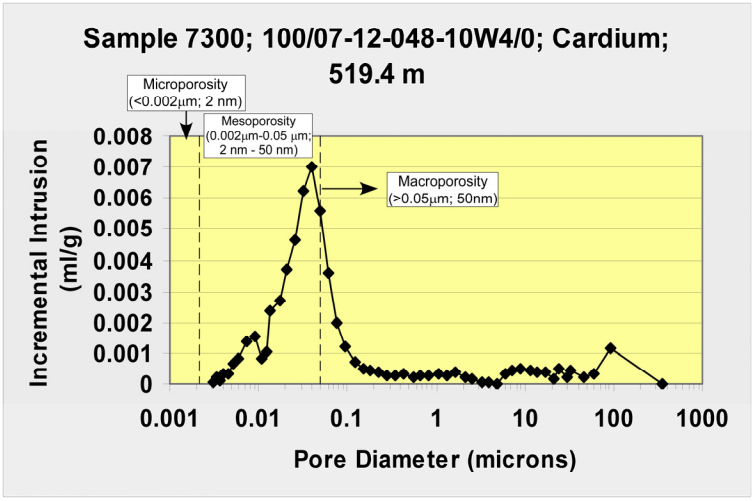


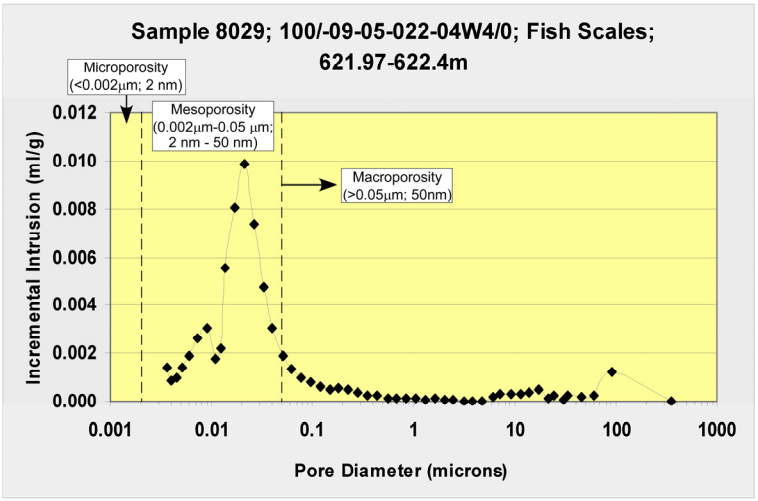
Porosity is easily observed in image 8565_2, with clay plates trending in a variety of directions giving the sample a somewhat chaotic appearance. The silt grain in the left centre of the image (yellow arrow) appears to be loosely resting on clay plates, while the lower yellow arrow points to a silt grain that is coated with clay plates. The upper red arrow may identify an additional silt grain with good porosity above the grain. The difference in colour of the clay sheets is a simply a function of the direction of light (from the right) relative to the sample.

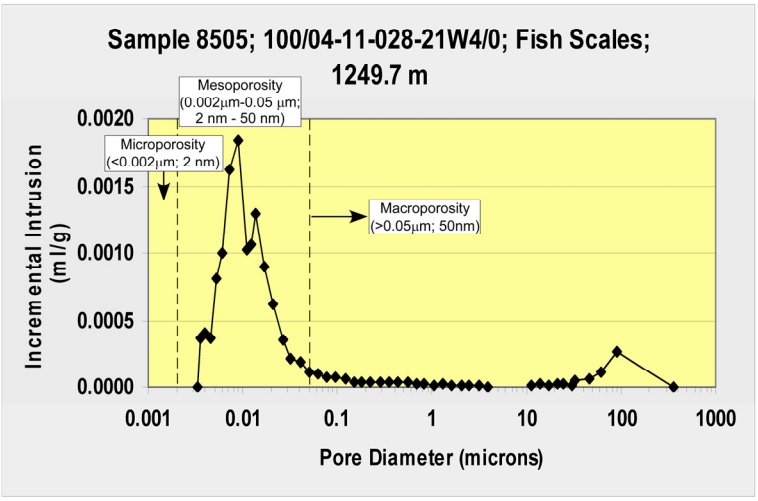
Appendix 8 – Colorado Group Mercury Porosimetry Graphs

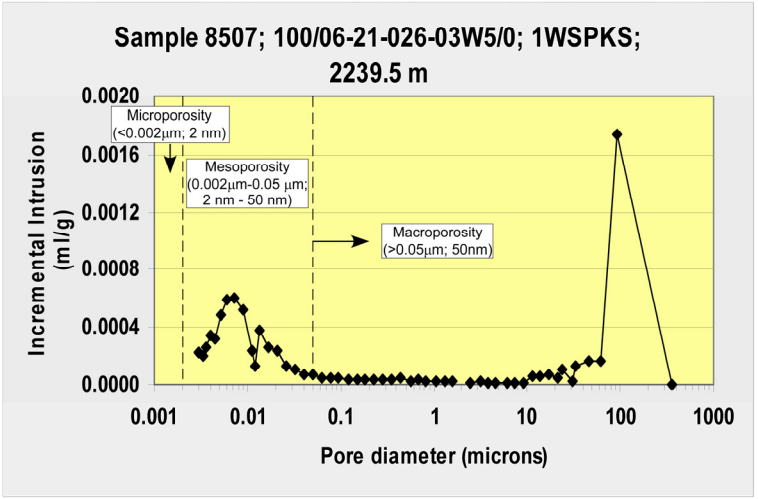


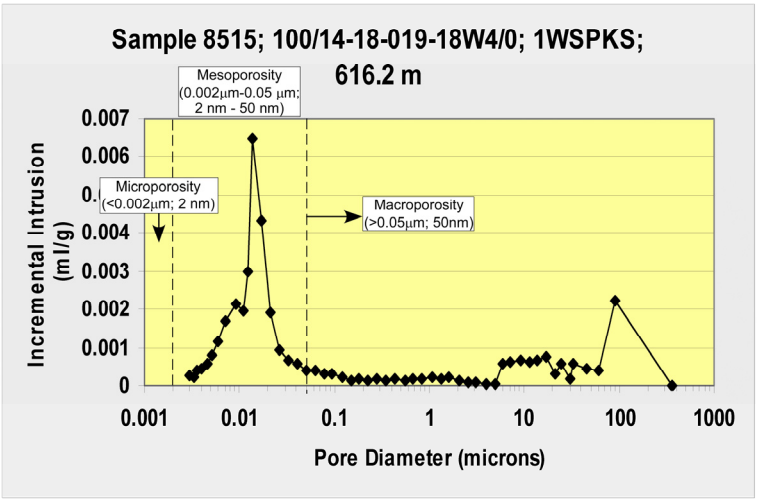


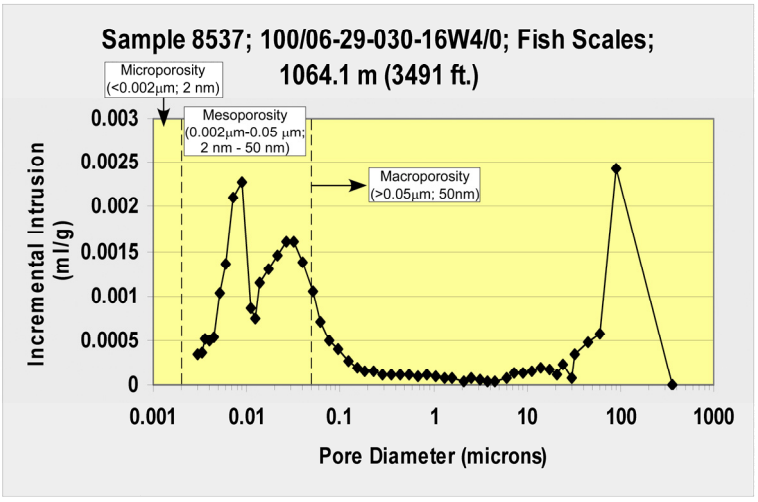


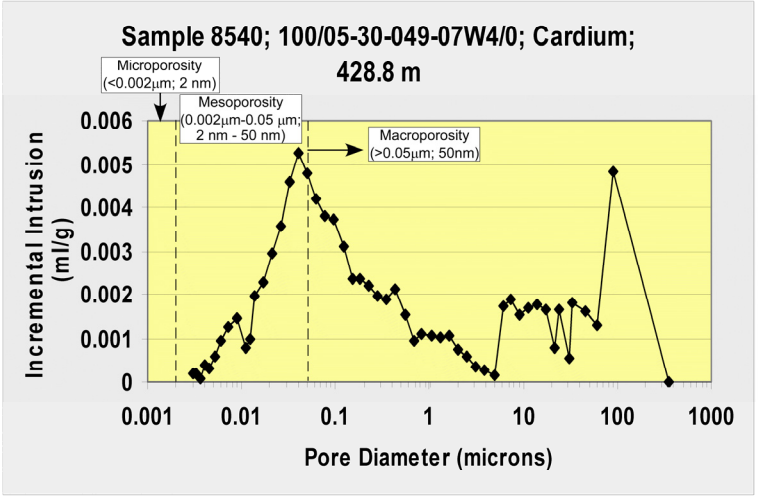

Sample 8029; 100/-09-05-022-04W4/0; Fish Scales;
621.97-622.4m
Microporosity
(<0.002µm; 2 nm)
Mesoporosity
(0.002µm-0.05 µm;
2 nm - 50 nm)
Macroporosity
(>0.05µm; 50nm)
Incremental Intrusion (ml/g)
0.012
0.010
0.008
0.006
0.004
0.002
0.000
0.001
0.01
0.1
1
10
100
1000
Pore Diameter (microns)

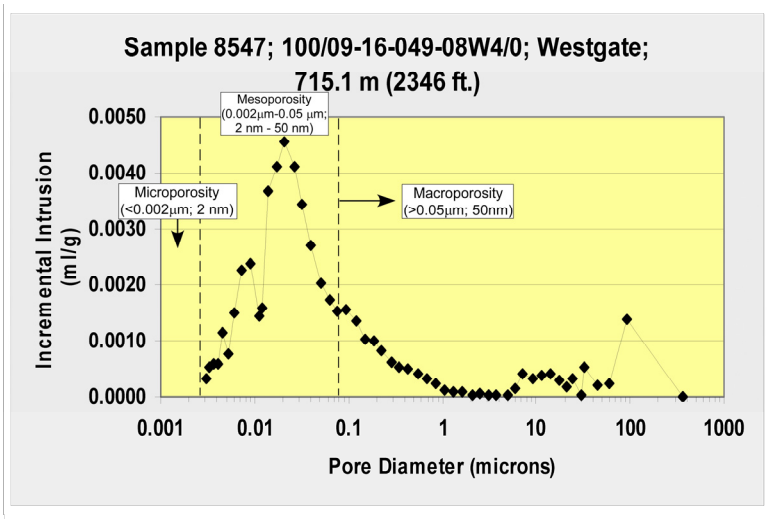

Sample 8505; 100/04-11-028-21W4/0; Fish Scales;
1249.7 m
Mesoporosity
(0.002µm-0.05 µm;
2 nm - 50 nm)
Microporosity
(<0.002µm; 2 nm)
Macroporosity
(>0.05µm; 50nm)
Incremental Intrusion
(ml/g)
0.0020
0.0015
0.0010
0.0005
0.0000
0.001
0.01
0.1
1
10
100
1000
Pore Diameter (microns)

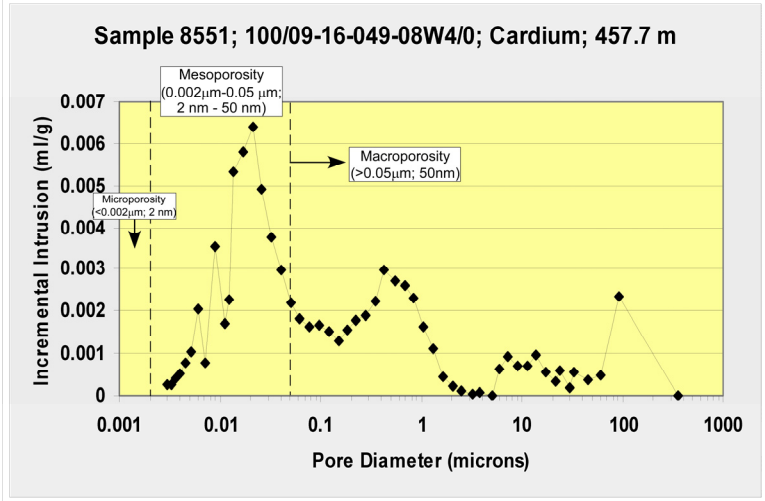

Sample 8507; 100/06-21-026-03W5/0; 1WSPKS;
2239.5 m
Microporosity
(<0.002µm; 2 nm)
Mesoporosity
(0.002µm-0.05 µm;
2 nm - 50 nm)
Macroporosity
(>0.05µm; 50nm)
Incremental Intrusion
(ml/g)
0.0020
0.0016
0.0012
0.0008
0.0004
0.0000
0.001
0.01
0.1
1
10
100
1000
Pore diameter (microns)

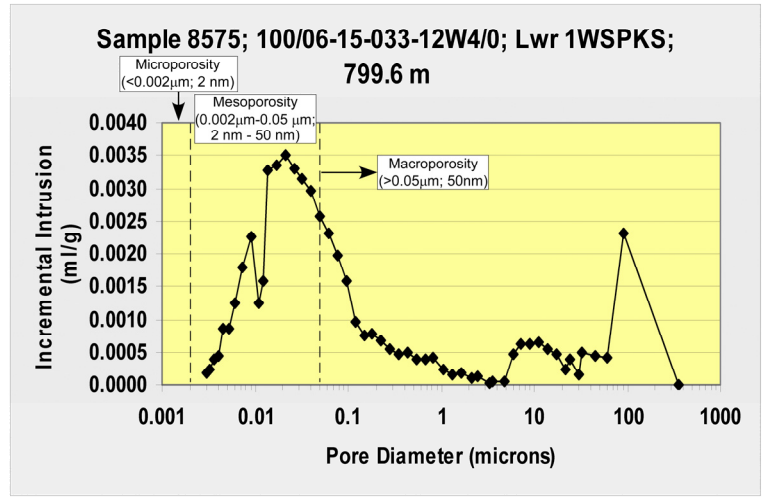

Sample 8515; 100/14-18-019-18W4/0; 1WSPKS;
616.2 m
Mesoporosity
(0.002µm-0.05 µm;
2 nm - 50 nm)
Microporosity
(<0.002µm; 2 nm)
Macroporosity
(>0.05µm; 50nm)
Incremental Intrusion
(ml/g)
0.007
0.006
0.004
0.003
0.002
0.001
0
0.001
0.01
0.1
1
10
100
1000
Pore Diameter (microns)

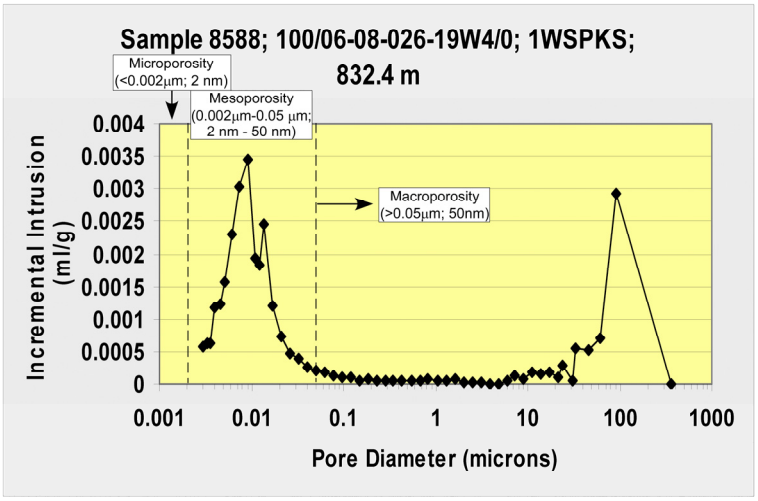

Sample 8537; 100/06-29-030-16W4/0; Fish Scales;
1064.1 m (3491 ft.)
Microporosity
(<0.002µm; 2 nm)
Mesoporosity
(0.002µm-0.05 µm;
2 nm - 50 nm)
Macroporosity
(>0.05µm; 50nm)
Incremental Intrusion
(ml/g)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
0.001
0.01
0.1
1
10
100
1000
Pore Diameter (microns)

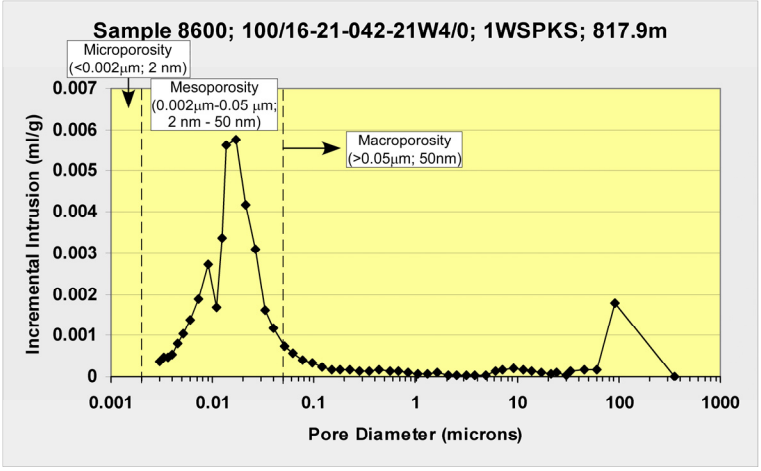

Sample 8540; 100/05-30-049-07W4/0; Cardium;
428.8 m
Microporosity
(<0.002µm; 2 nm)
Mesoporosity
(0.002µm-0.05 µm;
2 nm - 50 nm)
Macroporosity
(>0.05µm; 50nm)
Incremental Intrusion
(ml/g)
0.006
0.005
0.004
0.003
0.002
0.001
0
0.001
0.01
0.1
1
10
100
1000
Pore Diameter (microns)

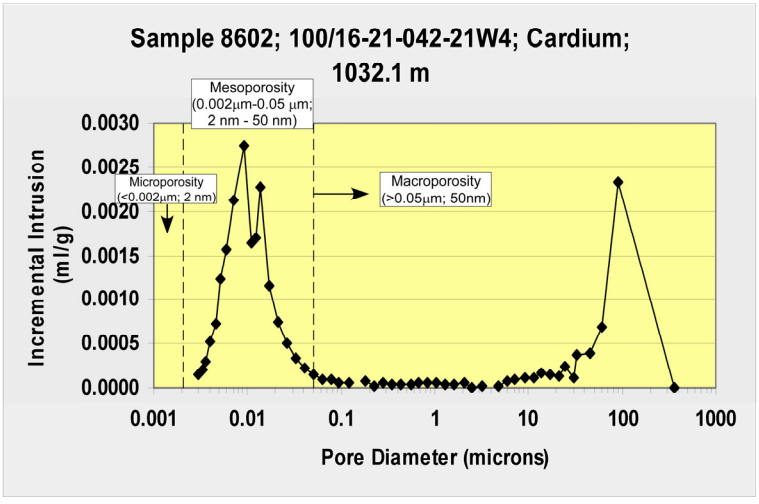

Sample 8547; 100/09-16-049-08W4/0; Westgate; 715.1 m (2346 ft.)
Mesoporosity (0.002µm-0.05 µm; 2 nm - 50 nm)
Microporosity (<0.002µm; 2 nm)
Macroporosity (>0.05µm; 50nm)
Incremental Intrusion (ml/g)
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
0.001
0.01
0.1
1
10
100
1000
Pore Diameter (microns)

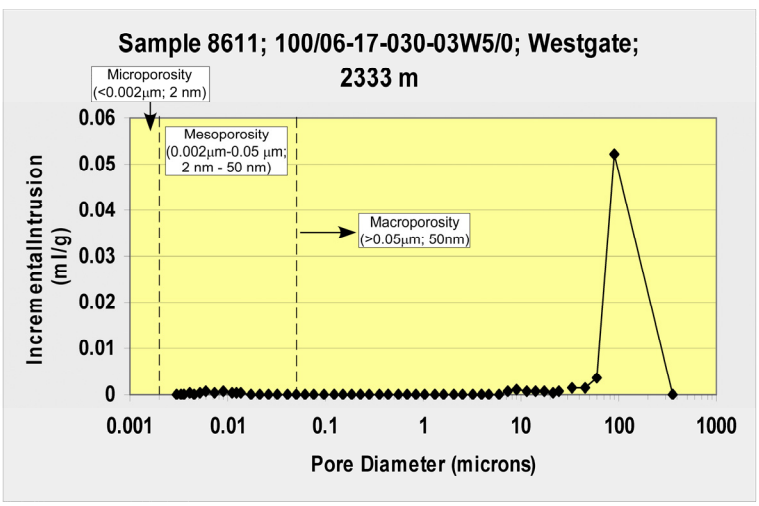

Sample 8551; 100/09-16-049-08W4/0; Cardium; 457.7 m
Mesoporosity (0.002µm-0.05 µm; 2 nm - 50 nm)
Macroporosity (>0.05µm; 50nm)
Microporosity (<0.002µm; 2 nm)
Incremental Intrusion (ml/g)
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
0.001
0.01
0.1
1
10
100
1000
Pore Diameter (microns)

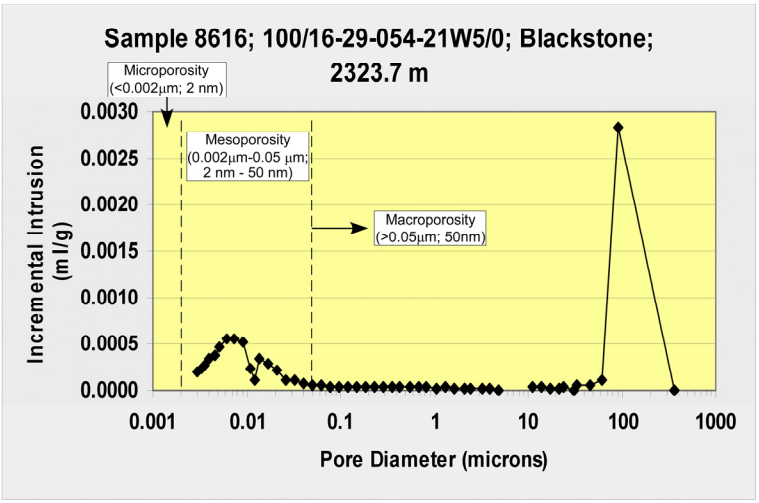

Sample 8575; 100/06-15-033-12W4/0; Lwr 1WSPKS; 799.6 m
Microporosity (<0.002µm; 2 nm)
Mesoporosity (0.002µm-0.05 µm; 2 nm - 50 nm)
Macroporosity (>0.05µm; 50nm)
Incremental Intrusion (ml/g)
0.0040
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
0.001
0.01
0.1
1
10
100
1000
Pore Diameter (microns)

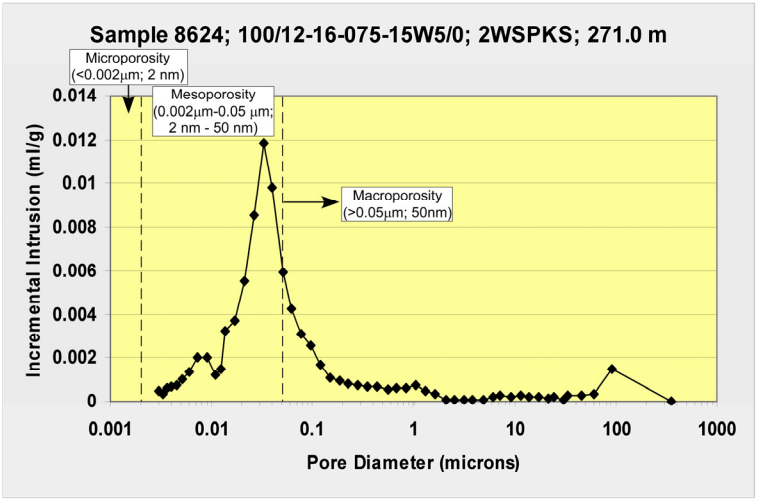

Sample 8588; 100/06-08-026-19W4/0; 1WSPKS; 832.4 m
Microporosity (<0.002µm; 2 nm)
Mesoporosity (0.002µm-0.05 µm; 2 nm - 50 nm)
Macroporosity (>0.05µm; 50nm)
Incremental Intrusion (ml/g)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
0.001
0.01
0.1
1
10
100
1000
Pore Diameter (microns)

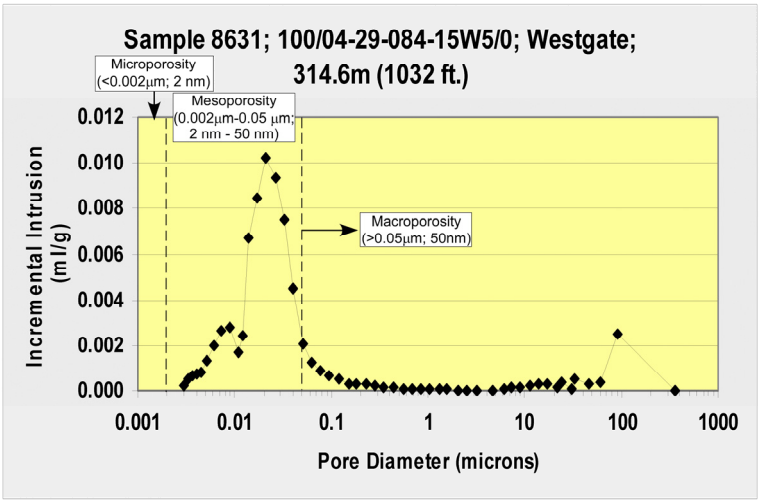

Sample 8600; 100/16-21-042-21W4/0; 1WSPKS; 817.9m
Microporosity (<0.002µm; 2 nm)
Mesoporosity (0.002µm-0.05 µm; 2 nm - 50 nm)
Macroporosity (>0.05µm; 50nm)
Incremental Intrusion (ml/g)
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
0.001
0.01
0.1
1
10
100
1000
Pore Diameter (microns)

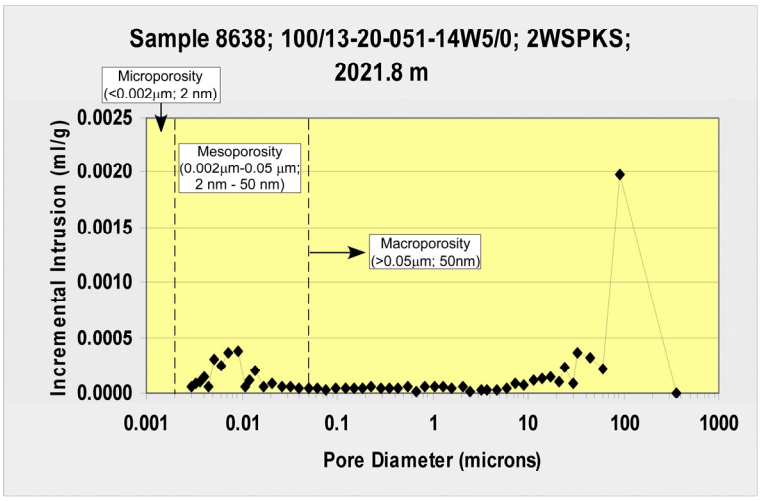

Sample 8602; 100/16-21-042-21W4; Cardium; 1032.1 m
Mesoporosity (0.002µm-0.05 µm; 2 nm - 50 nm)
Microporosity (<0.002µm; 2 nm)
Macroporosity (>0.05µm; 50nm)
Incremental Intrusion (ml/g)
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
0.001
0.01
0.1
1
10
100
1000
Pore Diameter (microns)

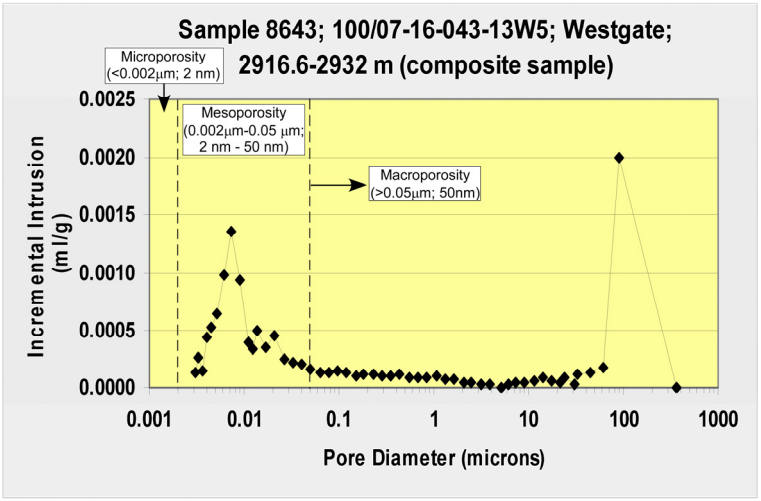

Sample 8611; 100/06-17-030-03W5/0; Westgate; 2333 m
Microporosity (<0.002µm; 2 nm)
Mesoporosity (0.002µm-0.05 µm; 2 nm - 50 nm)
Macroporosity (>0.05µm; 50nm)
Incremental Intrusion (ml/g)
0.06
0.05
0.04
0.03
0.02
0.01
0
0.001
0.01
0.1
1
10
100
1000
Pore Diameter (microns)

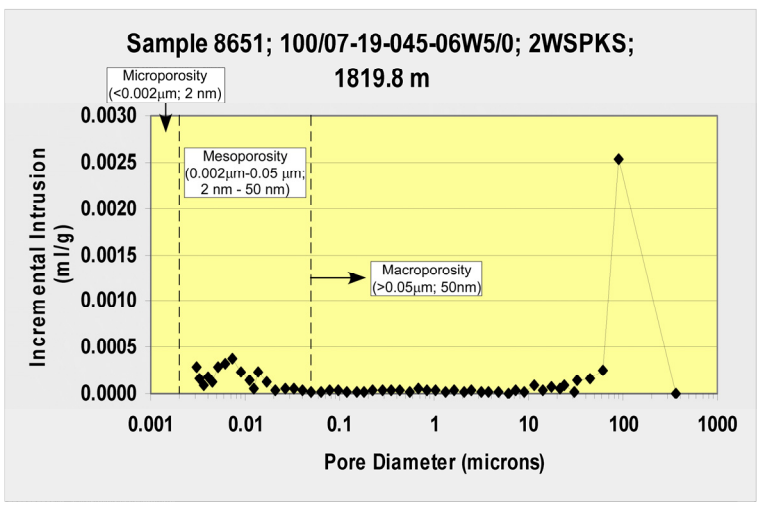

Sample 8616; 100/16-29-054-21W5/0; Blackstone; 2323.7 m
Microporosity (<0.002µm; 2 nm)
Mesoporosity (0.002µm-0.05 µm; 2 nm - 50 nm)
Macroporosity (>0.05µm; 50nm)
Incremental Intrusion (ml/g)
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
0.001
0.01
0.1
1
10
100
1000
Pore Diameter (microns)

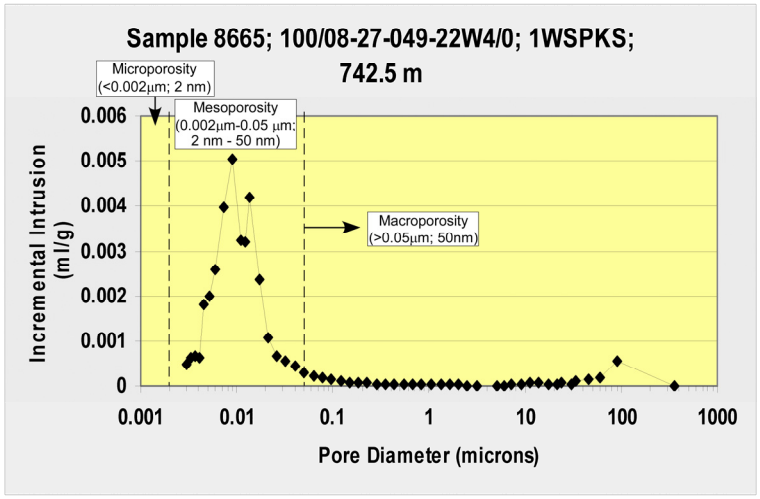

Sample 8624; 100/12-16-075-15W5/0; 2WSPKS; 271.0 m
Microporosity (<0.002µm; 2 nm)
Mesoporosity (0.002µm-0.05 µm; 2 nm - 50 nm)
Macroporosity (>0.05µm; 50nm)
Incremental Intrusion (ml/g)
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
0.001
0.01
0.1
1
10
100
1000
Pore Diameter (microns)


Sample 8631; 100/04-29-084-15W5/0; Westgate;
314.6m (1032 ft.)
Microporosity
(<0.002µm; 2 nm)
Mesoporosity
(0.002µm-0.05 µm;
2 nm - 50 nm)
Macroporosity
(>0.05µm; 50nm)
Incremental Intrusion
(ml/g)
0.012
0.010
0.008
0.006
0.004
0.002
0.000
0.001
0.01
0.1
1
10
100
1000
Pore Diameter (microns)


Sample 8638; 100/13-20-051-14W5/0; 2WSPKS;
2021.8 m
Microporosity
(<0.002µm; 2 nm)
Mesoporosity
(0.002µm-0.05 µm;
2 nm - 50 nm)
Macroporosity
(>0.05µm; 50nm)
Incremental Intrusion (ml/g)
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
0.001
0.01
0.1
1
10
100
1000
Pore Diameter (microns)


Sample 8643; 100/07-16-043-13W5; Westgate;
2916.6-2932 m (composite sample)
Microporosity
(<0.002µm; 2 nm)
Mesoporosity
(0.002µm-0.05 µm;
2 nm - 50 nm)
Macroporosity
(>0.05µm; 50nm)
Incremental Intrusion
(ml/g)
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
0.001
0.01
0.1
1
10
100
1000
Pore Diameter (microns)


Sample 8651; 100/07-19-045-06W5/0; 2WSPKS;
1819.8 m
Microporosity
(<0.002µm; 2 nm)
Mesoporosity
(0.002µm-0.05 µm;
2 nm - 50 nm)
Macroporosity
(>0.05µm; 50nm)
Incremental Intrusion
(ml/g)
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
0.001
0.01
0.1
1
10
100
1000
Pore Diameter (microns)


Sample 8665; 100/08-27-049-22W4/0; 1WSPKS;
742.5 m
Microporosity
(<0.002µm; 2 nm)
Mesoporosity
(0.002µm-0.05 µm;
2 nm - 50 nm)
Macroporosity
(>0.05µm; 50nm)
Incremental Intrusion
(ml/g)
0.006
0.005
0.004
0.003
0.002
0.001
0
0.001
0.01
0.1
1
10
100
1000
Pore Diameter (microns)