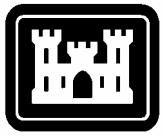
APPENDIX R

Soils Analysis Report, USACE Waterways Experiment Station



US Army Corps
of Engineers

Interim Report to Philadelphia District
Dupont-Chambers Uranium Mobility Study

By:

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8 June 2005

Introduction

The Philadelphia District, USACE, has contracted ERDC-Vicksburg to analyze a series of samples from the Dupont-Chambers FUSRAP Site for Uranium concentration and geochemical characterization. This report discusses the findings from the initial set of samples received on 06 October 2004. All chemical analyses reported were performed at the Environmental Chemistry Branch, Vicksburg, MS or Omaha, NE facilities. Subsamples for SEM and XRD analysis were subcontracted to New Mexico Institute of Mining and Technology for analysis.

Materials, Methods and Quality Control

Forty-nine samples were received with intact chain of custody seals on 06 October 2004. Samples were stored at 4ºC in a locked cooler. A battery of analytical tests was requested for these samples as outlined in the ERDC cost estimate attached to this report as Appendix 1. The tests requested included: Scanning Electron Microscopy (SEM), X-ray Diffraction (XRD), Sequential Extraction, Acid Digestion Uranium, Distribution Coefficient (K_d), Total Organic Carbon (TOC), and Cation Exchange Capacity (CEC). All experiments were determined on air-dried samples and the percent solids are given in table 1.

Liquid digestion or extractions samples were analyzed following US EPA SW846 Method 6020 (Inductively Coupled Plasma Mass Spectrometry) that utilizes laboratory blanks, sample duplicates, and NIST Traceable Standards for a four point calibration curve, continuing calibration standards, laboratory control samples, and internal standards (Holmiun-165). All QC was within acceptable limits. Bismuth-209 is normally used as an internal standard for Uranium analyses by ICP-MS, however, past samples analyzed by ERDC for the Dupont Chambers site identified anomalously high Bismuth concentrations in some samples, therefore, Holmium was chosen for the current work.

Aqueous samples for Uranium analysis (e.g. Distribution Coefficient and Sequential Extraction) were analyzed by Inductively Coupled Plasma Mass Spectrometry following EPA Standard Method 6020, using Holmium-165 as the internal standard. Total Uranium was determined by ICP-MS after digestion according to EPA Standard Method 3050B.

Sequential extraction procedures were modified from that described in Ryan et al. (2001). The modification of the sequential extraction procedure consisted of adding a ‘soluble’ phase prior to the ‘exchangeable’ phase and using a small deionized water wash (~2mL) between each extraction step to reduce carryover contamination.

Total organic carbon and soil cation exchange capacity were determined using standard combustion and modified ammonium acetate extraction methods, respectively (EPA Methods 9060 and 9081).

The Scanning Electron Microscopy (SEM) experimental procedure used consisted of scanning the electron beam across the sample in a high vacuum chamber and measuring 'backscattered' X-Rays emitted from the sample. Backscattered X-Rays are generated when the electron beam excites an inner-shell electron of an atom. The excited electron then drops back to a lower energy level, emitting the X-Ray of a specific energy, characteristic of that element. This causes backscatter X-Rays to be indicative of elements in an analogous manner to visible elemental spectroscopy in Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) or Flame Atomic Absorption Spectroscopy (FAAS).

Distribution coefficients (K_d) were determined following a method developed and modified by Laura Toran of Temple University and Anthony Bednar of ERDC. The procedure used three water chemistries representative of those found on-site. Appendix 2 contains the synthetic groundwater chemistry selected for the K_d studies. Samples from 2003 and 2004 were analyzed, negative values are not meaningful, the reason for these values is discussed below.

The method used involved spiking additional Uranium into a soil slurry. Because many of these samples already contained Uranium, the soils naturally desorb some Uranium when placed in aqueous suspensions, in a manner similar to the Sequential Extration experiments. Theoretically, if enough Uranium is spiked into the system, the Uranium already present should be negligible, however, at the concentrations needed to make the 'natural' Uranium negligible, solubility of Uranium minerals would be exceeded. Furthermore, saturation of sorption sites occurs at high spiking concentrations, therefore, a true equilibrium is not established. Despite the drawbacks to K_d measurements, some information is obtained from the study and is described below.

Of the 49 samples received, 6 were specifically requested to be analyzed in detail for the above mentioned battery of tests. The results of the tests are described and interpreted below.

Results and Discussion

Total Uranium Concentrations:

Uranium concentrations in the samples ranged from over 5200 to less than 1 mg/kg, in general agreement with the uranium activities reported by the field personal submitting the samples. Natural concentration levels of Uranium are usually less than 10 mg/kg, therefore, the samples with concentrations higher than this have been impacted by anthropogenic activities. However, the isotopic ratio of Uranium 235:238 was also measured on all samples analyzed for total Uranium, and found to be within 10% of the nominal natural abundance value (235:238 ~ 99.2:0.72). The small variation observed is due to the very small amount of Uranium-235 present (~0.72% of natural Uranium). The fact that all samples have very near natural isotopic ratios supports the fact that no Uranium enrichment processes were involved with the samples collected. Initial attempts were made at measuring Uranium-236, however, this natural isotope occurs at

concentrations an order of magnitude below that of Uranium-235 and was therefore too low to be quantified in most samples. The results for total Uranium are shown in table 2.

Sample pH:

The paste pH of the air dried samples is shown in table 3. For the most part, the samples are circumneutral to alkaline with the exceptions of 1-MW-08-B-P-04 and 1-MW-18-B-P-01 which are very alkaline (pH>10). High pH can contribute to mobilization of adsorbed metals by different mechanisms, particularly uranium, as it has a high affinity for carbonates, and therefore could increase uranium mobilization from these sample sites. These two samples specifically, have the majority of their Uranium in the carbonate phase of the sequential extraction, described below.

Sequential Extraction:

The data in table 4 shows the results of the sequential extraction experiments. Concentrations of other elements, in addition to Uranium, were also requested and are shown in table 4. A brief geochemical explanation for relevant phases of each sample that contains uranium is given below. No sample analyzed had a majority of its Uranium in the 'residual' or refractory phase, indicating that under certain geochemical conditions, the Uranium could be mobilized.

2-MW-2-B-P-03- This sample contains the majority of the Uranium in the carbonate phase, meaning it would become mobile in the event of acidic waters coming in contact with the soil. Interestingly, there is very little 'exchangeable' Uranium in this sample, although there is a large amount of exchangeable Calcium. This could suggest that geochemical reactions have occurred, incorporating Uranium into a carbonate phase and liberating calcium that is now exchangeable. This sample also contains iron in the "oxide" phase, and correspondingly this phase is the second largest repository of Uranium, held most likely in an amorphous mineral lattice because of the low Uranium concentration in the exchangeable phase. There are substantial amounts of Uranium and sulfur in the "organic matter and sulfide" phase, which could also be mobilized during acidic conditions. Therefore, it is suggested that Uranium could be mobilized from this location.

1-MW-08-B-P-04- This sample also contains the majority of the Uranium in the carbonate phase, although there is a slightly higher percentage of exchangeable in comparison to the previous sample. There is a large amount of Calcium in the carbonate phase, which supports the fact that this sample had a pH greater than 10. This sample also contains iron in the "oxide" phase, although less than the previous sample. However, the ratio of Uranium in the carbonate to oxide phases is higher in 1-MW-08-B-P-04, suggesting a different geochemical environment than 2-MW-2-B-P-03. SEM analysis of this sample suggests Uranium coatings on organic particles, and there is some Uranium noted in the organic matter and sulfide phase. Therefore, it is suggested that Uranium could be mobilized from this location, although reducing conditions might liberate more Uranium, proportionally, because of the higher oxide concentration.

2-MW-09-B-P-03- This sample again shows high amounts of Uranium in the carbonate phase, although there is less Calcium and Magnesium than previous samples. However, there is an inverse correlation between sulfur and Uranium in the "organic matter and sulfide" phase, when compared to the previous samples. A reducing environment would normally favor insoluble U(IV), yet there is a substantial amount of Uranium in the soluble phase of this sample, indicating possible mobility issues. The amount of iron in the oxide phase is comparable to the previous sample.

H-1-MW-09-B-P-04- Overall, this sample has a low total Uranium concentration, yet like the previous samples, contains a majority of it in the carbonate phase. There is less sulfur and iron in their respective phases. SEM analysis of this sample did not detect any distinct Uranium grains, coatings, or phases.

1-MW-17-B-P-05- This is the first sample analyzed to have the majority of the Uranium present in the organic matter and sulfide phase. However, there is no sulfur present suggesting that organic matter controls the Uranium in this sample. SEM analysis detected several small Uraniun-containing phases. This sample has a substantial amount of iron in both the 'oxide' and 'residual' phases, although little uranium is associated with either, suggesting an inverse relationship of uranium and iron.

1-MW-18-B-P-01- This sample also contains the majority of the Uranium in the carbonate phase. There is a large amount of Calcium in the carbonate phase, which supports the fact that this sample had a pH greater than 10. There is also substantial amounts of sulfur and Uranium in the organic matter and sulfide phase, which is supported by the SEM analysis. This sample contains less iron than 1-MW-17-B-P-05, although each phase contains more uranium, even though total uranium in the two samples is similar, further suggesting an inverse relationship of uranium and iron.

Based on the above described geochemical definitions, many samples have significant potential to be sources of mobile Uranium under varying geochemical conditions.

Total Organic Carbon

Organic matter is known to complex with metal cations, including radionuclides, and therefore it was determined in selected samples (Lenhart, et al., 2000). Table 5 lists the organic carbon content of the four samples requested. As can be seen, sample 2-MW-2-B-P-03 is the highest at 4.5 % carbon. The other samples were 0.5 to 3.8 % organic carbon; none of these values are out of line with what would be expected for a soil. Incidentally, 2-MW-2-B-P-03 did have Uranium in the organic matter and sulfide phase.

Cation Exchange Capacity

Samples 1-MW-08-B-P-04 and 2-MW-2-B-P-03 had the highest CEC of the samples requested for analysis (table 6). However, these samples did not have particularly large amounts of Uranium in the exchangeable phase, likely because of the high affinity for carbonate complexation, Uranium is likely to exist as an anion in many carbonate-rich environments and may not sorb as expected in a lower alkalinity soil.

Scanning Electron Microscope

Samples were submitted to New Mexico Institute of Mining and Technology for SEM analysis. This lab was chosen because they are currently doing collaborative work with ECB, Vicksburg on radionuclide containing soils.

In order to investigate further for the presence of U, X-ray maps were collected over a 4x4 mm area, scanning for Si, U, and Pb (as well as also collecting a BSE image of the same area). After this data was collected, additional elements were requested by NAP. NMT archives samples for this purpose, and subsequent element maps of approximately the same areas were generated showing Mg, Mn, P, S, and Ca. The object of this analysis was to determine the location and distribution of U within the sample, as well as associations with other elements of interest.

The SE Micrographs are attached to this report as Appendix 3. The U maps reveal that no significant, discrete concentrations of U exist in H-1-MW-09-B-P-04 and 2-MW-11-B-P-03, in general agreement with the total Uranium and Sequential Extraction Analyses.

However, samples 2-MW-2-B-P-03, 1-MW-08-B-P-04, 1-MW-17-B-P-05, 1-MW-18-B-P-01, and 2-MW-03-B-P-03 contain discrete particles of Uranium which were imaged in greater detail (higher magnification), as shown in Appendix 3. The elements described in the sequential extraction section and given in table 4 can be correlated to the qualitative SEM data. For example, large calcium-rich particles can be seen with the SEM and have corresponding uranium phases in the carbonate sequential extraction procedure. The SE Micrographs of 2-MW-2-B-P-03, for example, show dissemination of uranium in several particles that track magnesium, iron, phosphorus, and silicon quite closely, suggesting relationships with these elements are also supported by the sequential extraction data.

X-Ray Diffraction

The results are reported in table 7. There were no phases observed in any sample that contained uranium as a major constituent. Quartz is observed as the major mineral phase in these samples. Several samples had dolomite, a calcium magnesium carbonate, detected as a possible phase, consistent with the sequential extraction data showing calcium and magnesium in the carbonate phase.

Distribution Coefficient (K_d)

Using all three synthetic groundwater chemistries described in Appendix 2, most of the samples yielded similar K_d values in the 1-5 mL/g range, which suggests that uranium could be mobilized. This is in general agreement with the sequential extraction results suggesting that many samples have substantial amounts of uranium in the more mobile geochemical phases (soluble through carbonate, particularly). However, one specific sample, 2-MW-11-B-P-03, when using the 3SB15 groundwater, had an order of magnitude higher Kd value, suggesting less mobility. This sample has very low uranium, and almost none of what is present is in the more mobile phases of the sequential extraction procedure, suggesting that samples of this type, when in contact with waters of

similar chemistry to 3SB15, will not mobilize as much uranium as the other two groundwater types. Groundwater 3SB15 is slightly acidic, approximately pH of 4-5, implying little dissolved carbonate is present, which is known to complex uranium.

Distribution coefficients could not be determined for samples 2-MW-2-B-P-03, 1-MW-08-B-P-04, 2-MW-03-B-P-03, and 1-MW-17-B-P-05 because of the previously described desorption saturation issue. However, shown in table 8 are K_d's for 3 soil samples, using 3 different synthetic waters closely approximating water chemistries found at the site. Additionally, samples from the 2003 collection were repeated using the new procedure, and K_d values are reported for some of these samples as well.

Samples from the 2003 study were also investigated using the new procedure and generally produced similar results except for 5-SB-10-B-1-03, 1-BH-007-2-4, and 1-BH-0180-2 (the third sample using the 3SB15 water) which yielded Kd values of about 22000, 1800, and 220, respectively. These values suggest less uranium mobility from these sample types with this groundwater geochemistry. Sample 5-SB-10-B-1-03 contains very little uranium suggesting it might sorb any uranium that is carried to it by groundwater.

Future Research

The research capabilities exist to increase knowledge of the mobility of the uranium contamination at the Dupont Chambers site. The USACE Environmental Chemistry Branch has recently developed methods for uranium speciation using the ICP-MS in conjunction with HPLC separation. Molecular weight cut-off filters can further be used to determine if colloidal uranium is leached from the sediments, which can be overlooked by traditional 'dissolved' 0.45μm filtration. Additionally, following EPA method 1312, a Synthetic Precipitation Leaching Procedure can mimic the effects of acid rain on the contaminated site and would provide more information concerning uranium mobility under 'natural' leaching of the sediments exposed to acid rain.

References

Langmuir, D., 1997. Aqueous Environmental Geochemistry. Prentice-Hall, Inc. Upper Saddle River, NJ, 600 pp.

Lenhart, J.J., Cabaniss, S.E., MacCarthy, P., Honeyman, B.D., 2000. Uranium(VI) complexation with citric, humic, and fulvic acids. *Radiochim. Acta.,* **88**, 345-53.

Ryan, J.A., Zhang, P., Hesterberg, D., Chou, J., Sayers, D.E., 2001. Formation of Chloropyromorphite in a lead-contaminated soil amended with hydroxyapatite. *Environ. Sci. & Tech.,* **35**, 3798-803.

Appendix 1: ERDC cost estimate for requested analytical procedures.
Appendix 2: K_d procedure developed by Dr. Laura Toran with input from the authors.
Appendix 3: SE Micrographs of Dupont Chambers samples.

Appendix 1

Project Info: **USACE Cost Estimate for DuPont Chambers, Deepwater New Jersey**
Uranium Mobility Study
USACE ERDC, Vicksburg, MS

Date: 8-Nov-04

Philadelphia Project George Bock, 215-656-6513

Philadelphia POC: Glen Stevens, 215-656-6687

Philadelphia Technical POC: Dr. Laura Toran, 215-204-2352

ERDC POC: Dr. Anthony Bednar, 601-634-3652

ERDC POC: Lynn Escalon, 601-634-2741

Item number	Line item price lists for Uranium mobility study Analytical Procedure	Price/ sample ($) with overhead	number of samples	Total Cost
1	Sequential Extraction (Soluble) Elements mobilized (solubilized) with DI water.	$68.00	6	$408.00
2	Sequential Extraction (Exchangable) Elements sorbed to soil particles by exchanging with magnesium cations.	$68.00	6	$408.00
3	Sequential Extraction (Carbonate) Elements associated with carbonate soil constituents which can be mobilized under mildly acidic conditions.	$68.00	6	$408.00
4	Sequential Extraction (Oxides) Elements associated with iron and manganese oxide soil constituents.	$68.00	6	$408.00
5	Sequential Extraction (Organics) Elements associated with organic matter coatings.	$68.00	6	$408.00
6	Sequential Extraction (Acid Leachable) Elements associated with strong acid soluble mineral phases.	$68.00	6	$408.00
7	Sequential Extraction (Residual) This determines the remaining soil material except some silicates.	$68.00	6	$408.00
8	Total Soil Organic Carbon includes 2 dup	$105.00	15	$1,575.00
9	Soil Cation Exchange Capacity includes 2 dup	$215.00	15	$3,225.00
10	X-ray Diffraction Determines if a specific mineral phase of an element is present.	$175.00	13	$2,275.00
11	Scanning Electron Microcroscopy/ Electron Microprobe Analysis Will suggest if element phases are dynamic, i.e. if soil particles are coated with secondary minerals	$375.00	13	$4,875.00

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Item number	Line item price lists for Uranium mobility study Analytical Procedure	Price/ sample ($) with overhead	number of samples	Total Cost
12	Distribution Coefficient (Kd) - performed in triplicate Will indicate potential for desorption of elements from soil particles, and thus the potential for migration. (**$400/single analysis**)	$850.00	13	$11,050.00
	Elemental Analysis will determine the concentration of elements in soil, laboratory extract, and water samples.			
13	Uranium, (Digestion included)	$95.00	49	$4,655.00
14	Strontium (Digestion cost included in U analysis)	$20.00	0	$0.00
15	SemiQuant Sr-90 or other metals	$450.00	0	$0.00
16	Report preparation, method development, literature search, and administrative (for FY04)	$3,000.00	1	$3,000.00
17	Consultation (60 hours @ $70/hr)	$4,500.00	1	$4,500.00
			Grand Total	**$38,011.00**

Duplicates will be performed on analytical batches. Other QC (MS/MSD) will be performed and are includ

ERDC Sample Summary 2004

				Field Samples			QA/QC Samples									
Parameters	Analytical Method	Matrix	Primary Lab	Number of Sampling Events	Total Number of Samples	Field Filtered	Field Duplicate	MS	MSD	Equip[1] Rinseate	Trip Blank	TAT Needed	Total Number of Samples	Total Number of Splits to CQAL	Unit Cost	Total Cost
OU1/OU3 2004 Soil																
Cation Exch. Capacity	EPA 9081	soil	ERDC	1	6	0	1	0	0	0	0	35 day	7	0	$215.00	$1,505.00
Moisture content	ASTM D2216	soil	ERDC	1	6	0	0	0	0	0	0	35 day	6	0	$0.00	$0.00
Phase Partitioning (K_d)	ASTM 4319	soil	ERDC	1	6	0	0	0	0	0	0	35 day	6	0	$850.00	$5,100.00
XRD	[non-quantitative]	soil	ERDC	1	6	0	0	0	0	0	0	35 day	6	0	$175.00	$1,050.00
SEM	[non-quantitative]	soil	ERDC	1	6	0	0	0	0	0	0	35 day	6	0	$375.00	$2,250.00
U Elemental Analysis (not asso. W/ other analytical)	SW 6020	soil	ERDC	1	47	0	0	1	1	0	0	35 day	49	0	$95.00	$4,655.00
Sequential Extraction (7 steps)	Draft NIST method[3]	soil	ERDC	1	6	0	0	0	0	0	0	35 day	6	0	$476.00	$2,856.00
Total Organic Carbon	SW 9060	soil	ERDC	1	6	0	1	0	0	0	0	35 day	7	0	$105.00	$735.00
OU2 2004 (OU2 repeat) Soil																
Cation Exch. Capacity	EPA 9081	soil	ERDC	1	7	0	1	0	0	0	0	35 day	8	0	$215.00	$1,720.00
Moisture content	ASTM D2216	soil	ERDC	1	7	0	0	0	0	0	0	35 day	7	0	$0.00	$0.00
Phase Partitioning (K_d)	ASTM 4319	soil	ERDC	1	7	0	0	0	0	0	0	35 day	7	0	$850.00	$5,950.00
XRD	[non-quantitative]	soil	ERDC	1	7	0	0	0	0	0	0	35 day	7	0	$175.00	$1,225.00
SEM	[non-quantitative]	soil	ERDC	1	7	0	0	0	0	0	0	35 day	7	0	$375.00	$2,625.00
Total Organic Carbon	SW 9060	soil	ERDC	1	7	0	1	0	0	0	0	35 day	8	0	$105.00	$840.00
Admin Cost															$7,500.00	$7,500.00
Totals					**131**	**0**	**4**	**1**	**1**	**0**	**0**		**137**	**0**		**$38,011.00**

Notes:

1. Equipment rinsate samples are to be collected after each day of sampling, so the number of samples depends on the number of field-work days.

2. 23 TAL metals analyzed by SW-846 6010B with the exception of Hg (SW-846 7470A, Cold Vapor AA).

3. Duplicate groundwater samples will be collected in equal number for filtered and unfiltered.
conditions for the exchangeable fraction

Abbreviations: **CQAL** Corps (of Engineers) Quality Assurance Lab, **TAT** - turn around time, **MS** - matrix spike, **MSD** - matrix spike duplicate, **SEM** - scanning electron microscope, **XRD** - x-ray diffraction

Appendix 2

Materials (rough checklist)
ICP-MS for U measurement
Centrifuge
Centrifuge tubes
Shaker
pH meter
pipets
filtration equipment and 0.45 um filters
sediment from field site
synthetic groundwater
pH buffers

Sediment
Minimal sample preparation is preferred. The sample can be examined to remove non-soil outliers, or pebbles, but no sizing, crushing, or washing will be conducted.

Solutions
Create a synthetic groundwater similar to one of the types found at the field site. There are several groundwater types, and a sodium-calcium-bicarbonate type will be used for these experiments.

Example composition:

Sample ID	Bicarbonate mg/L	Chloride mg/L	Sulfate mg/L		Calcium mg/L	Magnesium mg/L	Sodium mg/L	Potassium mg/L	pH
2BH026	230	210	20		30	15	140	5	6-7
3SB15	25	500	600		200	160	180	20	4-5
D07-M02B	230	80	5		15	0.2	90	60	8-9

These concentrations are based on site water chemistry. It is acceptable to deviate 10% or so from these concentrations in order to use existing lab chemicals for formulation.

Tracer addition
Using dry,natural abundance U, create 5 different solution spikes. The spikes will be synthetic groundwater plus U at concentrations of 5, 1, 0.5, 0.1, and 0.01 mg/L total U. Equilibrate 24 hours with the synthetic water, filter, then remove an aliquot to re-measure the U concentration just before equilibration with sediment.

Sediment Equilibration

Use 40 ml of filtered groundwater containing the U tracer in each tube and 10 g of air dried solid. In addition, one blank tube is used for each sediment sample and one duplicate of a selected spike. Place on shaker for 24 hours. Remove a filtered aliquot to measure the U concentration in solution.

Calculate the tubing blank. Calculate the distribution ratio for each spike. Plot amount sorbed v amount in solution. Slope of the linear portion is Kd.

List of samples

SAMPLE	Spike 1	Spike 2	Spike 3	Spike 4	Spike 5	Dup	Blank
1	x	x	x	x	x	x	x
2	x	x	x	x	x	x	x
3	x	x	x	x	x	x	x
4	x	x	x	x	x	x	x
5	x	x	x	x	x	x	x
5 at pH 4	x	x	x	x	x	x	x
5 at pH 6	x	x	x	x	x	x	x
6	x	x	x	x	x	x	x
6 at pH 4	x	x	x	x	x	x	x
6 at pH 6	x	x	x	x	x	x	x

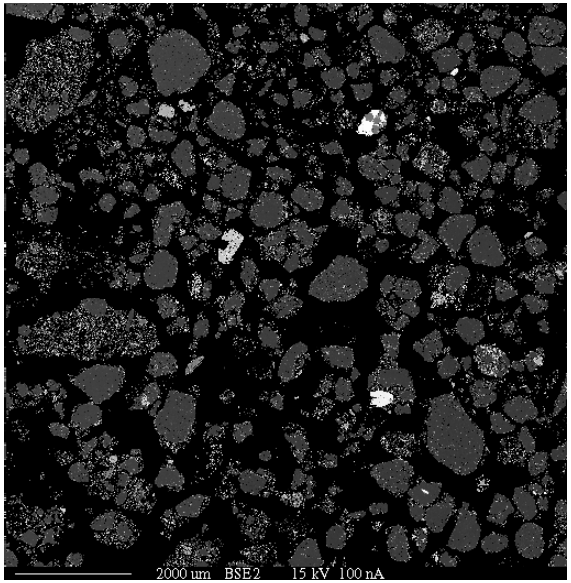
This procedure could also be used to redo the seven samples from 2003 sampling. The procedures could be re-evaluated after the 2004 samples and before the more limited quantities of 2003 sediment are used up.

SAMPLE	Spike 1	Spike 2	Spike 3	Spike 4	Spike 5	Dup	Blank
1 (2003)	x	x	x	x	x	x	x
2 (2003)	x	x	x	x	x	x	x
3 (2003)	x	x	x	x	x	x	x
4 (2003)	x	x	x	x	x	x	x
5 (2003)	x	x	x	x	x	x	x
5 at pH 4 (2003)	x	x	x	x	x	x	x
5 at pH 6 (2003)	x	x	x	x	x	x	x
6 (2003)	x	x	x	x	x	x	x
6 at pH 4 (2003)	x	x	x	x	x	x	x
6 at pH 6 (2003)	x	x	x	x	x	x	x
7 (2003)	x	x	x	x	x	x	x

Appendix 3

1-MW-9-BP-04 large scale maps
No U apparent

BSE



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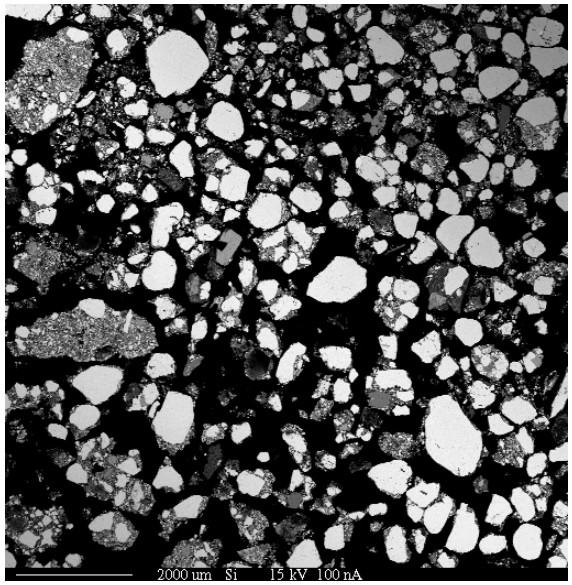
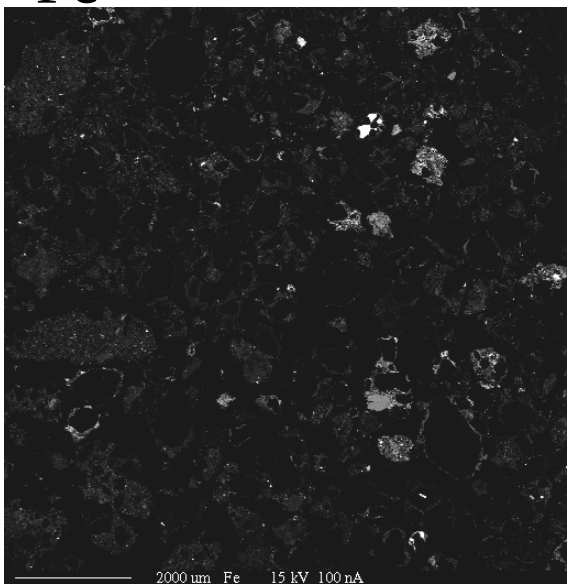


Fe



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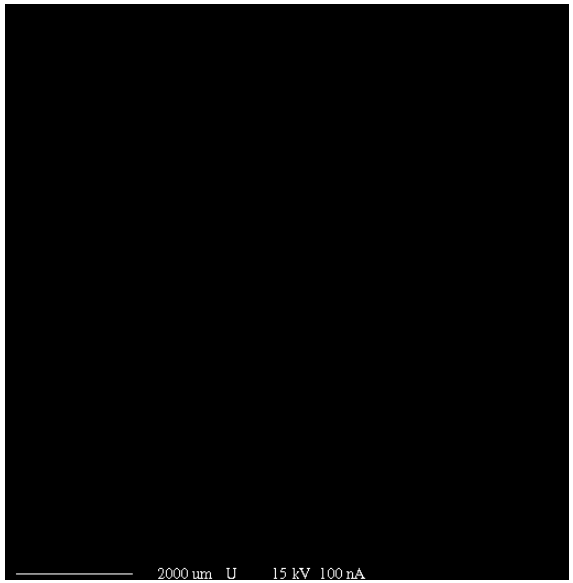
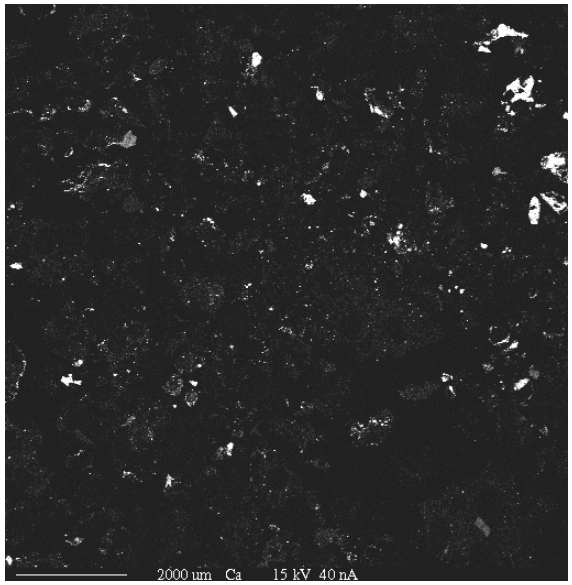
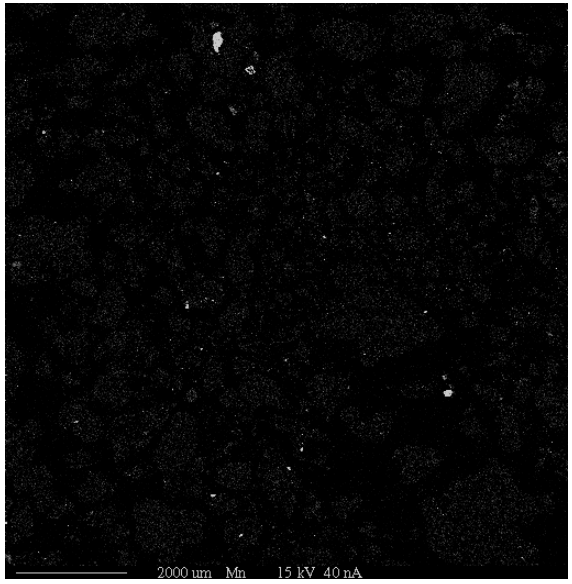


1-MW-9-BP-04

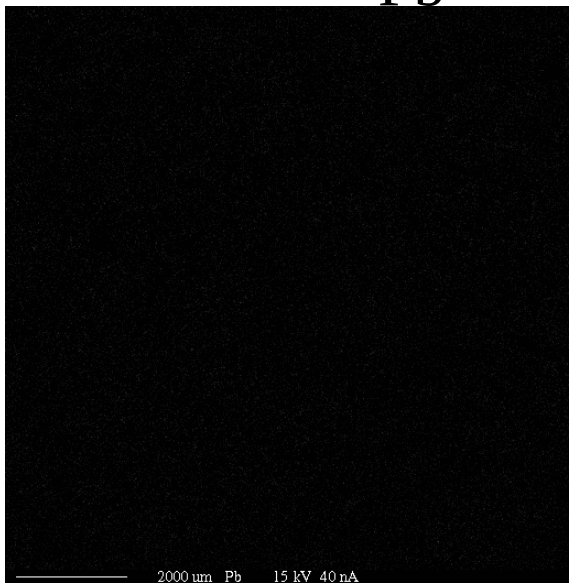
Ca



Mn

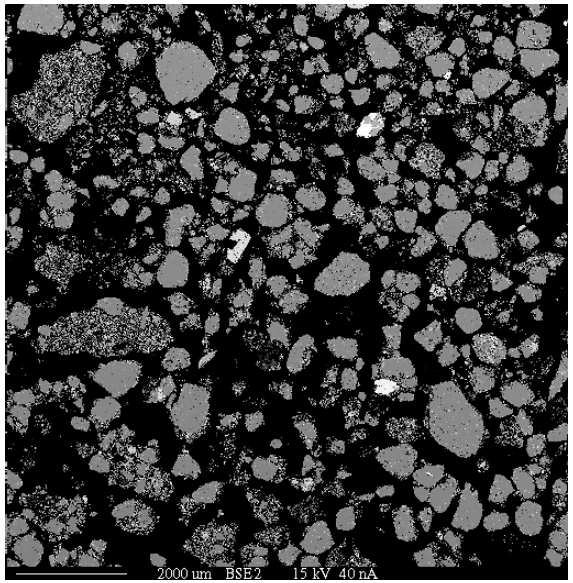


Pb

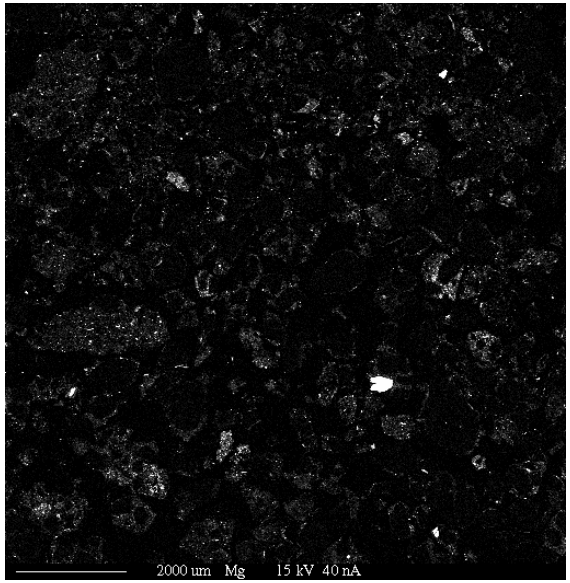


1-MW-9-BP-04

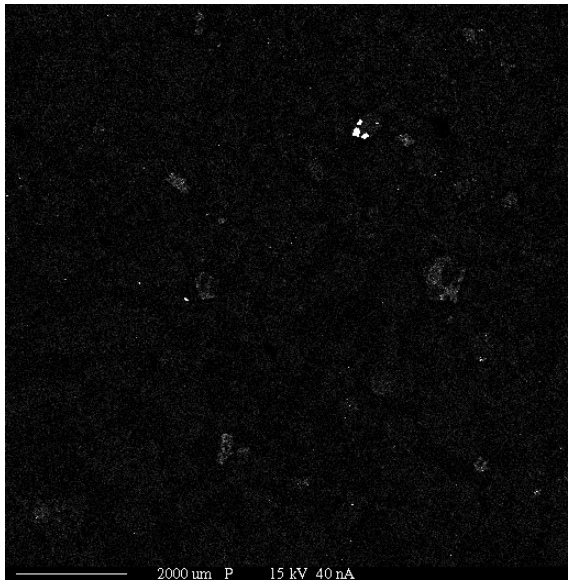
BSE



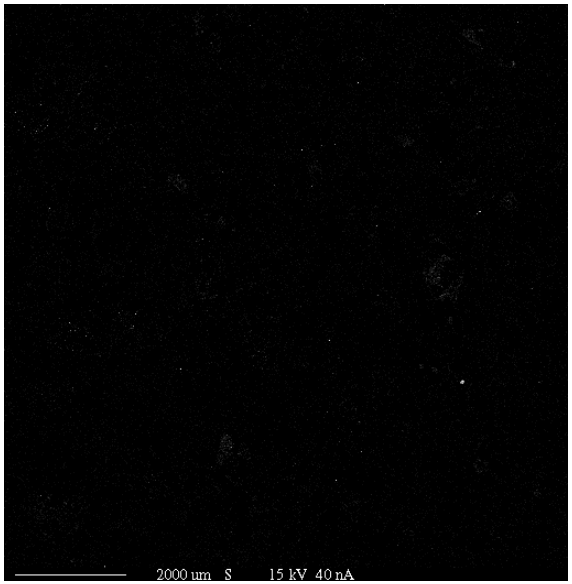
Mg



P

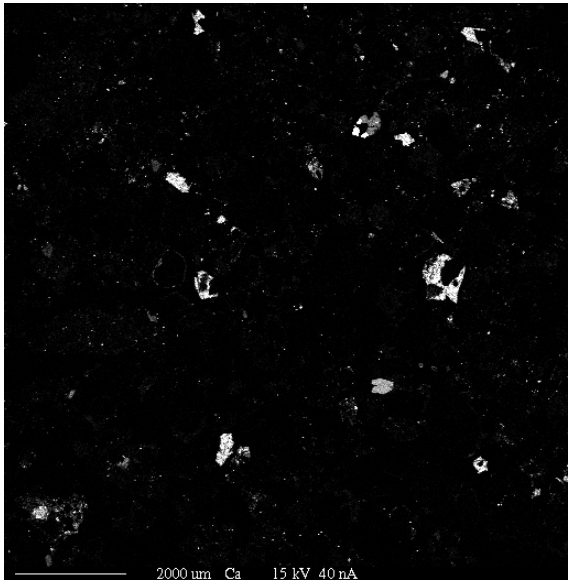


S

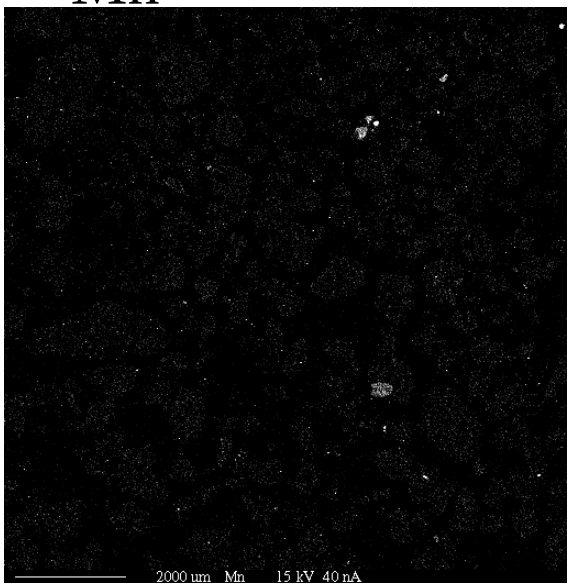


1-MW-9-BP-04

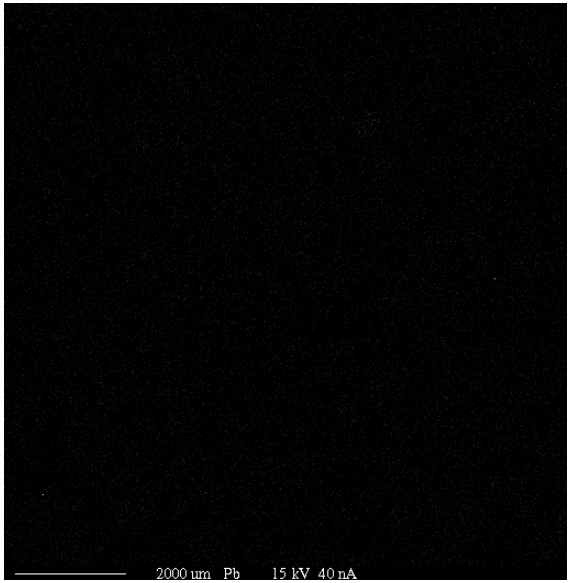
Ca



Mn

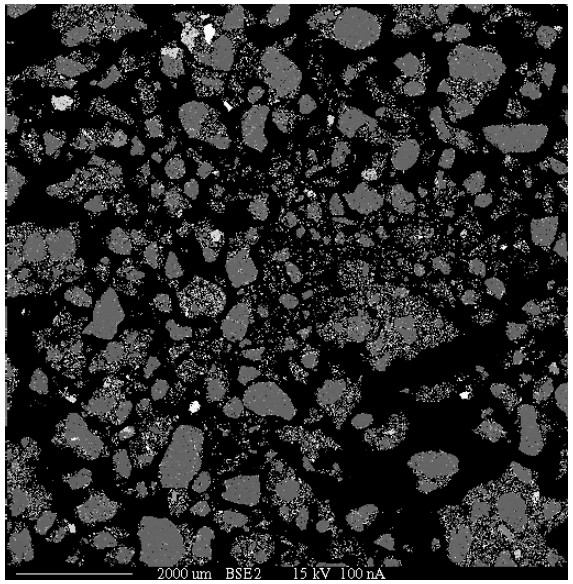


Pb

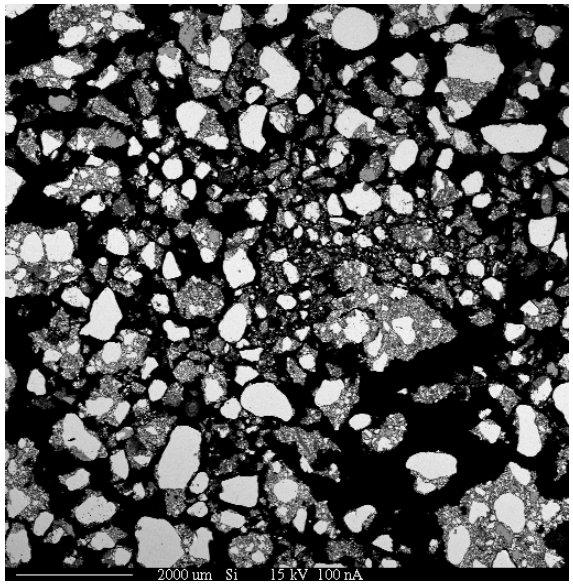


1-MW-8-BP-04 large scale maps
Contains U

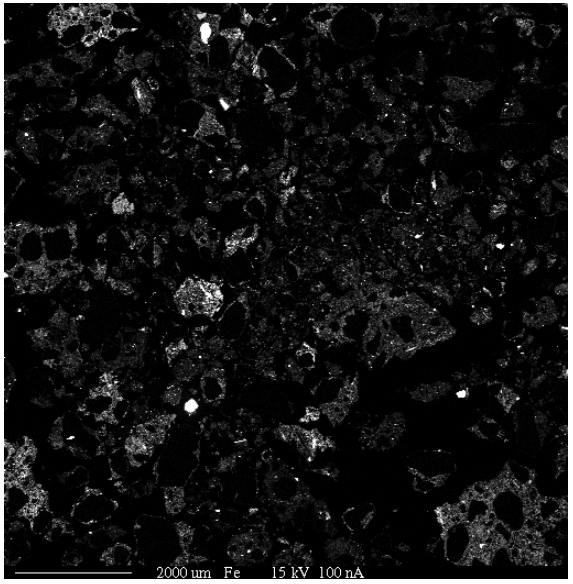
BSE



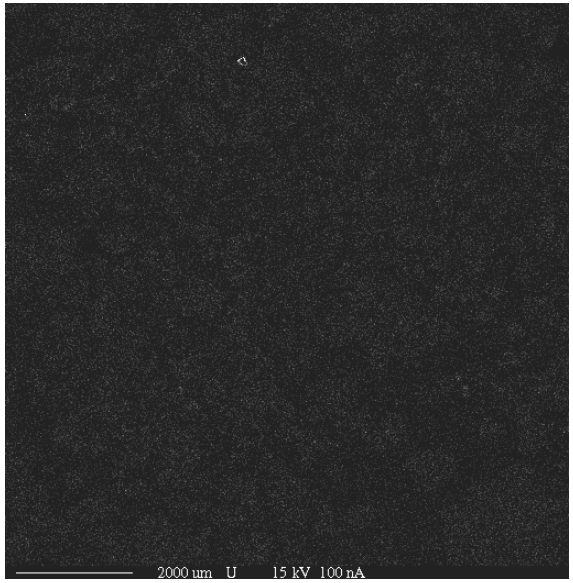
Si



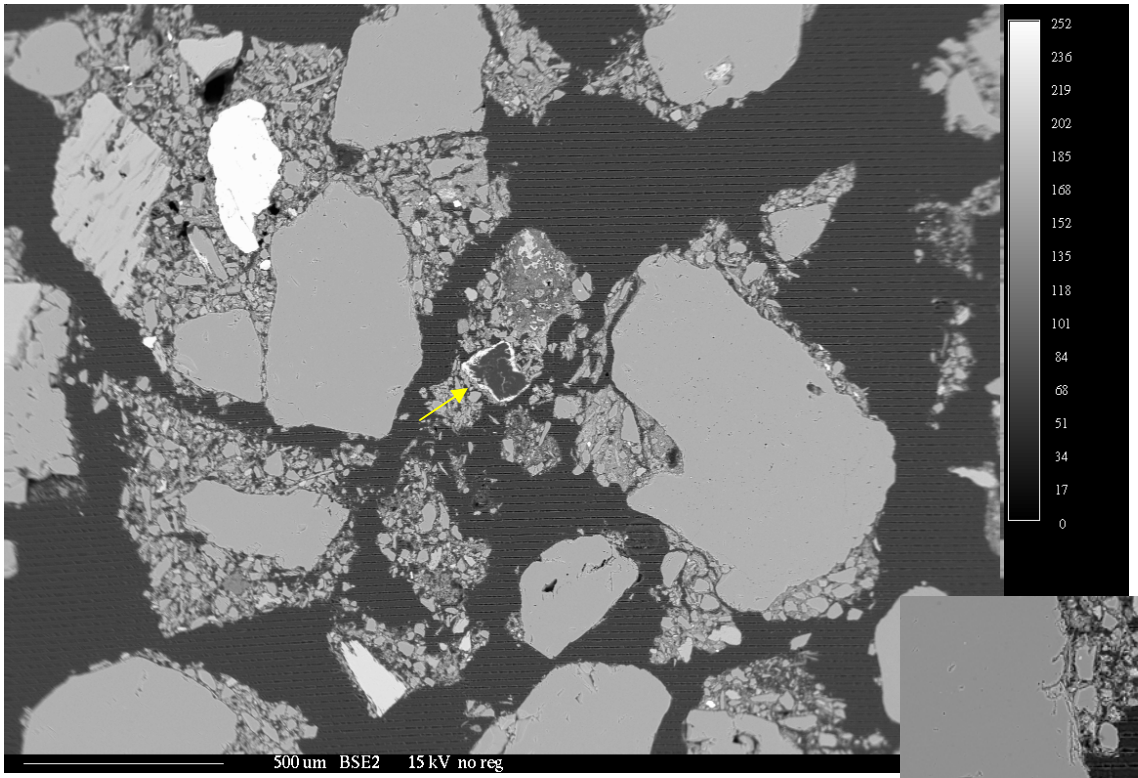
Fe

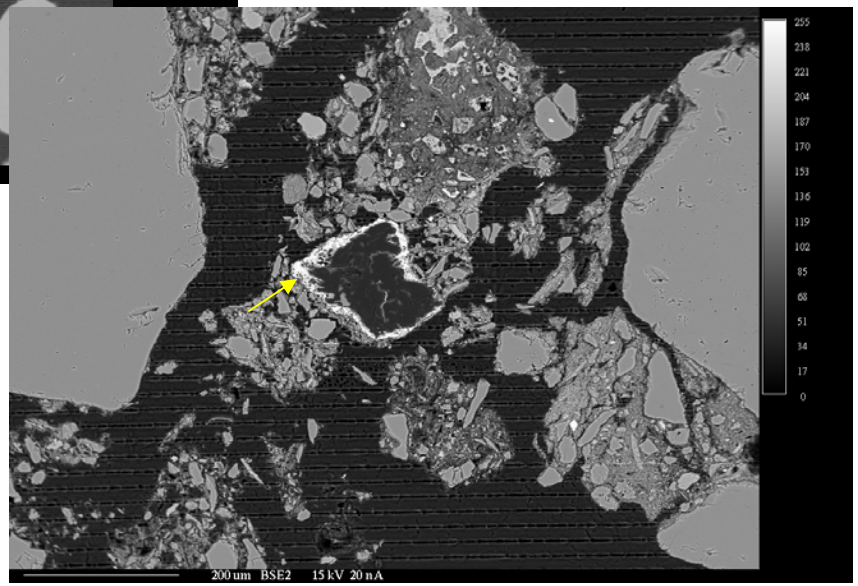


U



1-MW-8-BP-04 higher magnification BSE maps of U-bearing area

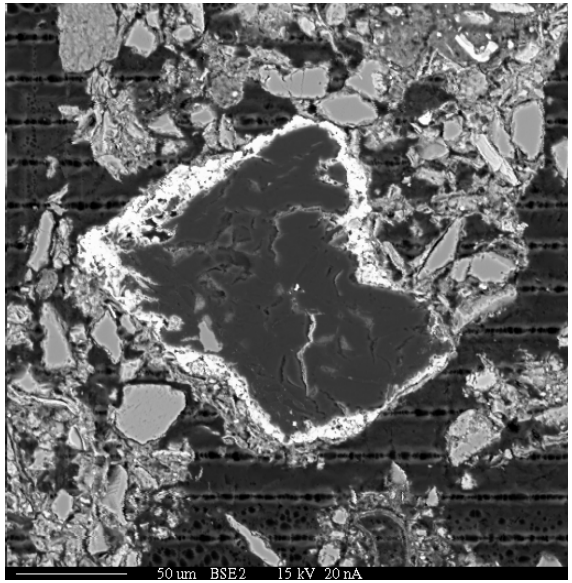




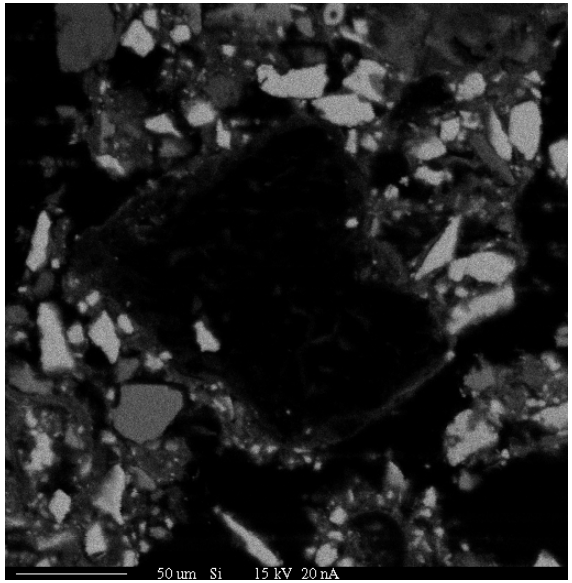
Bright area represents presence of U

1-MW-8-B-P-04 higher mag X-ray maps
U, Fe coating on organic (?) particle

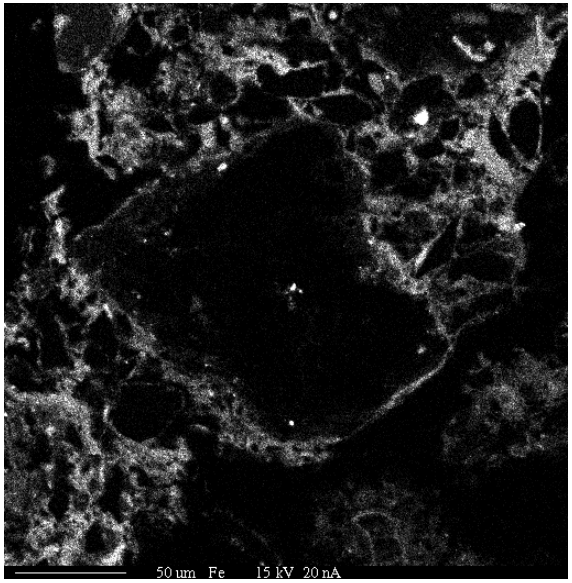
BSE



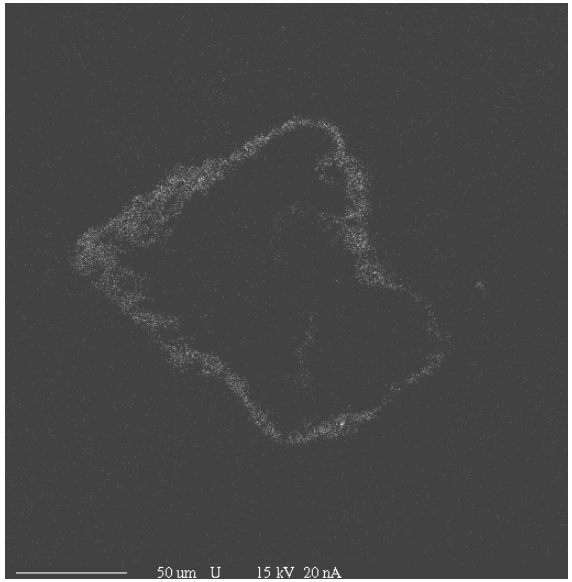
Si



Fe

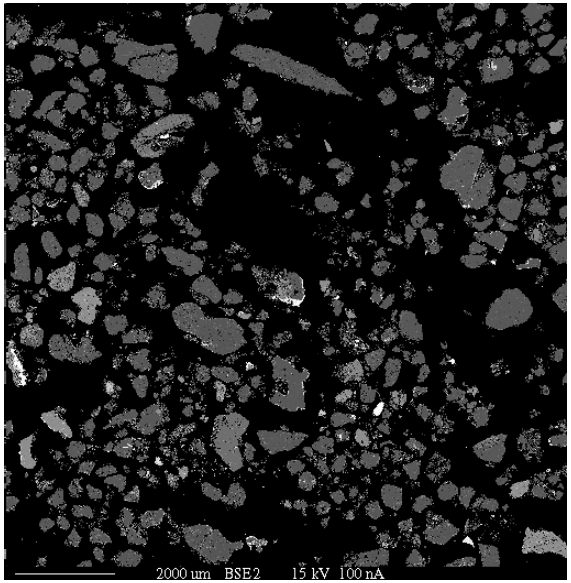


U



1-MW-17-BP-05 large scale maps
Contains U particles

BSE



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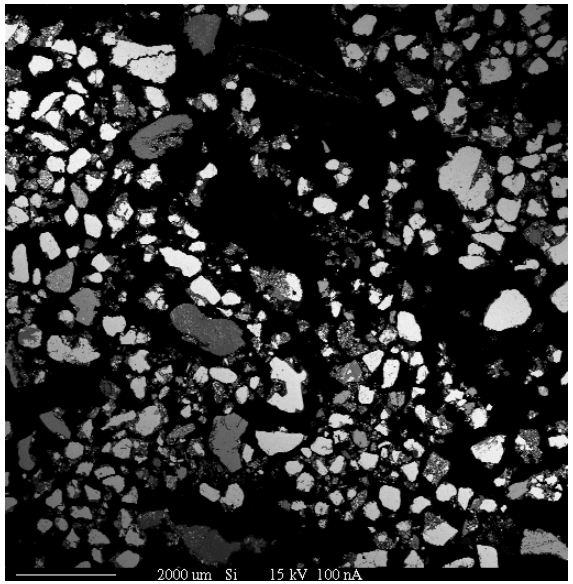

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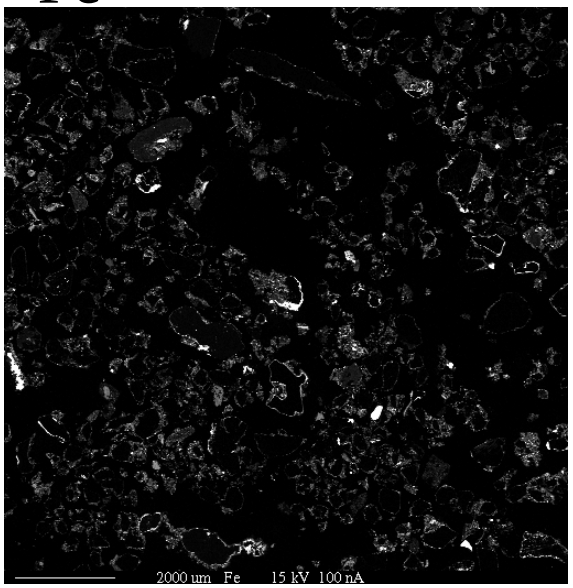
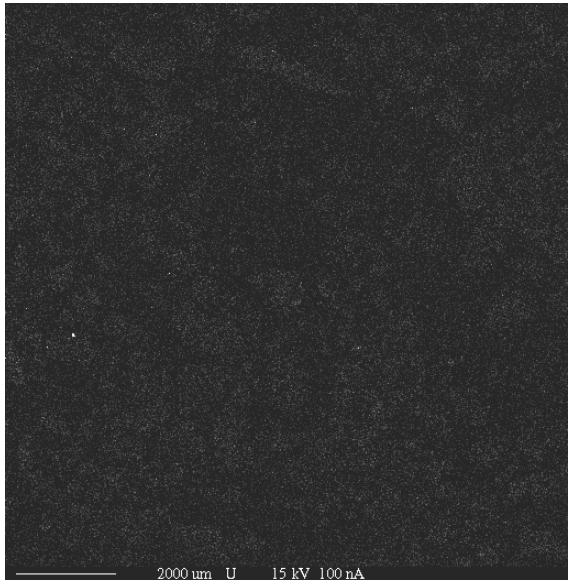
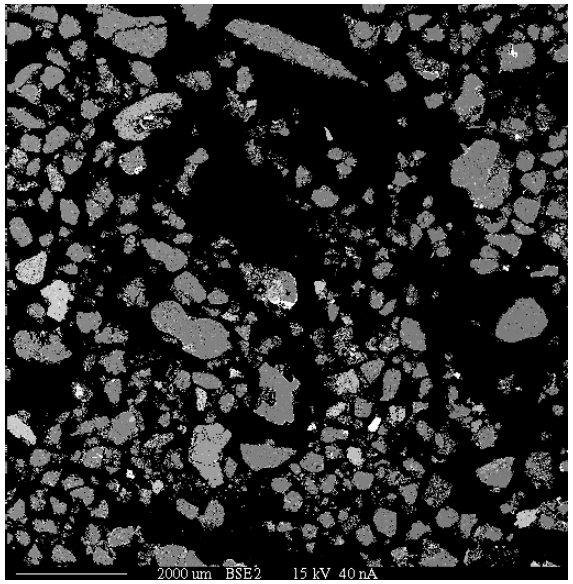


U

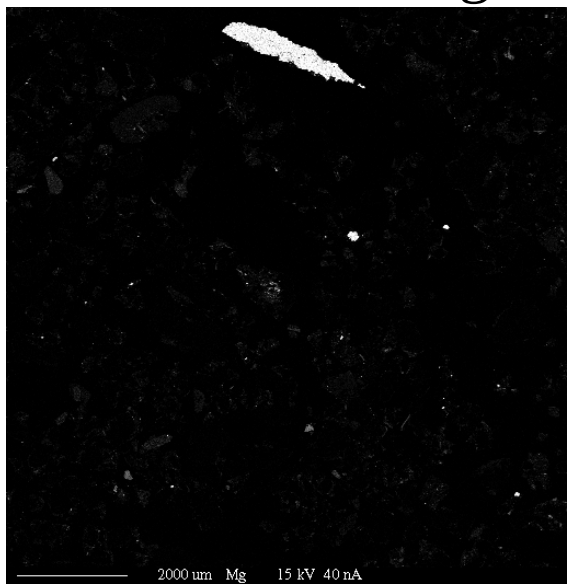


1-MW-17-BP-05

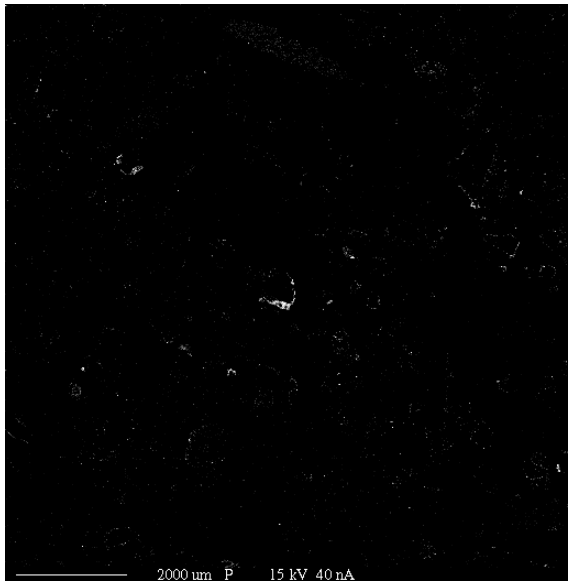
BSE



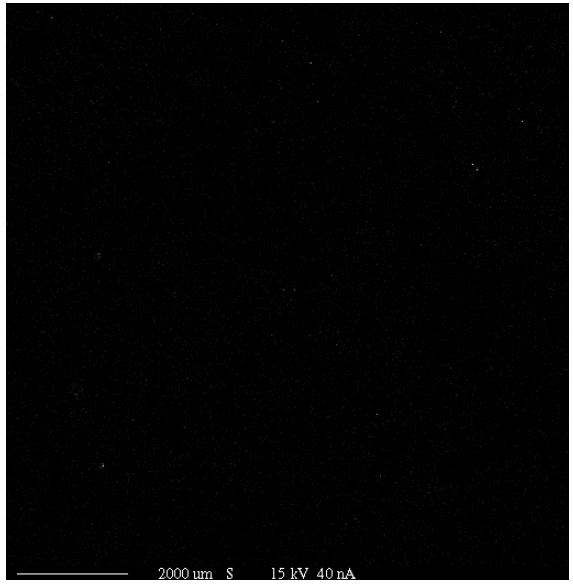
Mg



P

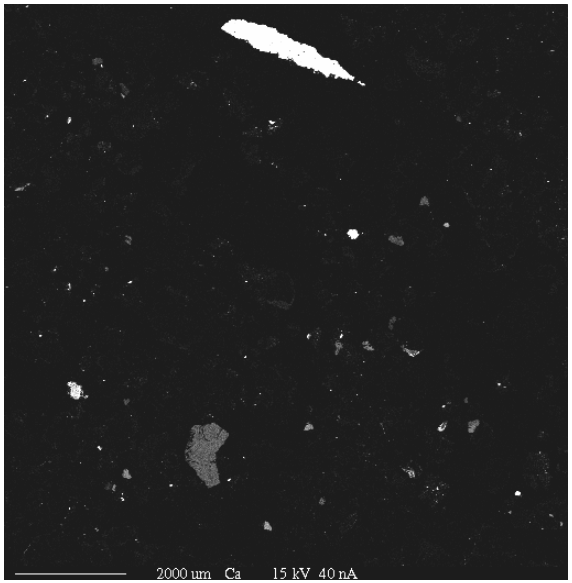


S

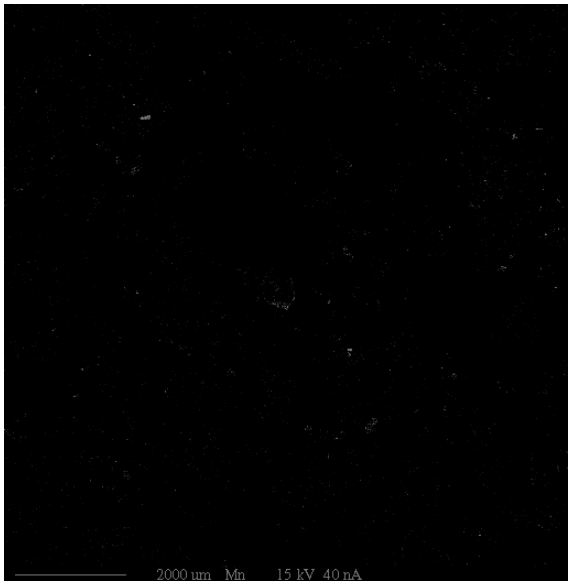


1-MW-17-BP-05

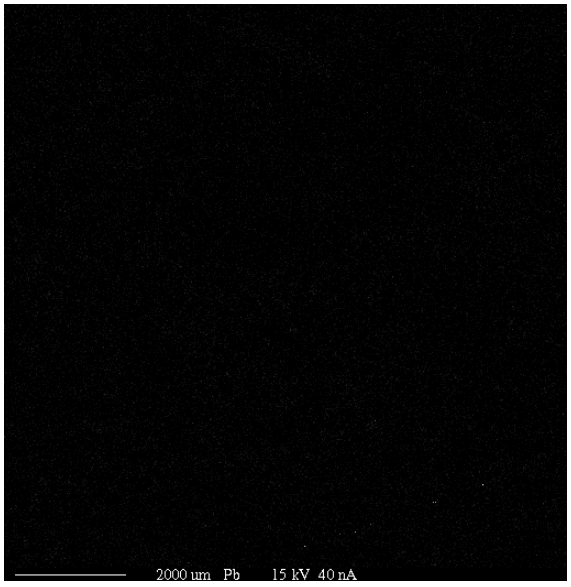
Ca



Mn

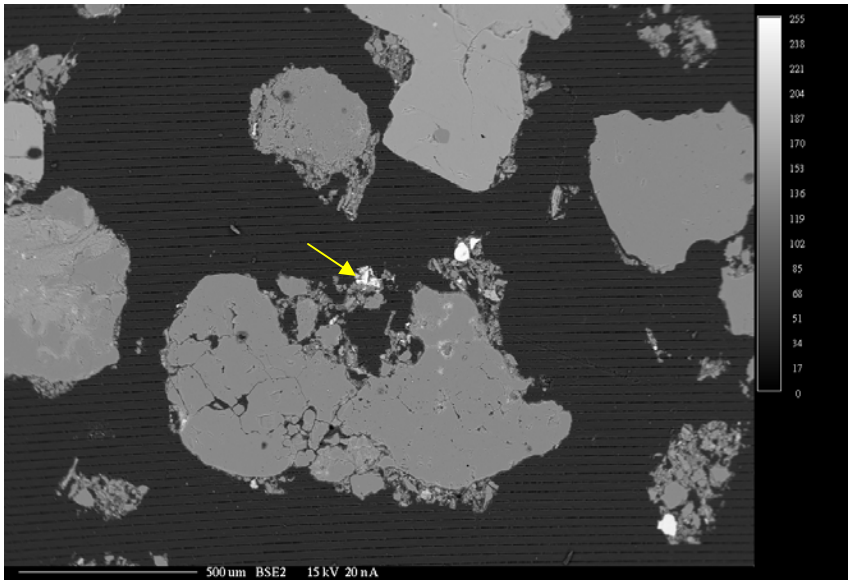


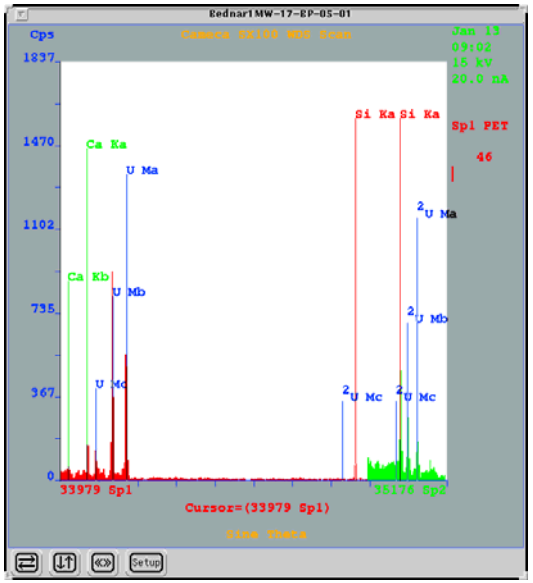
Pb



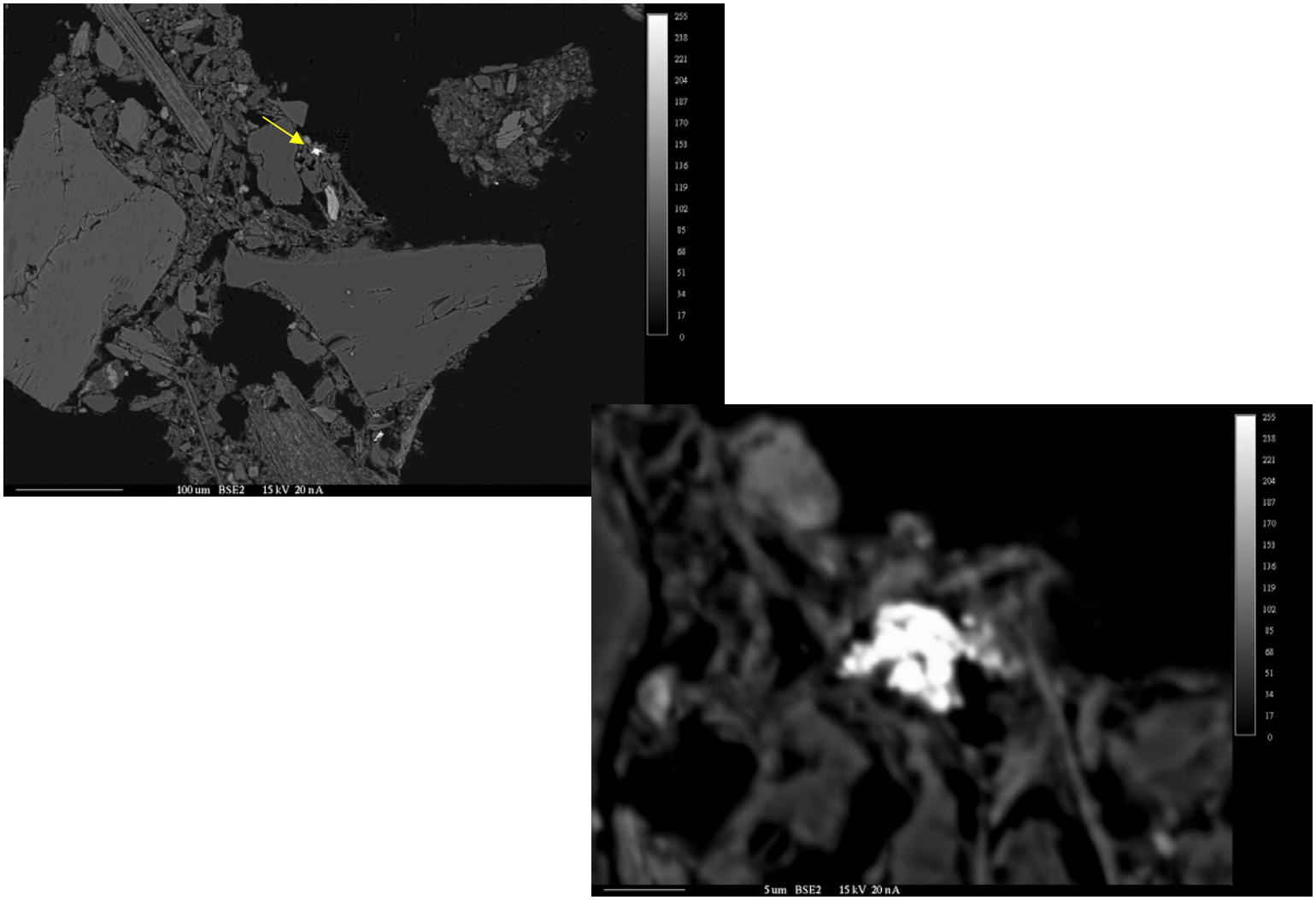
1-MW-17-BP-05 BSE images and qualitative scan of U particles.

Particle 1

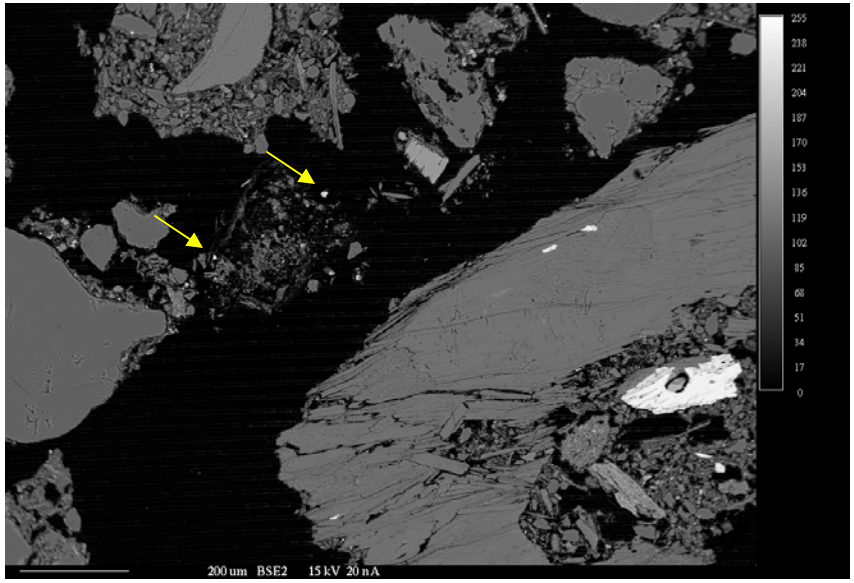


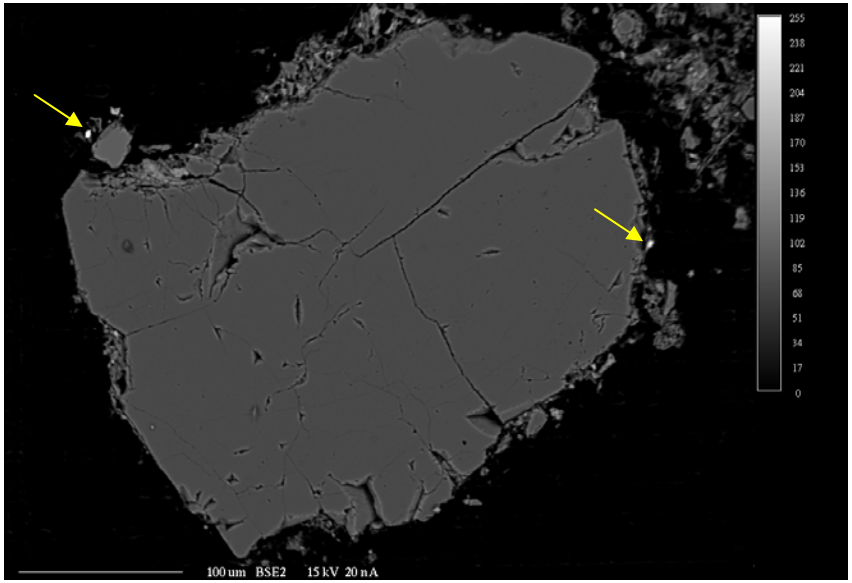


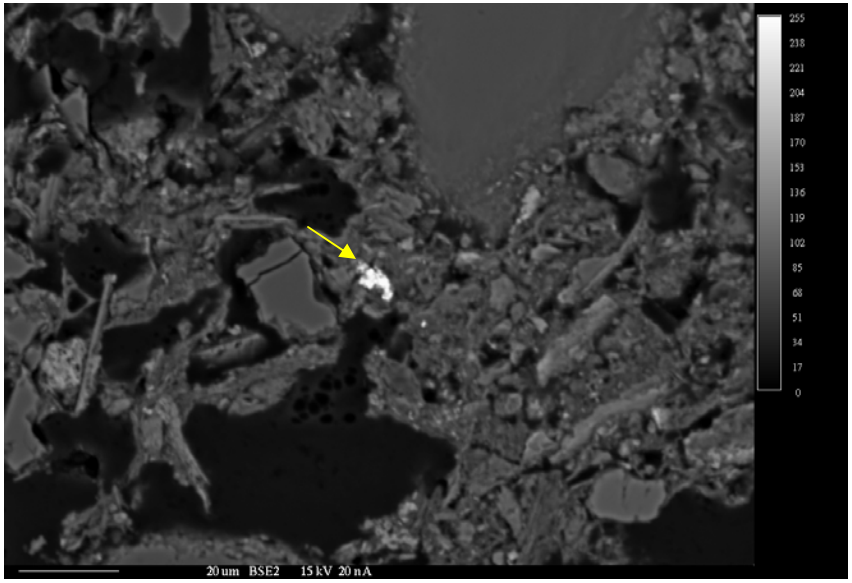
1-MW-17-BP-05 BSE images of U particles
Particle 2

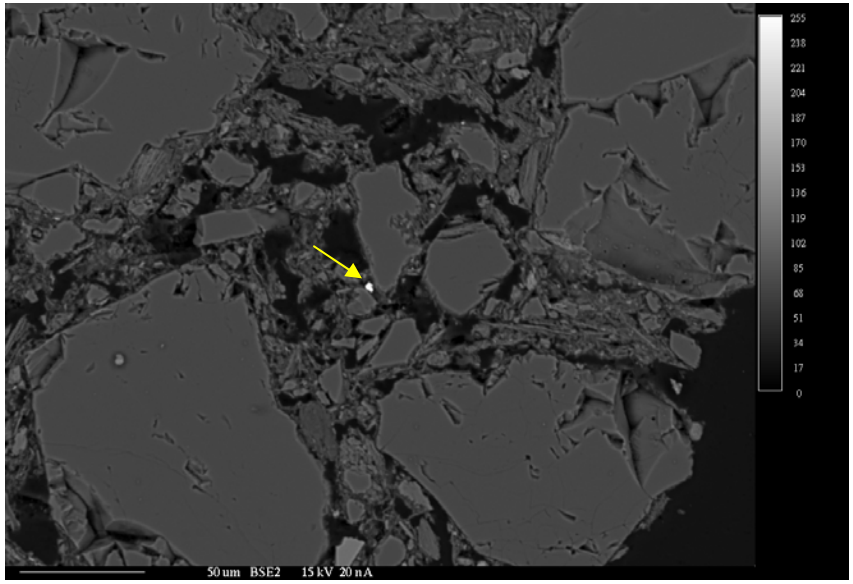


1-MW-17-BP-05 BSE images of U particles
Particles 3,4,5,6

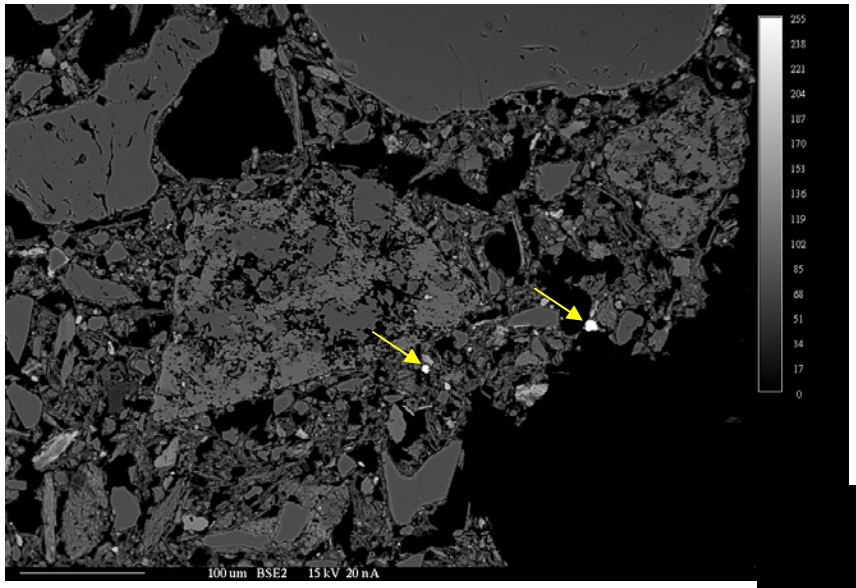


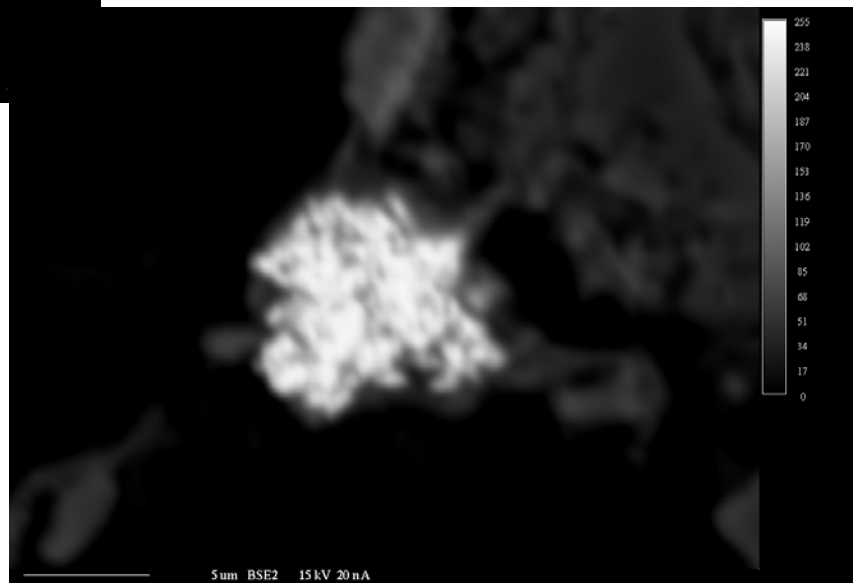






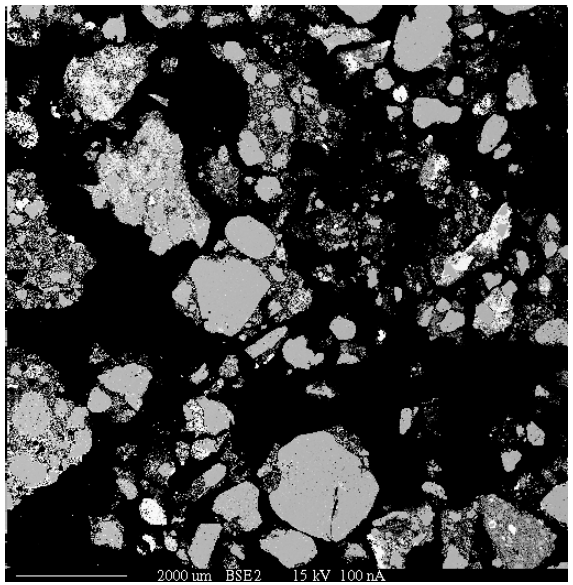
1-MW-17-BP-05 BSE images of U particles
Area 7



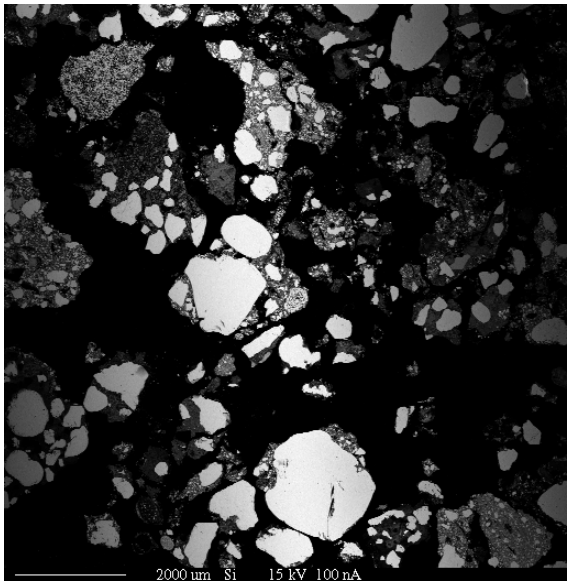


1-MW-18-BP-01 large scale maps
Contains U particles

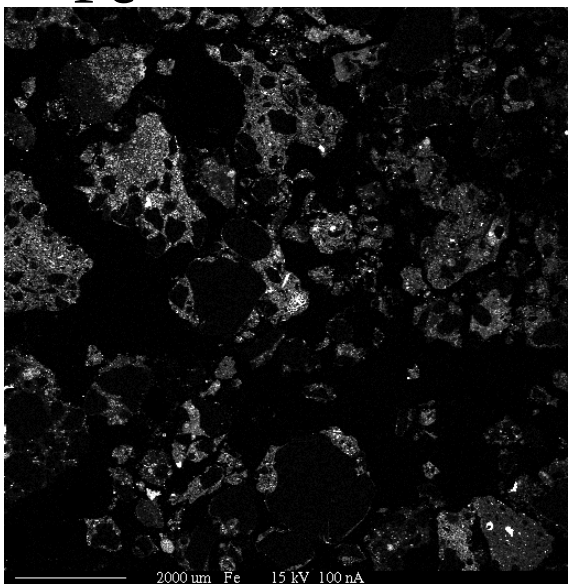
BSE



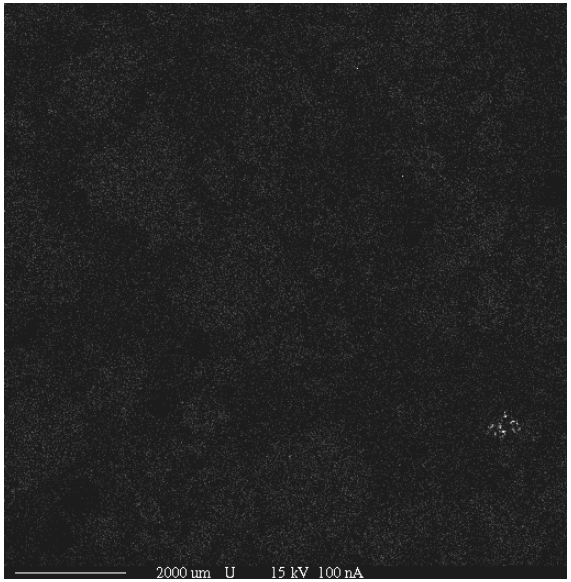
Si



Fe

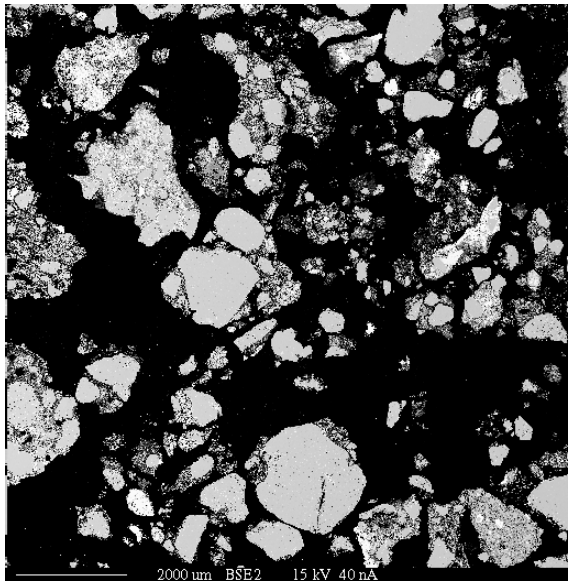


U

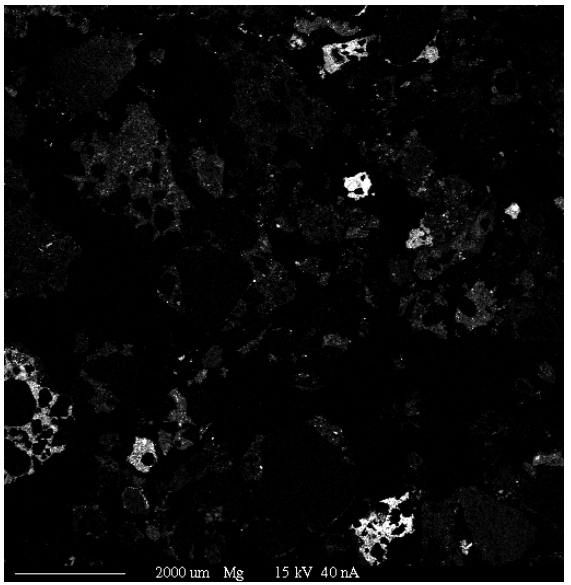


1-MW-18-BP-01

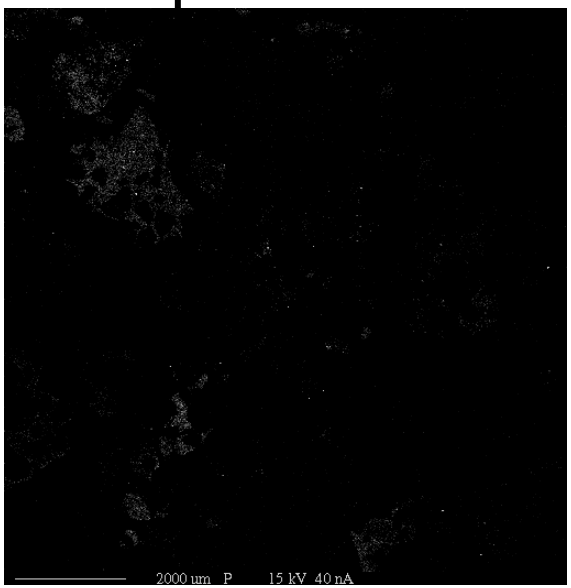
BSE



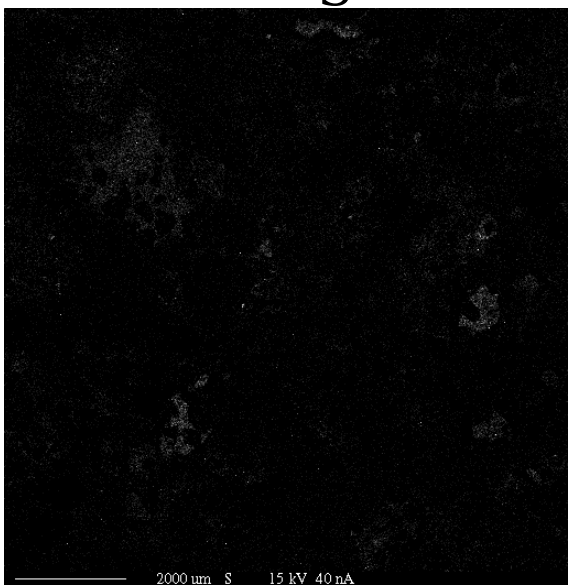
Mg



P

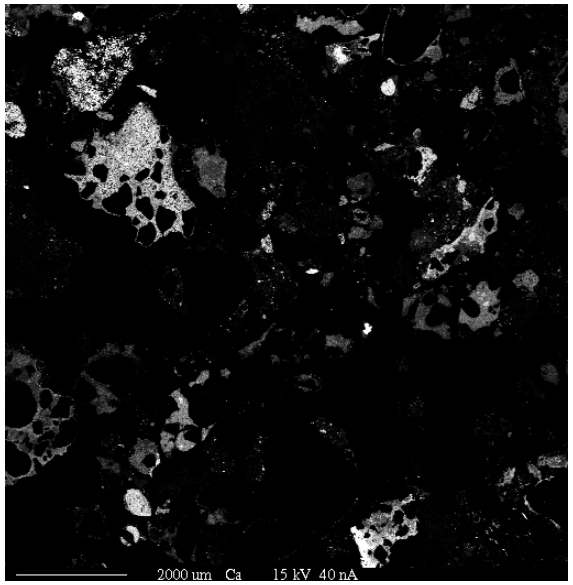


S

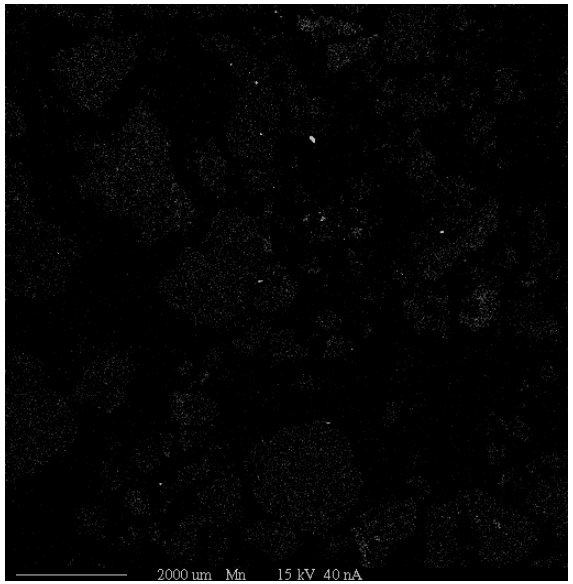


1-MW-18-BP-01

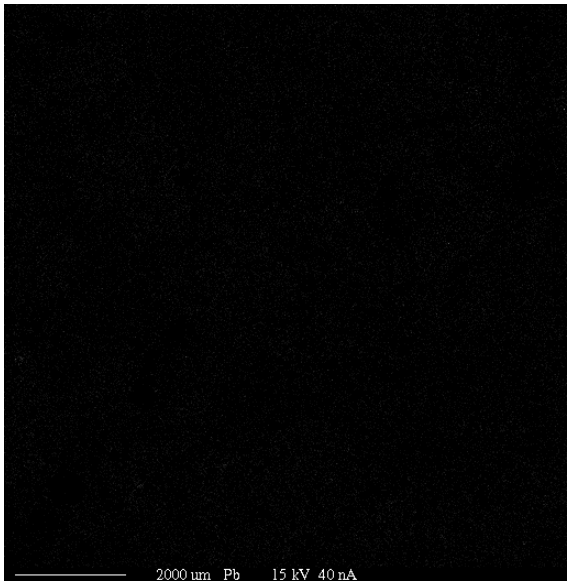
Ca



Mn

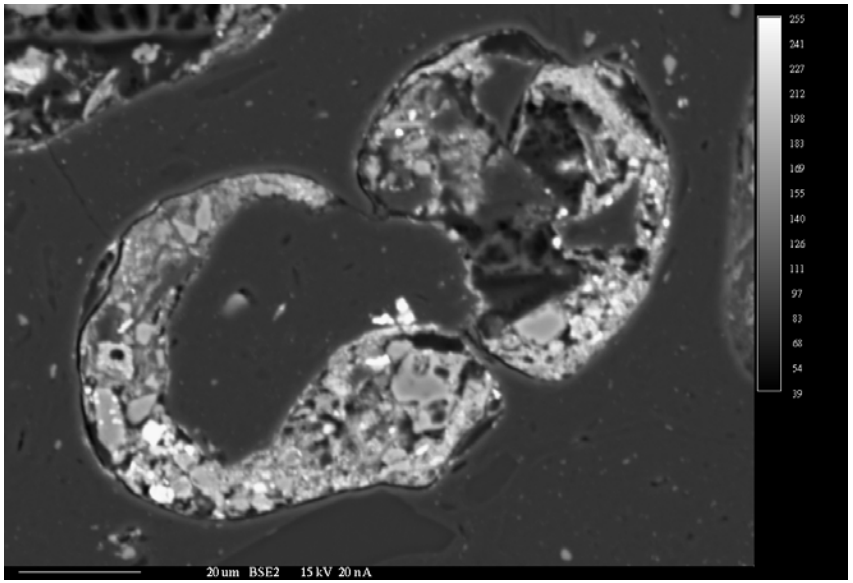


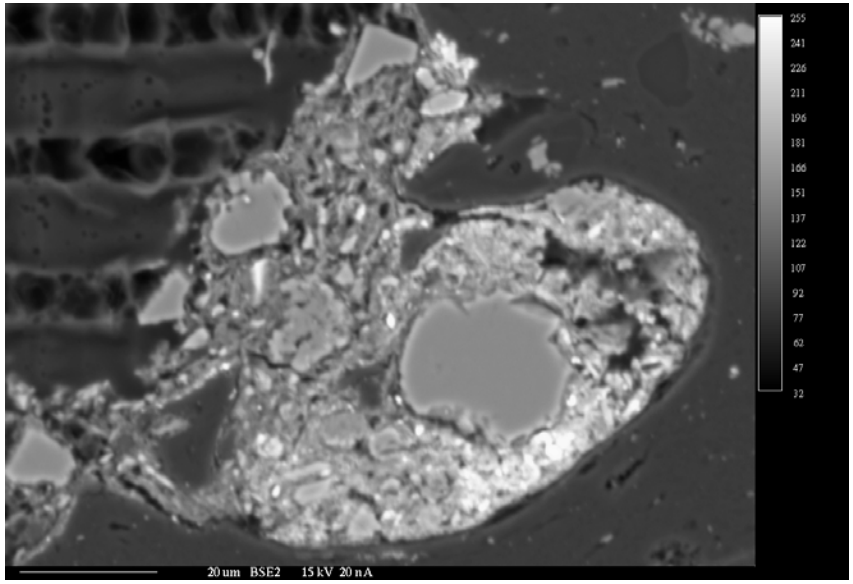
Pb



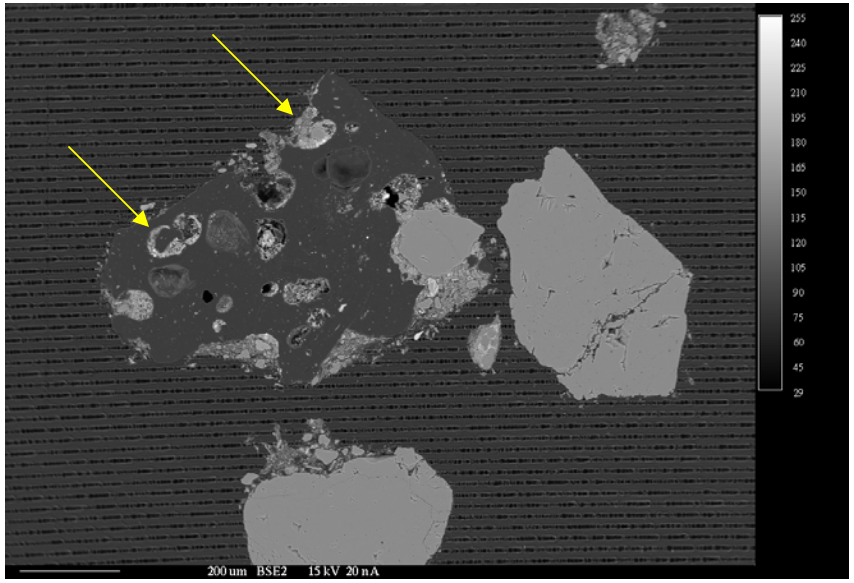
1-MW-18-BP-01 BSE images of U particles
Area 1

high magnification images



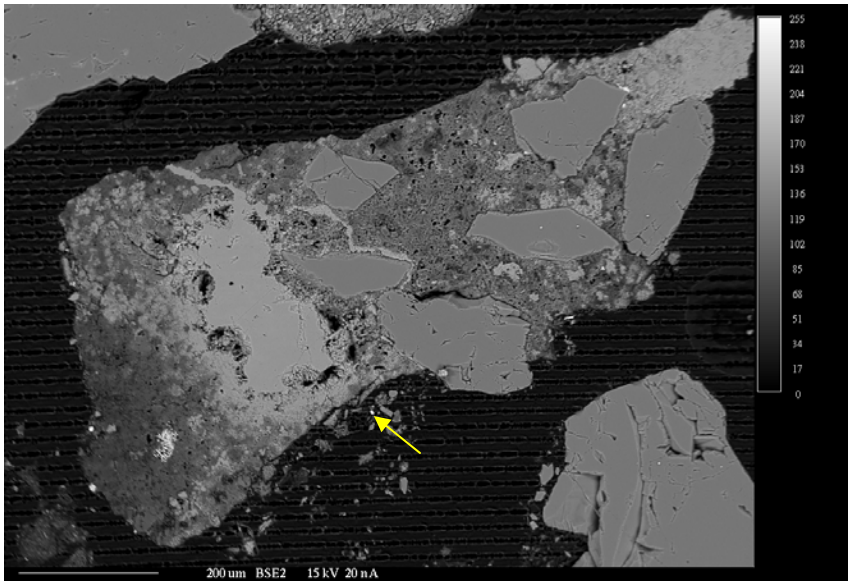


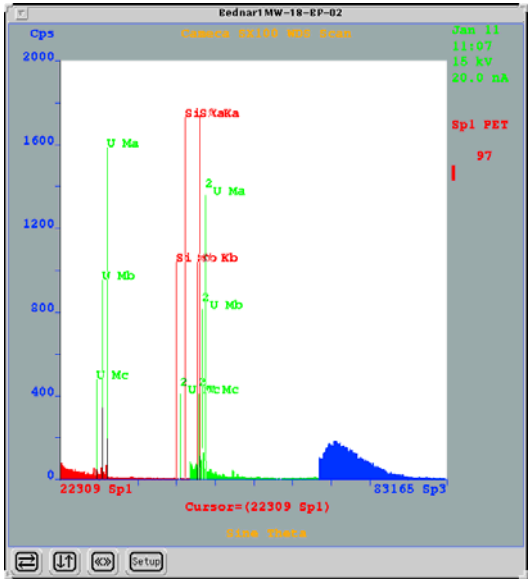
low magnification image

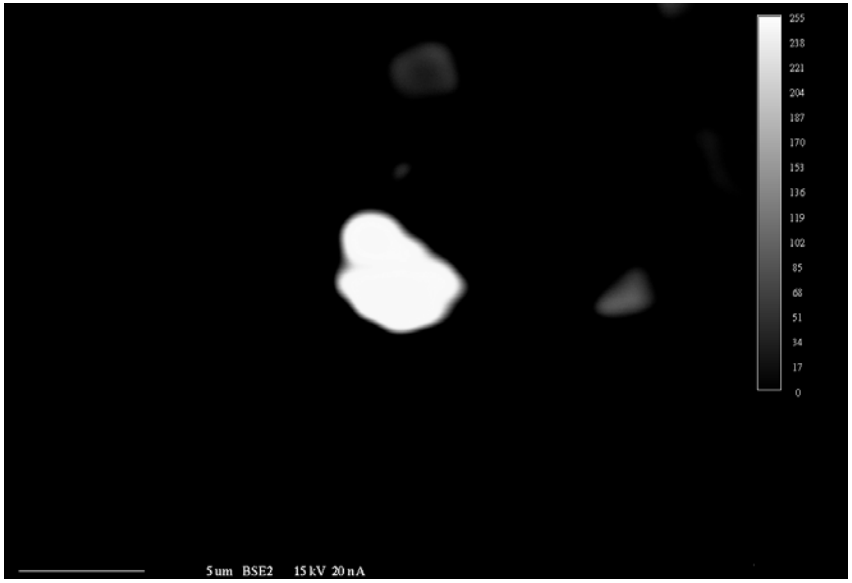


U present in bright areas

1-MW-18-BP-01 BSE images of U particles
Particle 2

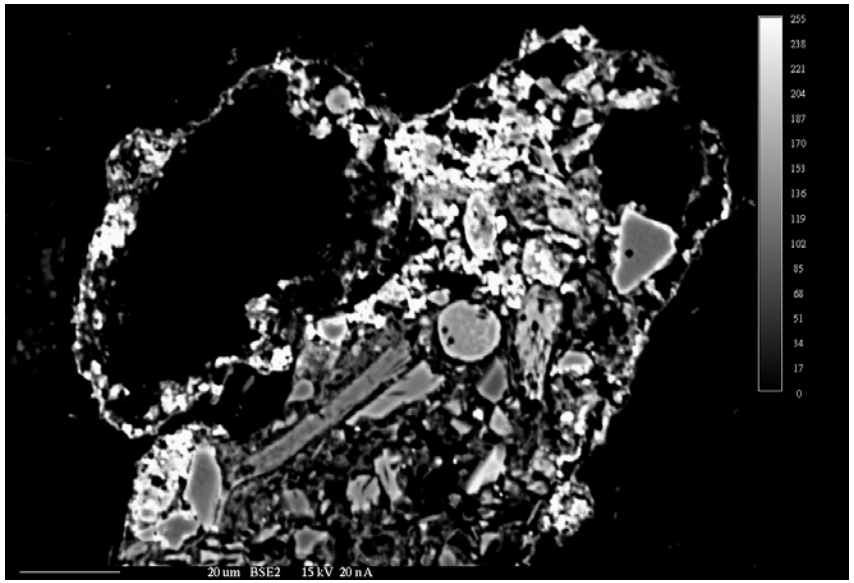


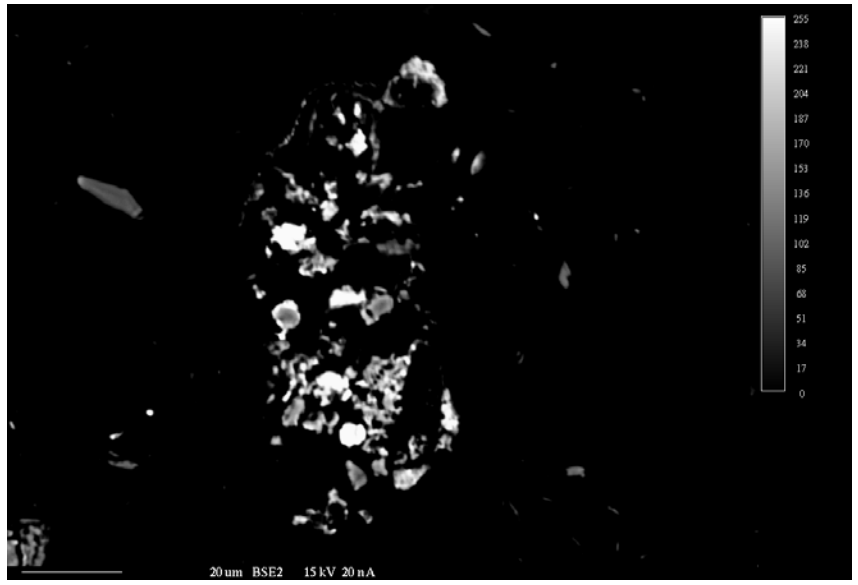




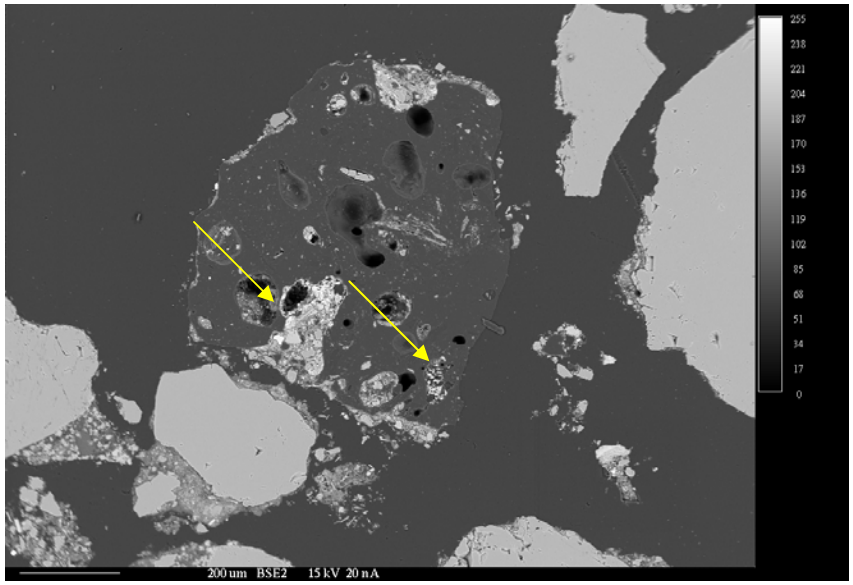
1-MW-18-BP-01 BSE images of U particles
Area 3

high magnification images





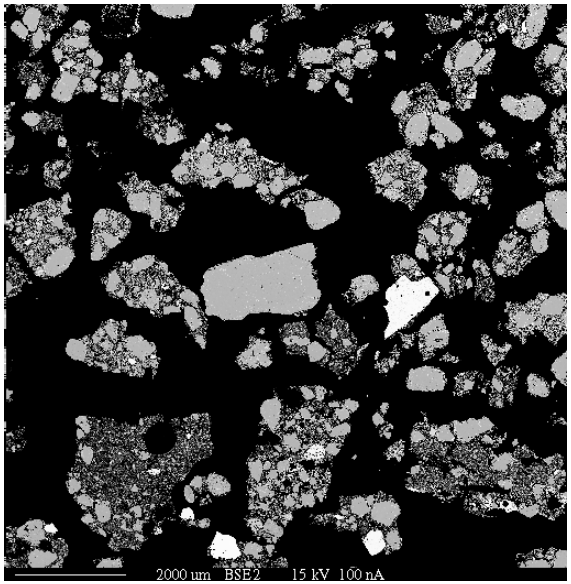
low magnification image



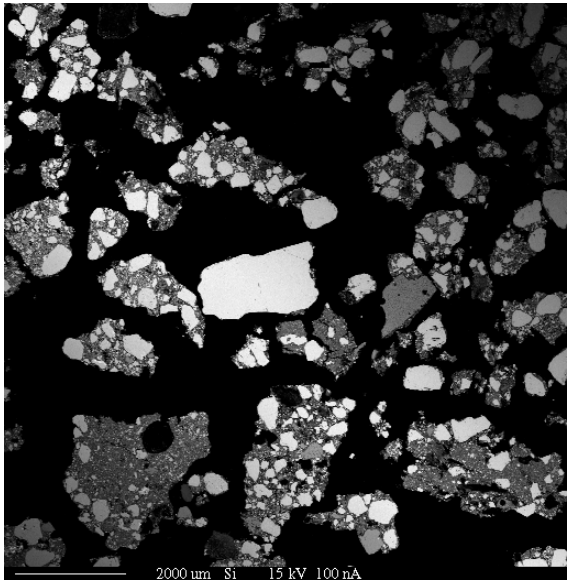
U present in bright areas

2-MW-2-BP-03 large scale maps
Contains U particles

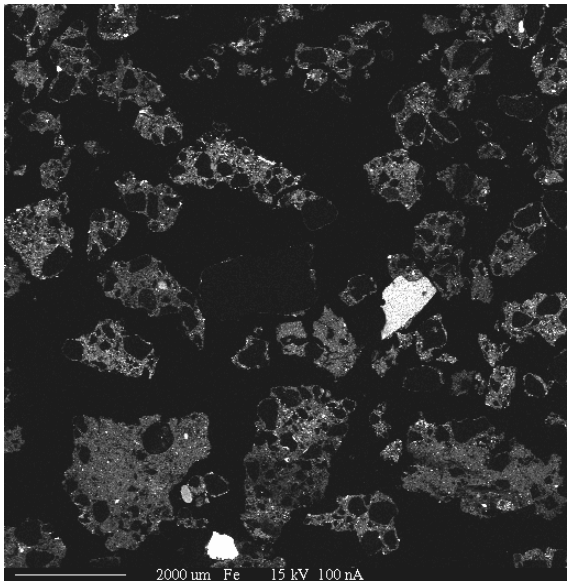
BSE



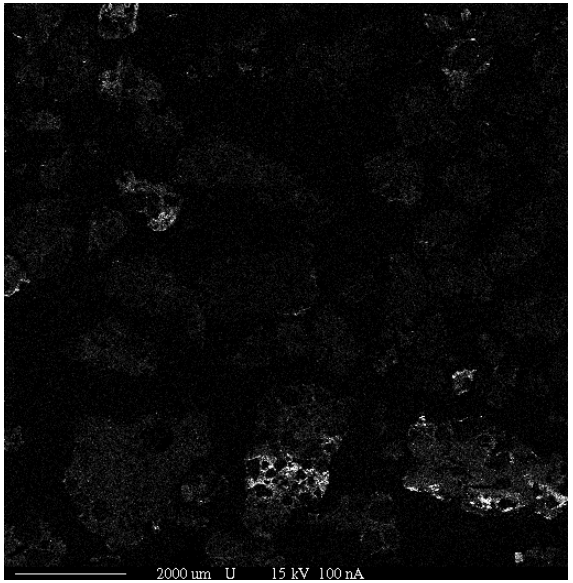
Si



Fe

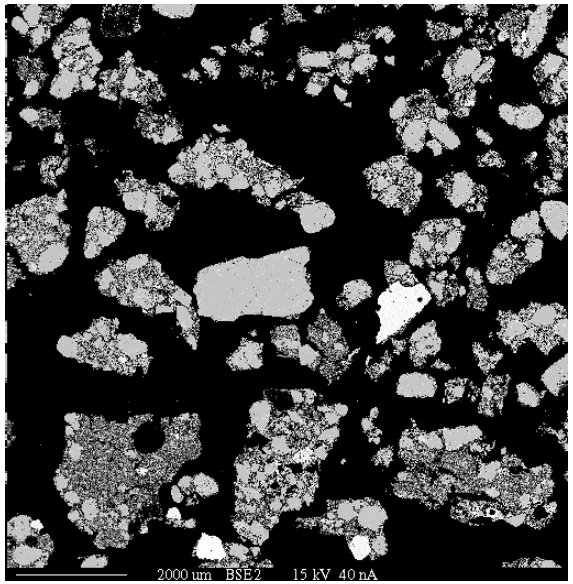


U

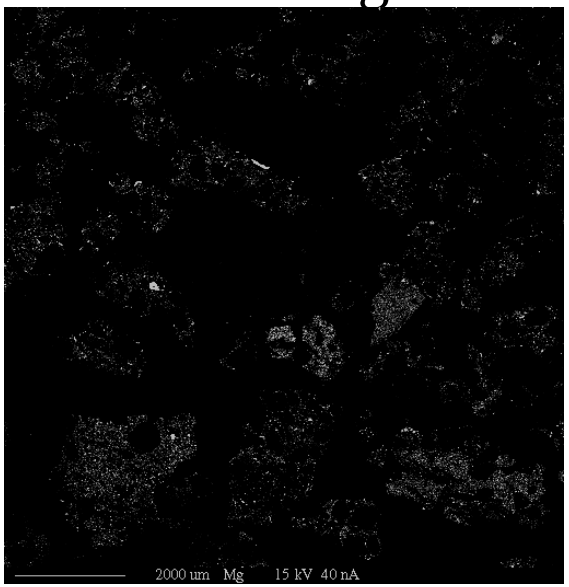


2-MW-2-BP-03

BSE



Mg



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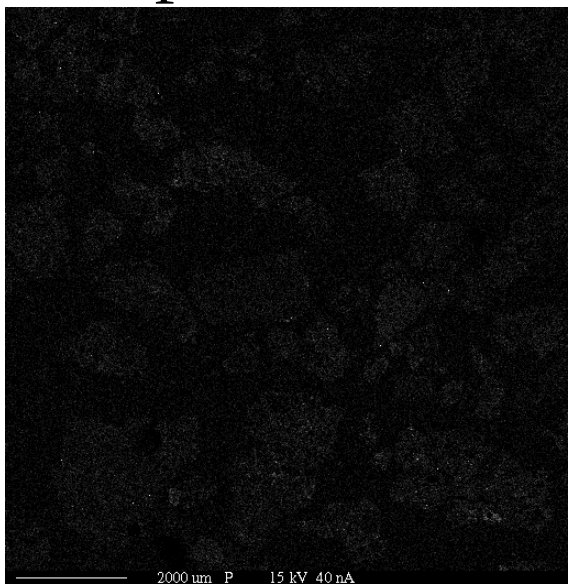

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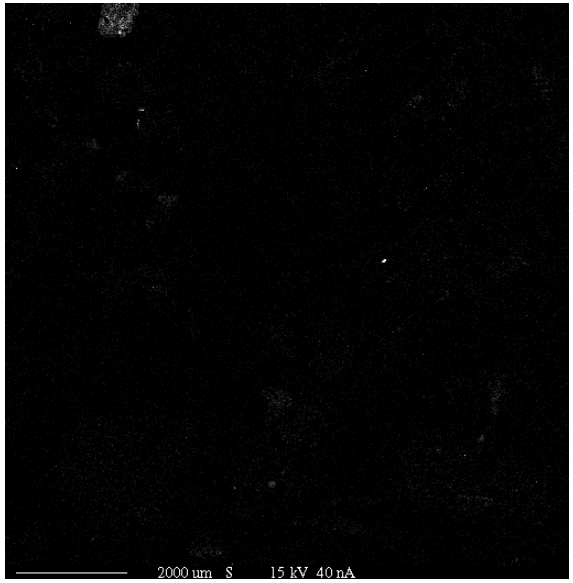
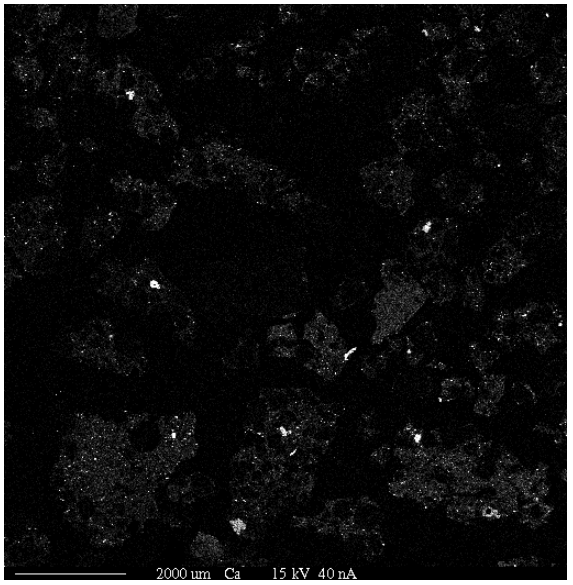
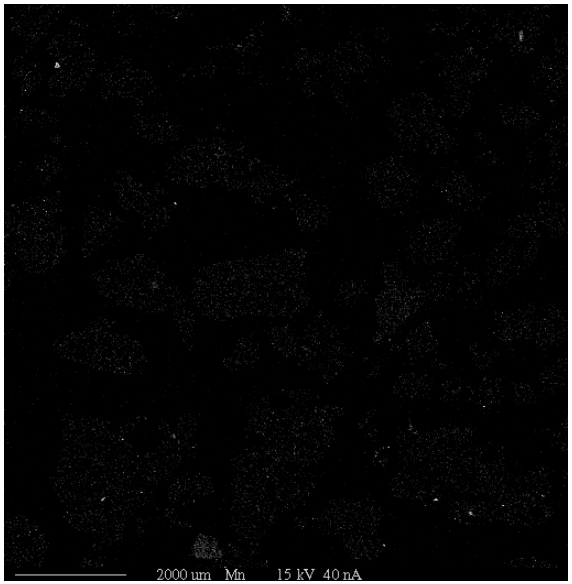


2-MW-2-BP-03

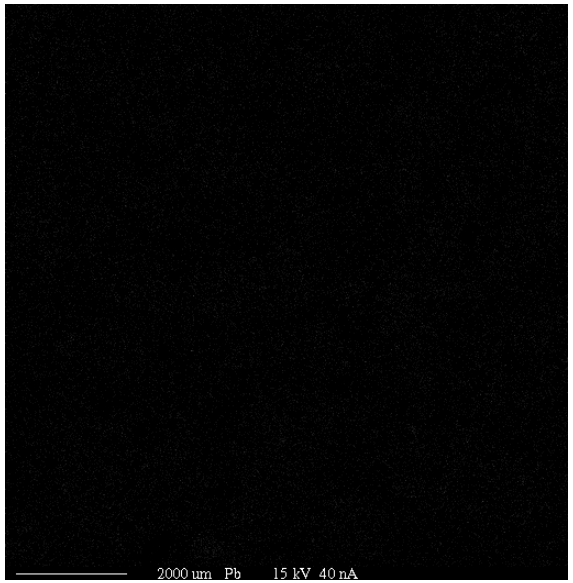
Ca



Mn

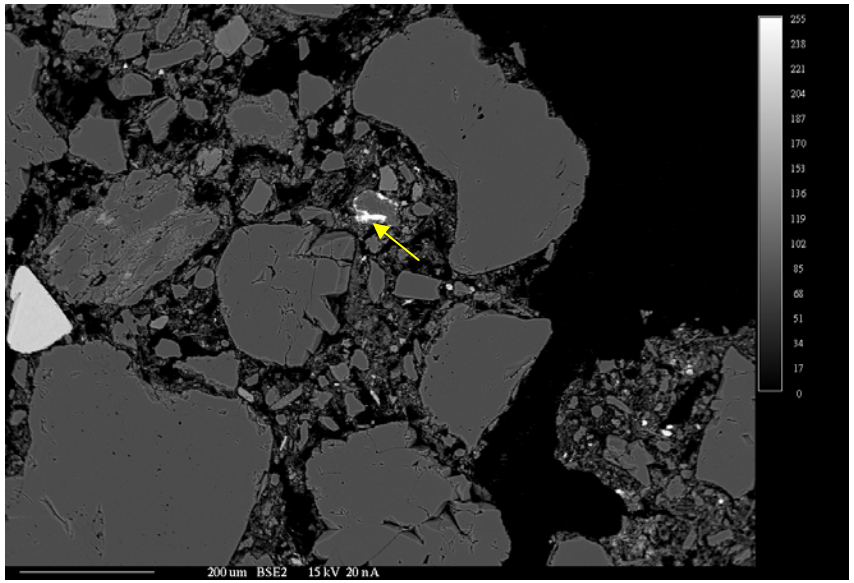


Pb

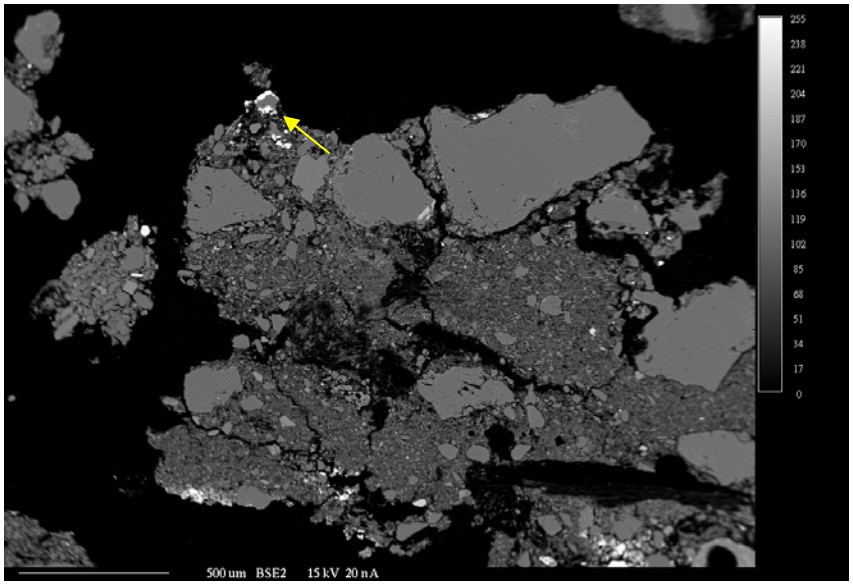


2-MW-2-BP-03 BSE images of U particles grains 1, 2, and 3

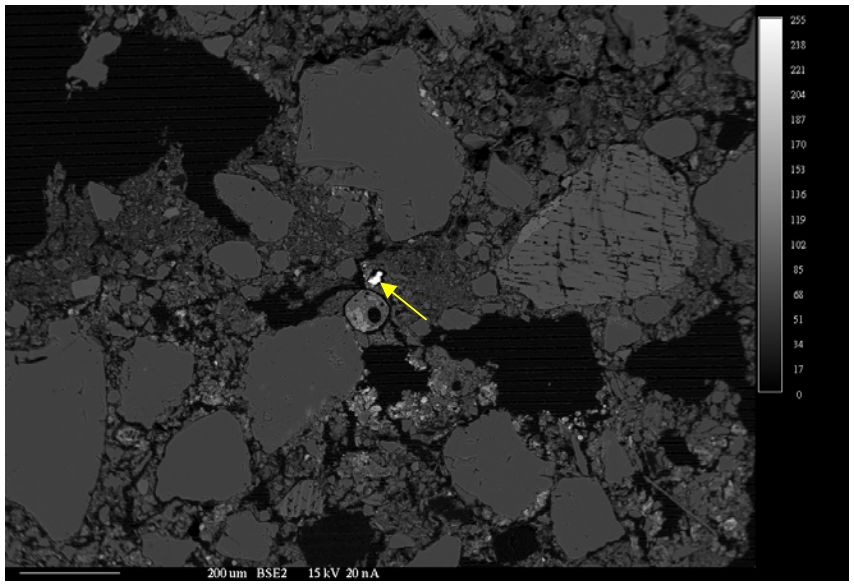
1

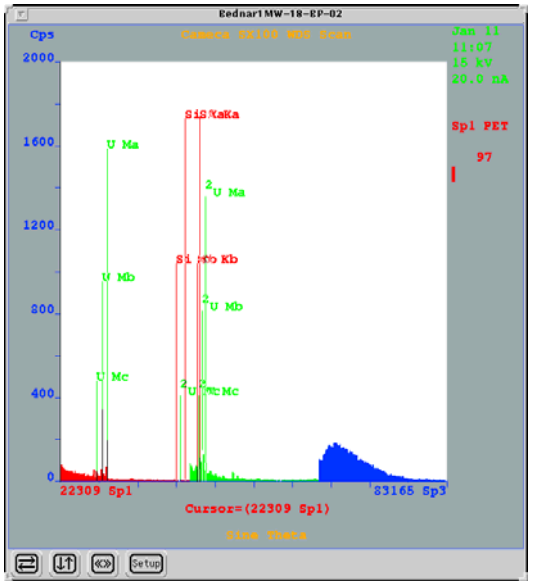


2

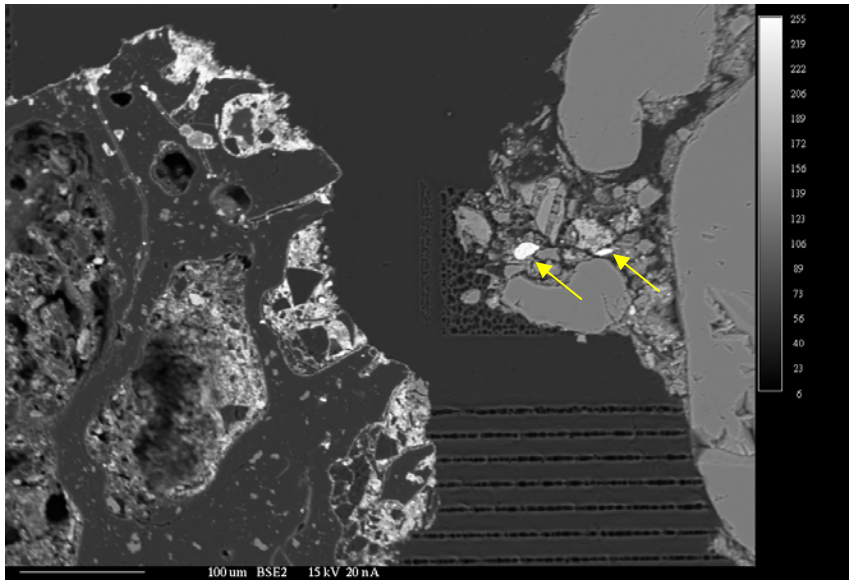


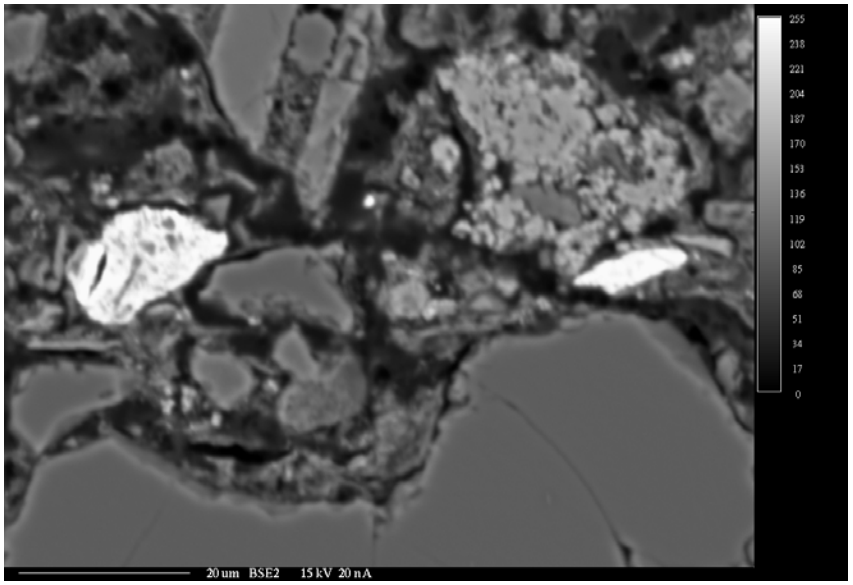
3





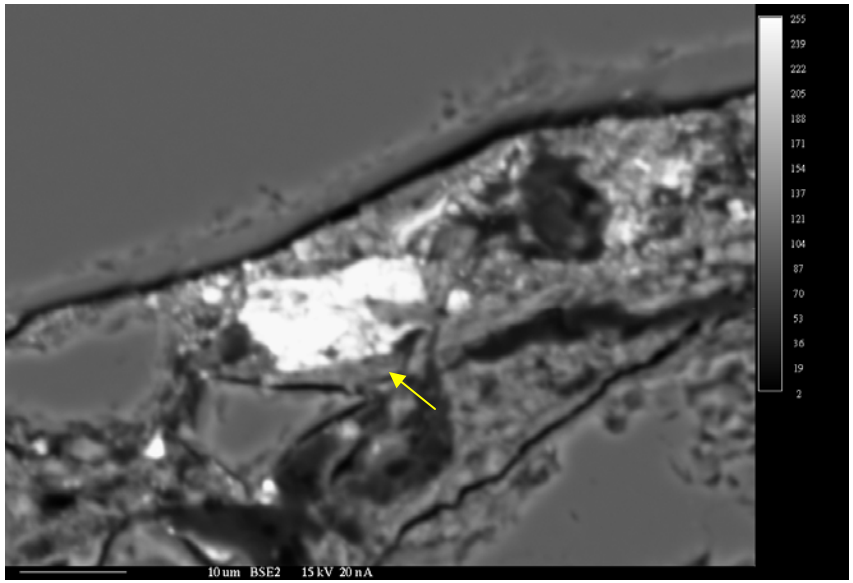
2-MW-2-BP-03 BSE images of U particles
Area 4



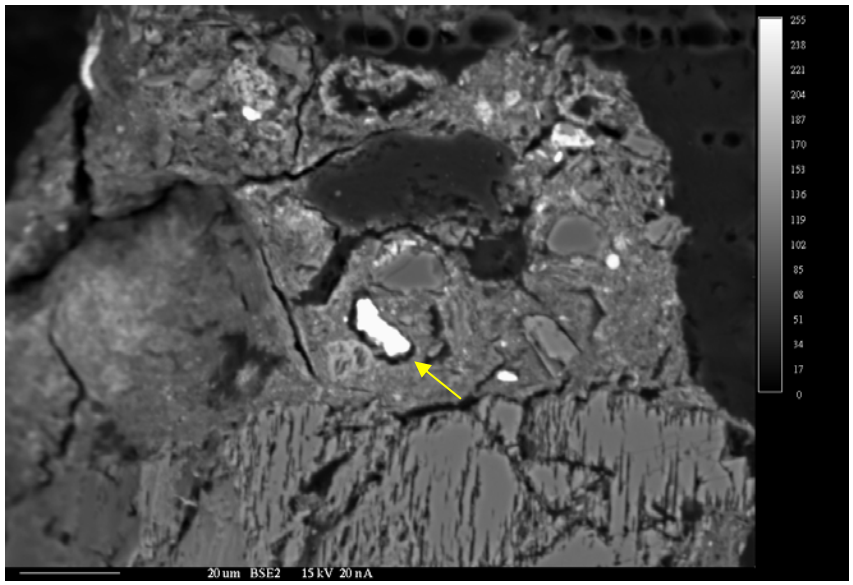


2-MW-2-BP-03 BSE images of U particles grains 5 and 6

5

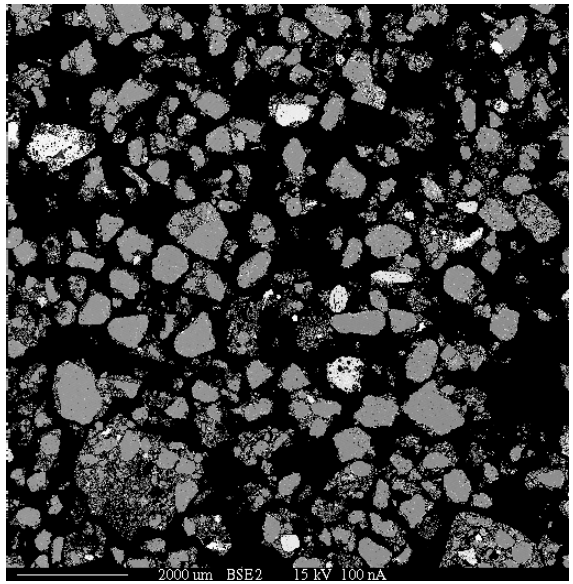


6

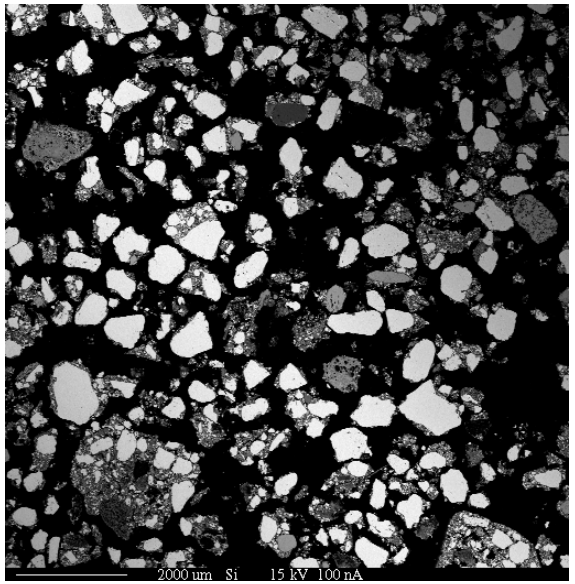


2-MW-3-BP-03 large scale maps
Contains U particles

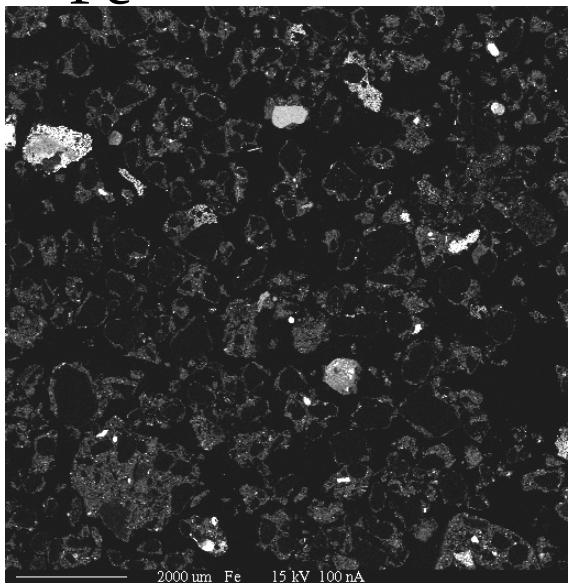
BSE



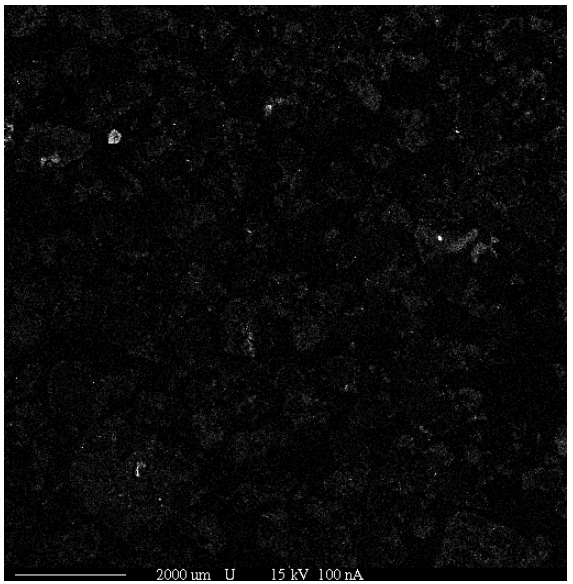
Si



Fe

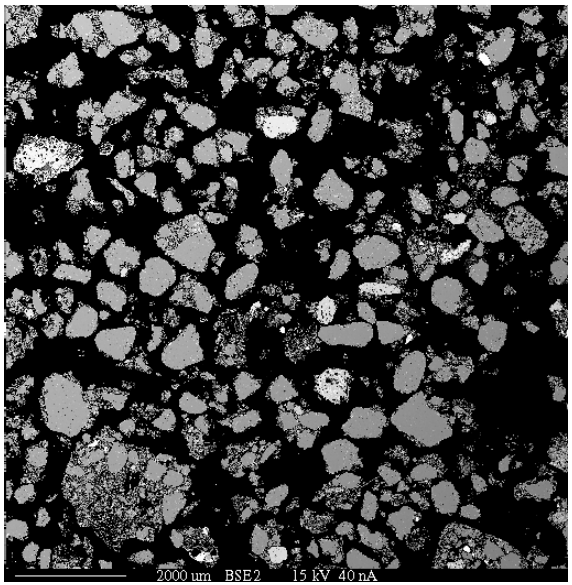


U

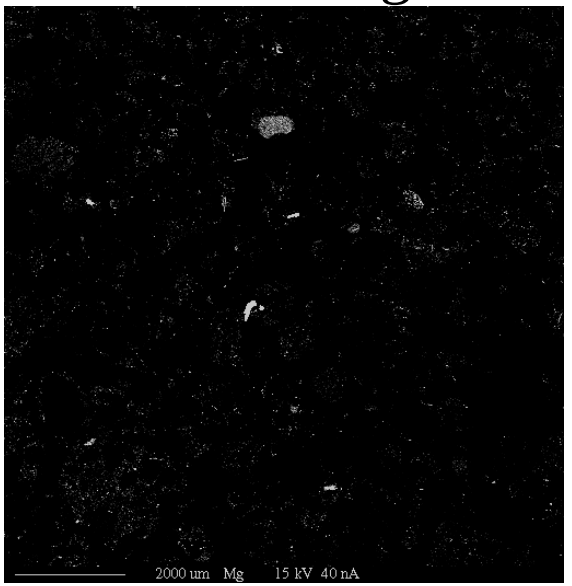


2-MW-3-BP-03

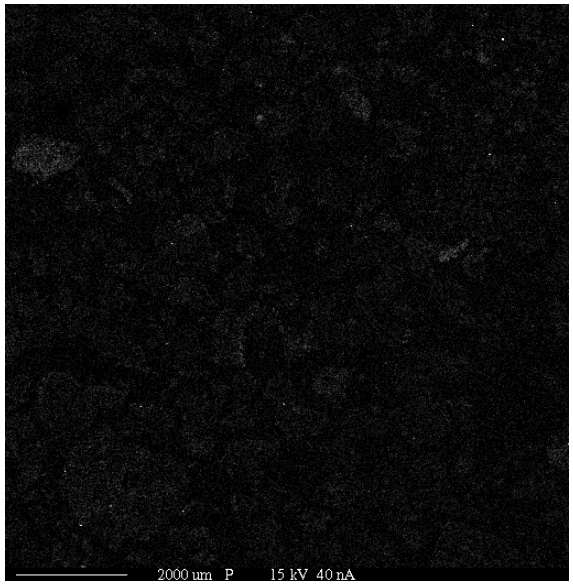
BSE



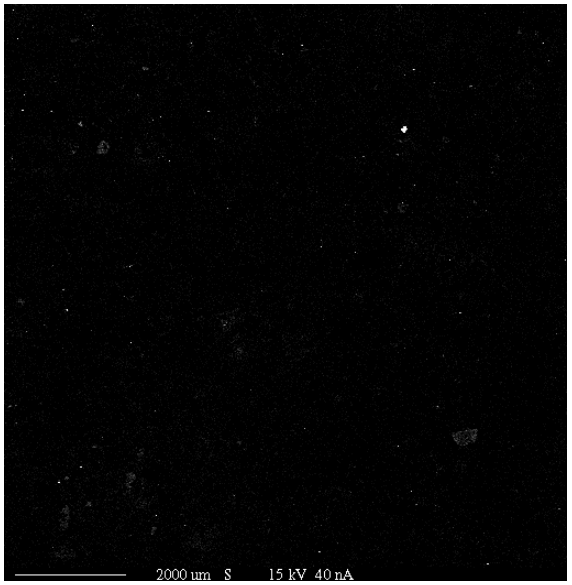
Mg



P

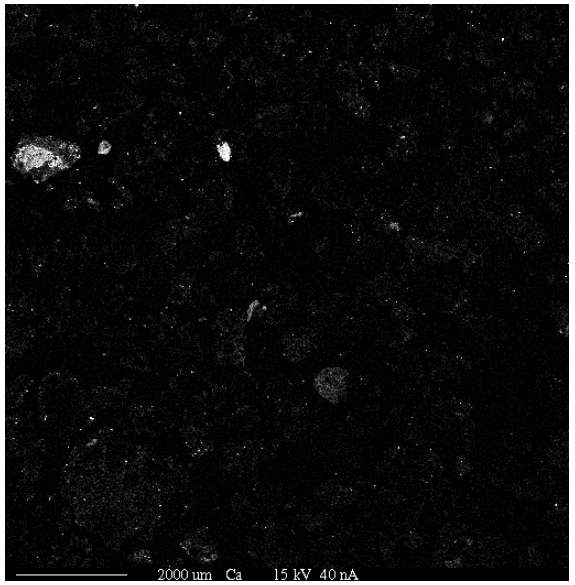


S

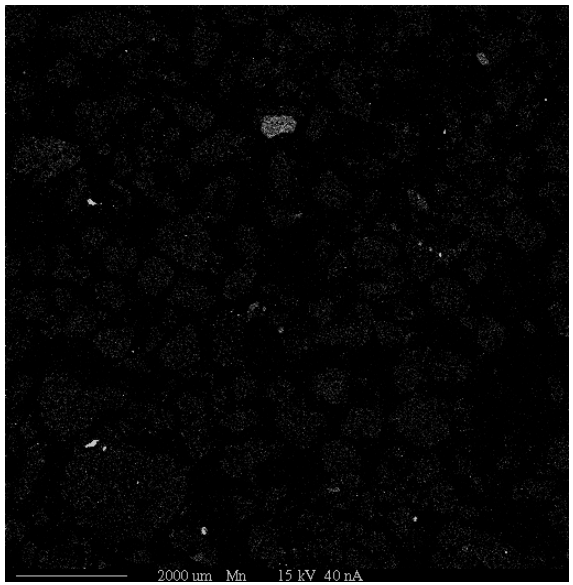


2-MW-3-BP-03

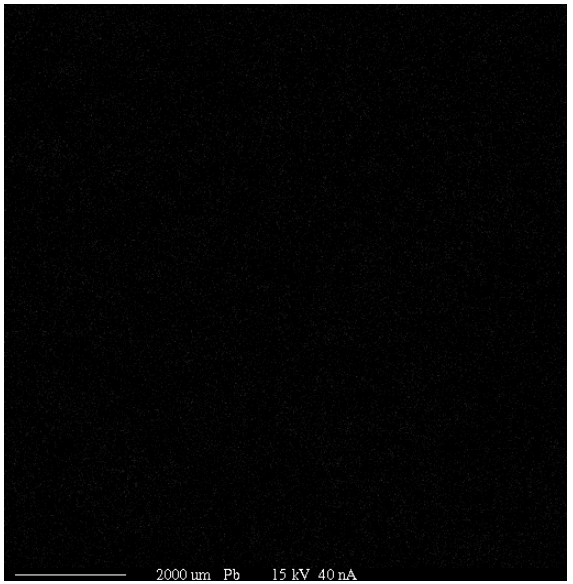
Ca



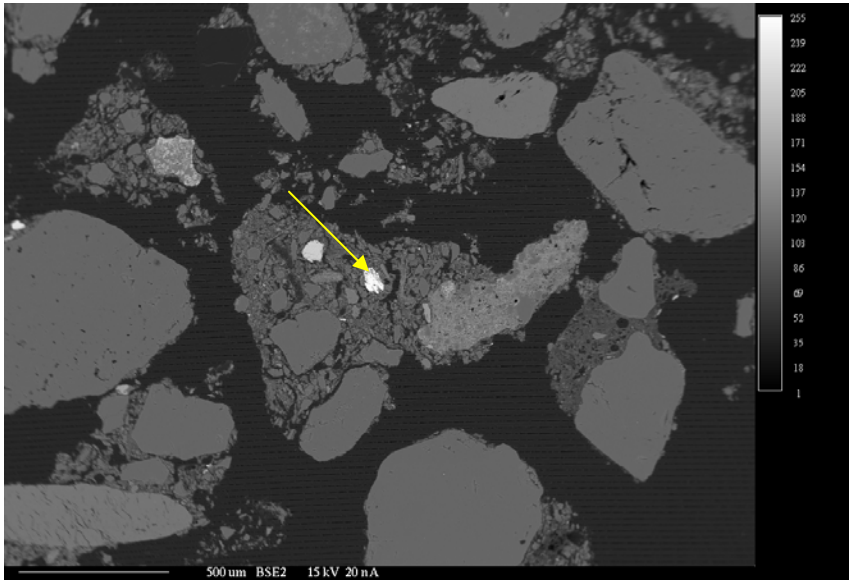
Mn

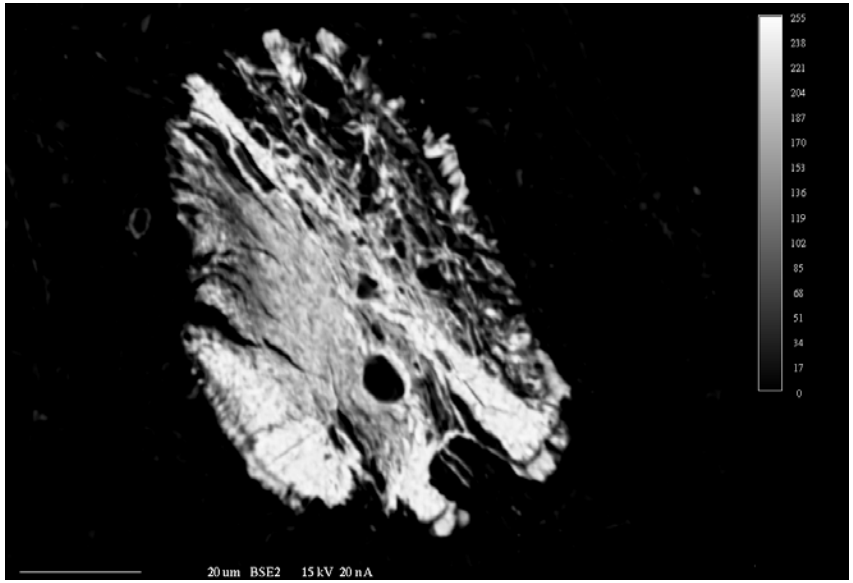


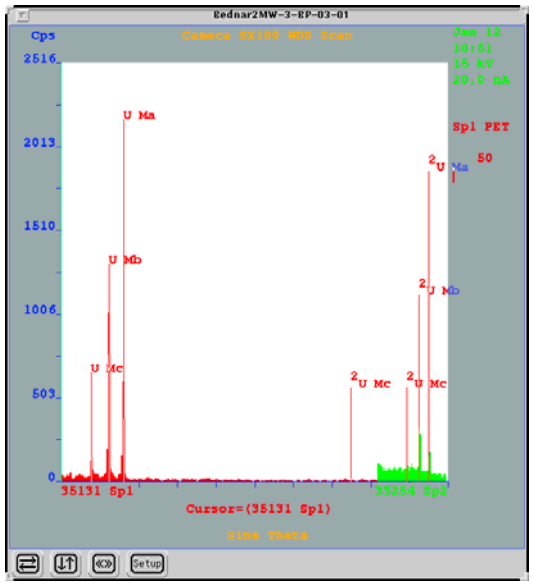
Pb



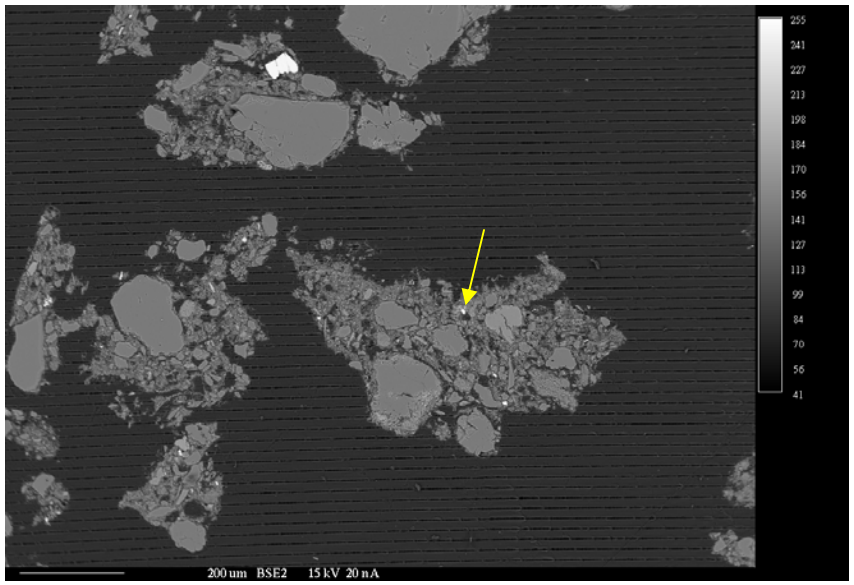
2-MW-3-BP-03 BSE images of U particles
Grain 1

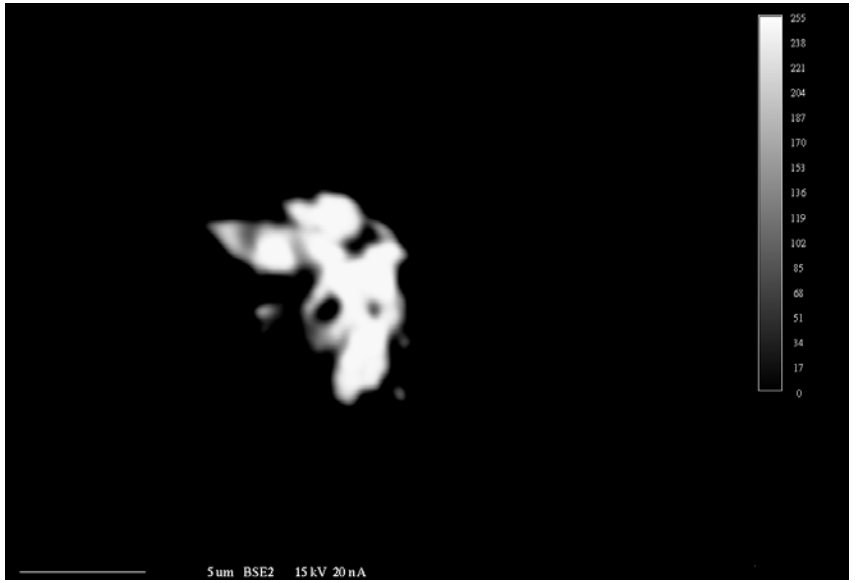




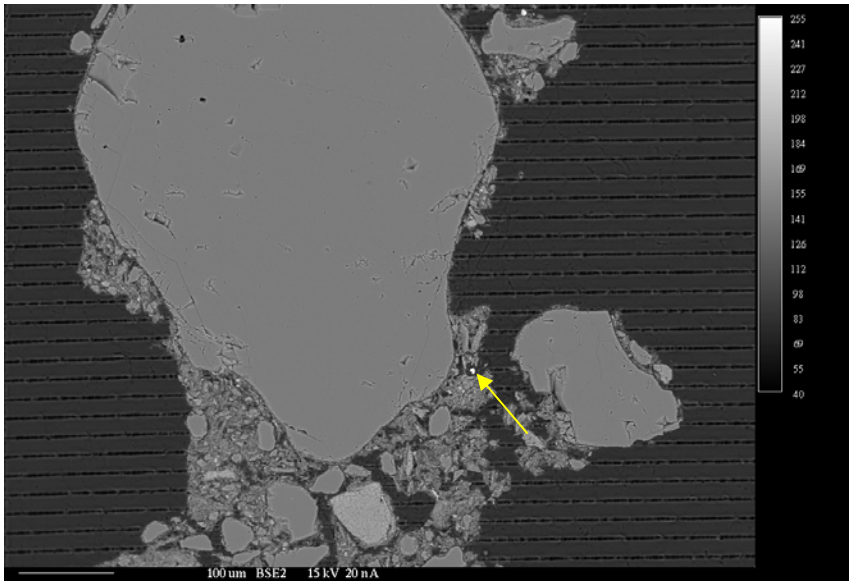


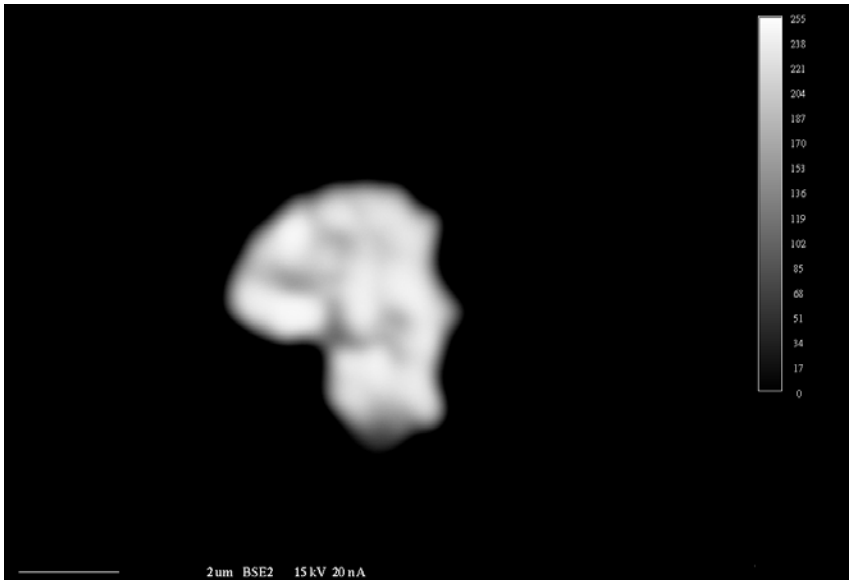
2-MW-3-BP-03 BSE images of U particles
Grain 2

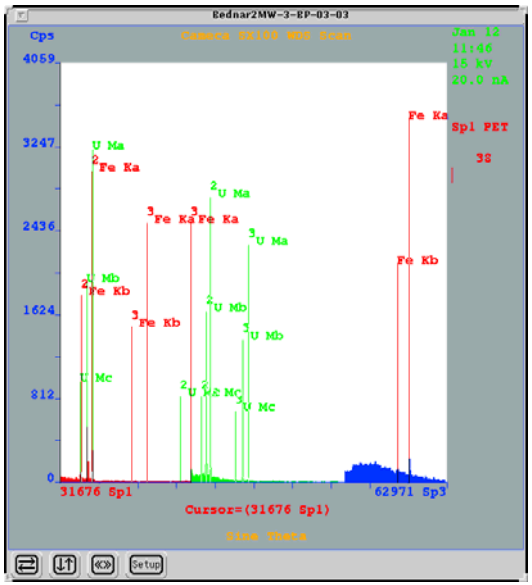




2-MW-3-BP-03 BSE images of U particles
Grain 3

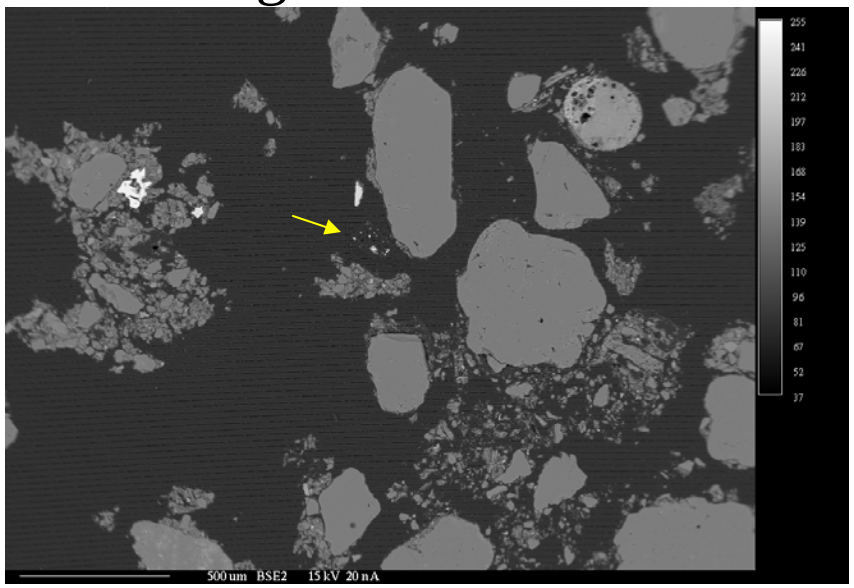




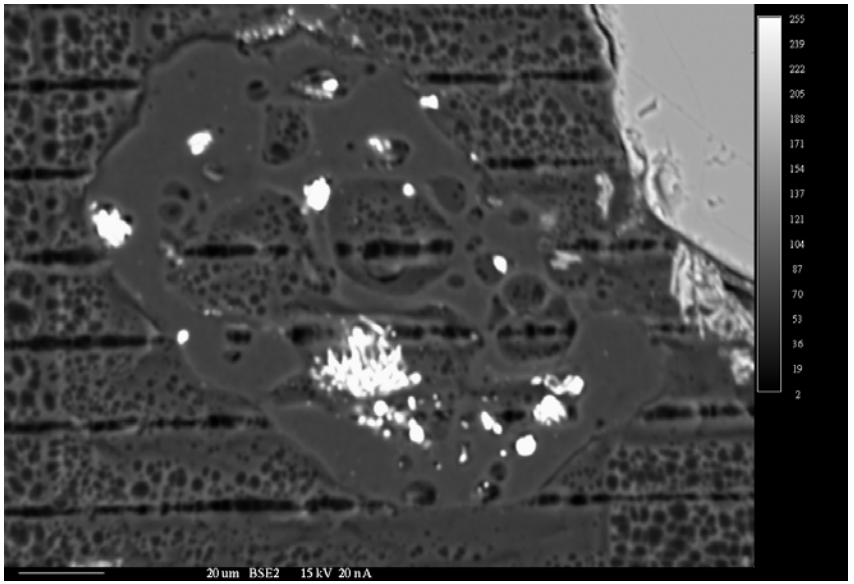


2-MW-3-BP-03 BSE images of U particles grains 4 and 5

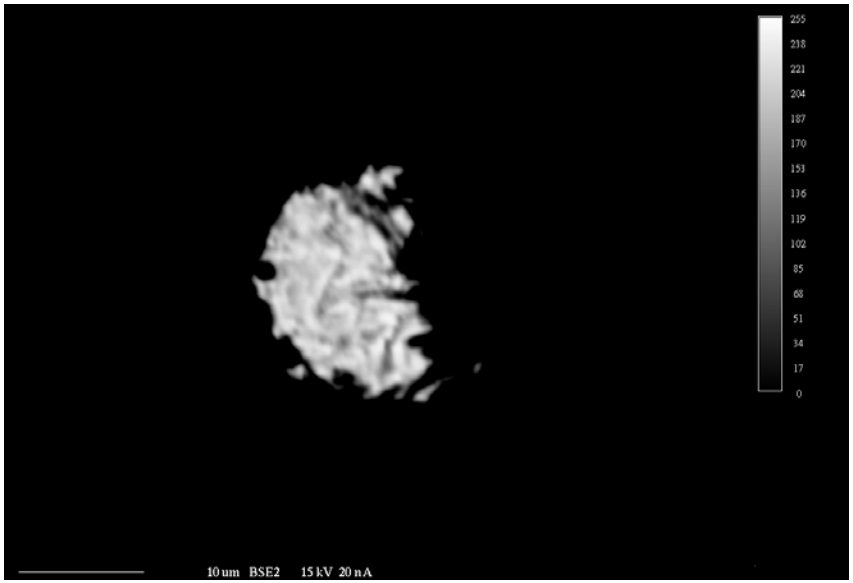
4 low mag



4 high mag

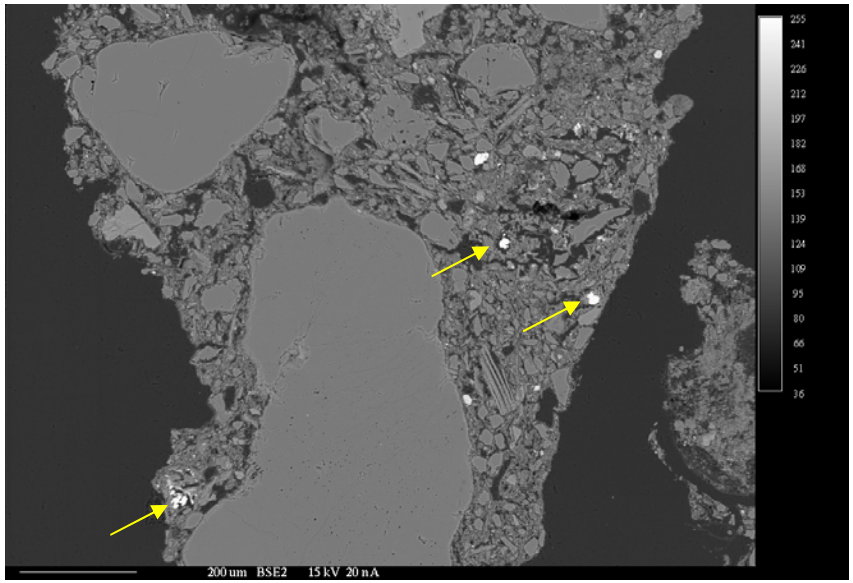


5

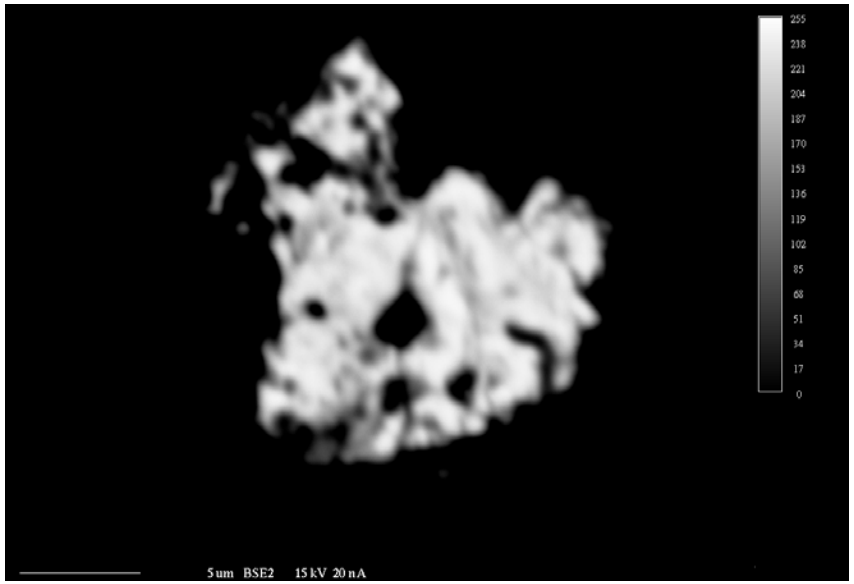


2-MW-3-BP-03 BSE images of U particles grains 6, 7, and 8

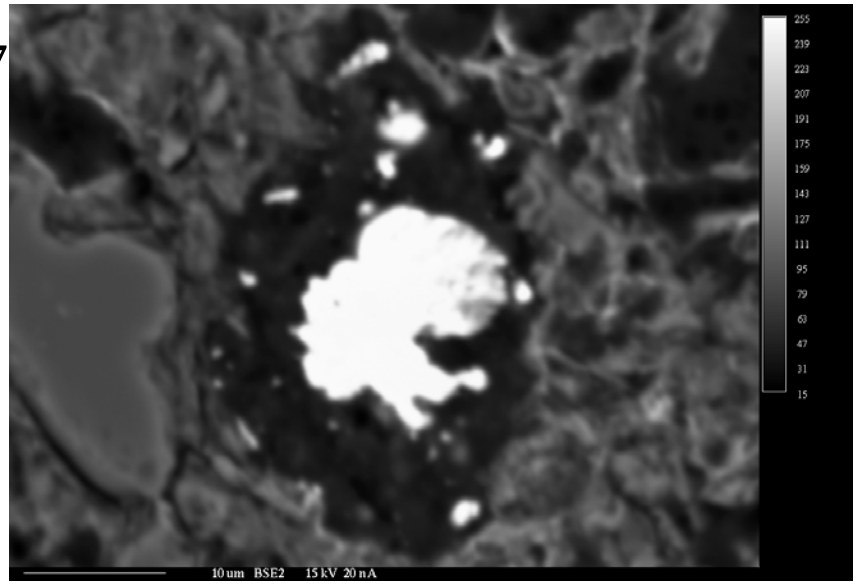
6,7,8 low mag

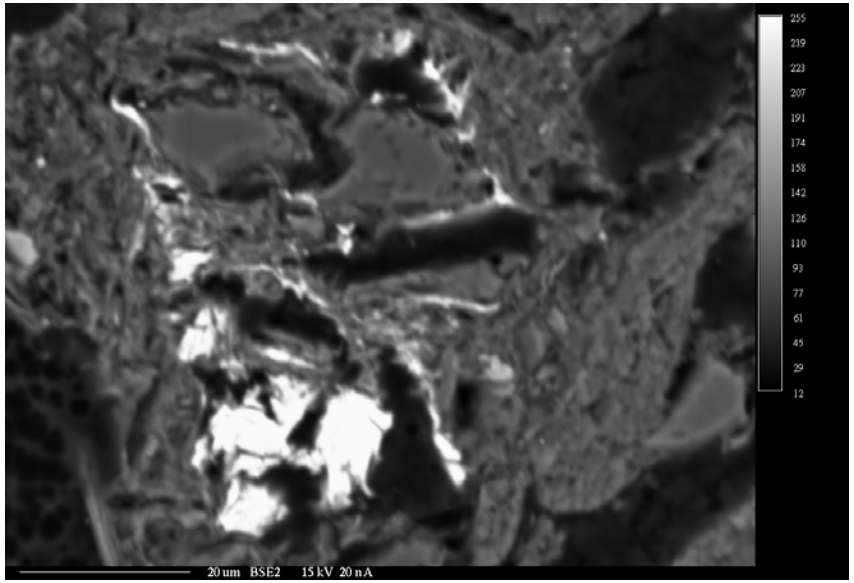


6



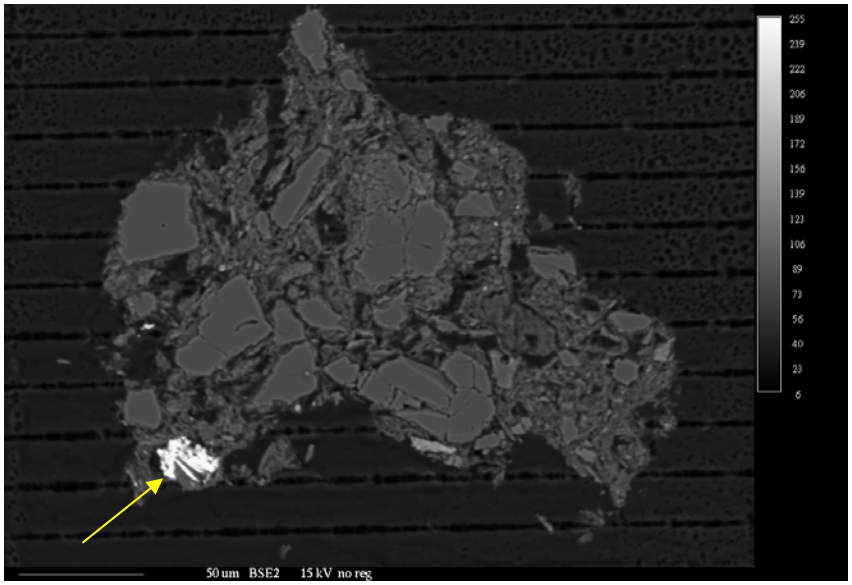
7





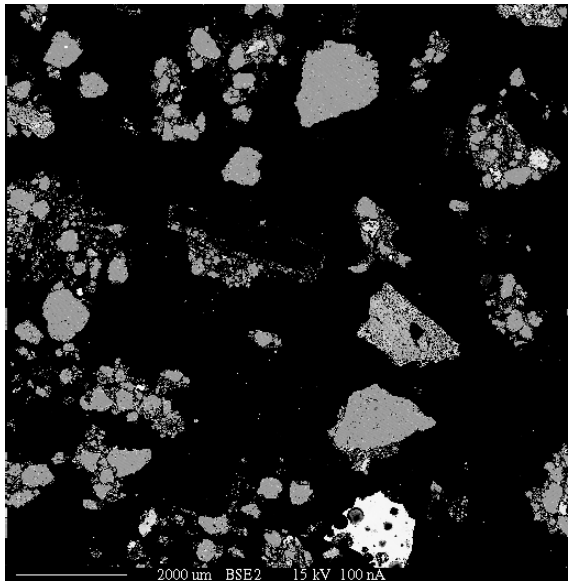
8

2-MW-3-BP-03 BSE images of U particles
Grain 9

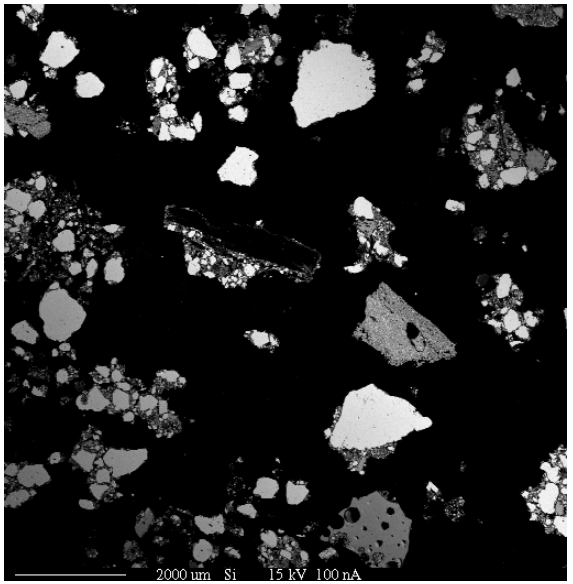


2-MW-11-BP-03 large scale maps
No U apparent

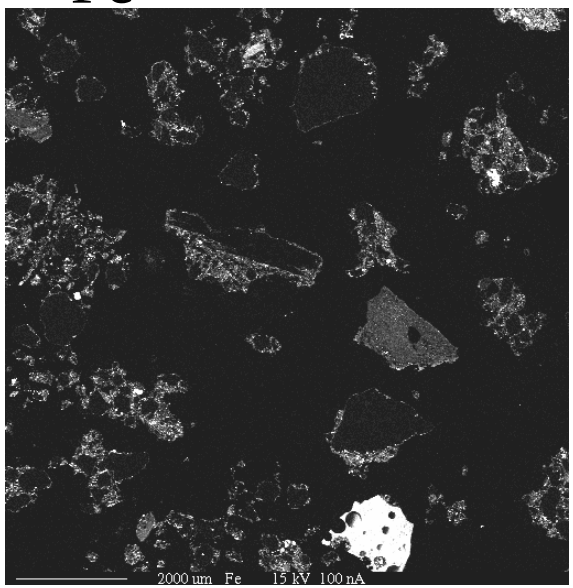
BSE



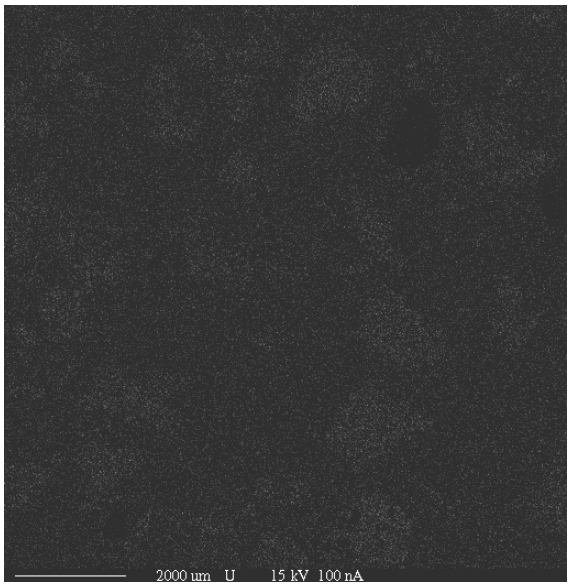
Si



Fe

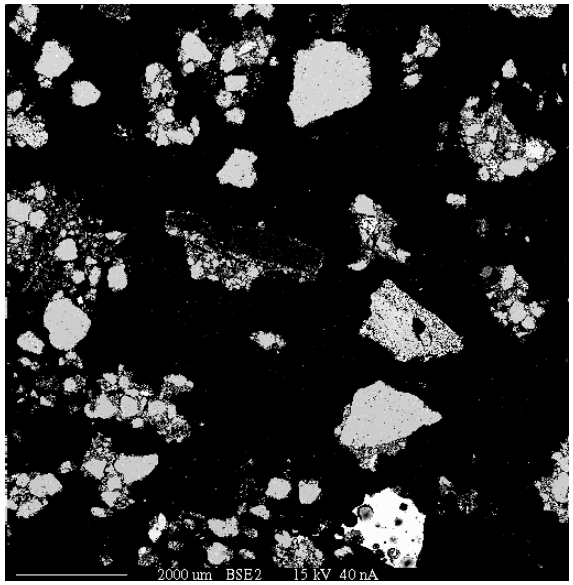


U

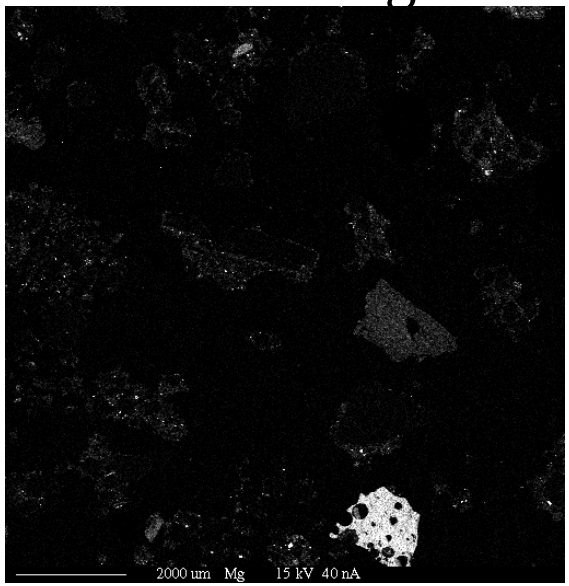


2-MW-11-BP-03

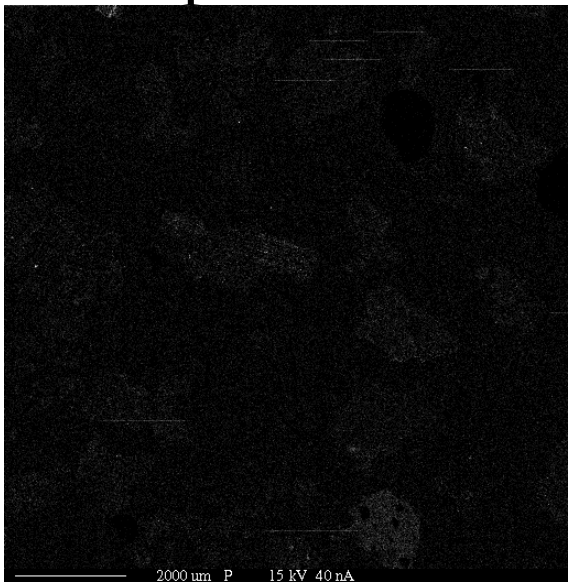
BSE



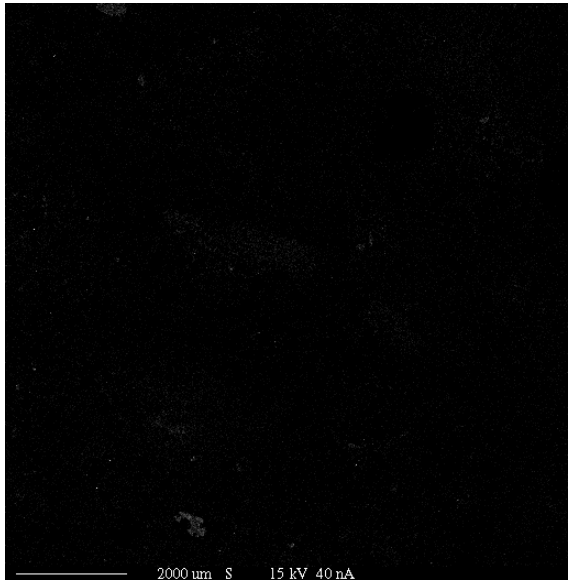
Mg



P

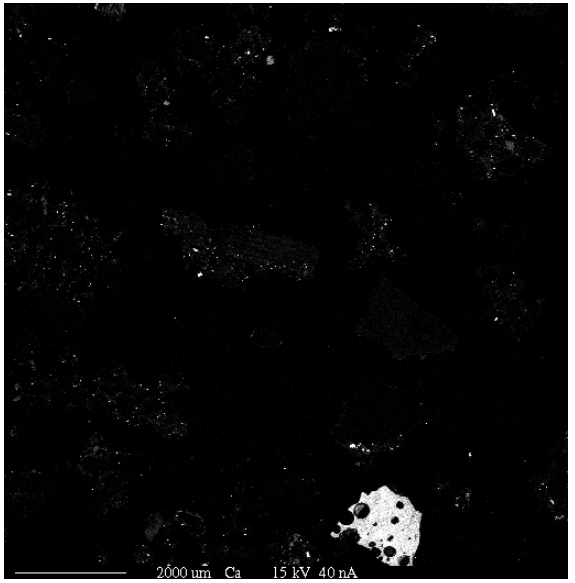


S

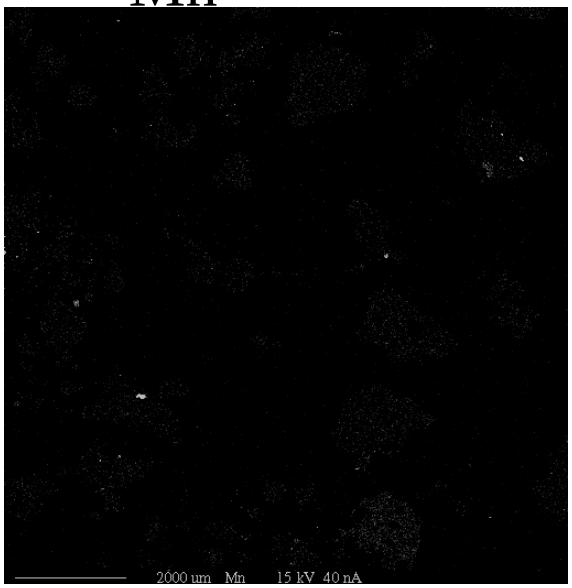


2-MW-11-BP-03

Ca



Mn



Pb

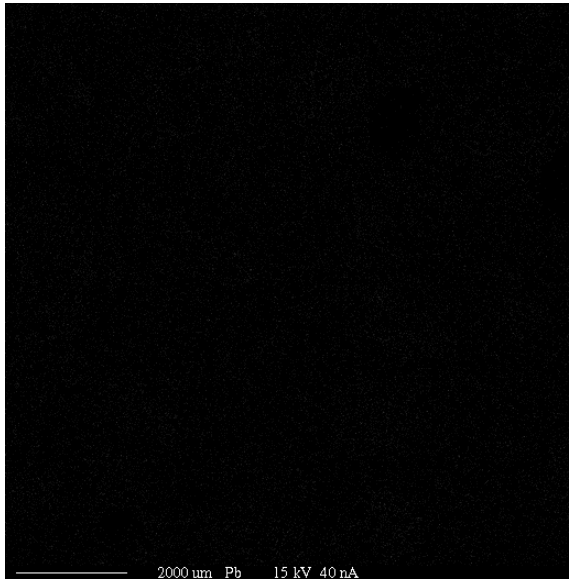


Table 1

Percent Solids

Sample ID	% Solid
1-MW-17-B-P-05	85.6
1-MW-18-B-P-01	83.7
2-MW-03-B-DUP-04	86.7
2-MW-02-B-P-03	88.0
2-MW-03-B-P-06	89.8
1-MW-08-B-P-04	92.5
1-MW-08-B-P-03	90.7
1-MW-09-B-P-02	93.0
2-MW-03-B-P-03	85.1
2-MW-03-B-P-05	85.2
2-MW-12-B-P-03	89.8
2-MW-12-B-P-04	83.2
2-MW-11-B-P-03	79.0
2-MW-04-B-P-03	84.8
2-MW-04-B-P-04	93.8
1-MW-07-B-P-05	93.5
1-MW-07-B-P-04	87.3
1-MW-18-B-P-03	81.0
2-MW-11-B-P-05	87.1
2-MW-11-B-P-04	90.5
1-MW-08-B-P-02	93.2
1-MW-09-B-P-04	92.1
1-MW-09-B-DUP-04	93.0
3-MW-13-B-P-03	86.7
3-MW-13-B-P-06	90.1
3-MW-13-B-P-05	84.5
3-MW-13-B-P-04	87.1
3-MW-14-B-P-04	86.3
3-MW-14-B-P-03	81.9
2-MW-06-B-P-03	88.3
2-MW-06-B-P-02	90.0
1-MW-17-B-P-03	86.4
1-MW-17-B-P-04	91.0
2-MW-16-B-P-04	91.8
2-MW-16-B-P-03	82.1
2-MW-02-B-P-04	94.8
2-MW-02-B-P-05	83.9
1-MW-09-B-P-03	92.4
2-MW-15-B-P-03	90.5
2-MW-15-B-P-02	90.6
2-MW-05-B-P-04	89.6
2-MW-05-B-P-03	89.8
2-MW-01-B-MS-03	91.0
2-MW-01-B-P-03	89.6
2-MW-01-B-MSD-03	90.4

TABLE 2

Total Digests - Dry Weight

Sample ID	U(mg/kg)
2-MW-3-B-P-06	96.3
1-MW-8-B-P-03	23.2
1-MW-9-B-P-02	272.4
2-MW-3-B-P-05	2260.5
2-MW-12-B-P-03	12.3
2-MW-12-B-P-04	2.2
2-MW-4-B-P-03	16.3
2-MW-4-B-P-04	0.6
1-MW-7-B-P-05	1.0
1-MW-7-B-P-04	0.9
1-MW-18-B-P-03	33.4
2-MW-11-B-P-05	2.0
2-MW-11-B-P-04	1.3
1-MW-8-B-P-02	192.2
3-MW-13-B-P-03	0.8
3-MW-13-B-P-06	0.6
3-MW-13-B-P-05	1.7
3-MW-13-B-P-04	1.5
3-MW-14-B-P-04	1.1
3-MW-14-B-P-03	4.5
2-MW-6-B-P-03	1.0
2-MW-6-B-P-02	0.8
1- MW-17-B-P-03	190.1
1-MW-17-B-P-04	2.6
2-MW-16-B-P-04	0.8
2-MW-16-B-P-03	1.0
2-MW-2-B-P-04	214.5
2-MW-2-B-P-05	1006.9
1-MW-9-B-P-03	0.6
2-MW-15-B-P-03	4.8
2-MW-15-B-P-02	0.8
2-MW-5-B-P-04	9.0
2-MW-5-B-P-03	142.0
2-MW-1-B-MS-03	165.5
2-MW-01-B-P-03	3.7
2-MW-01-B-MSD-03	3.9
2-MW-03-B-DUP-04	5253.9
2-MW-02-B-P-03	3190.9
2-MW-020BP-0	1293.0
1-MW-08-B-P-04	89.9
2-MW-3-B-P-03	4268.9
2-MW-11-B-P-03	1.6
1-MW-09-B-P-04	5.0
1-MW-9-B-DUP-04	8.0
1-MW-17-B-P-05	236.8
1-MW-18-B-P-01	27.5

Laboratory QC	U(mg/kg)	% Recovery	RPD
Blank 1	0.01		
Blank 2	0.02		
Duplicate(2-MW-03-B-P-06)	96.3		5.1
Duplicate(2-MW-6-B-P-03)	1		2.3
MS(1-MW-17-B-P-04)	24.3	93.4	
MS(2-MW-01-B-MSD-03)	25.9	100.7	

Table 3

pH

Sample ID	pH
2-MW-2-BP-03	8.05
1-MW-08-B-P-04	10.95
2-MW-11-B-P-03	9.61
1-MW-09-B-P-04	9.81
1-MW-17-B-P-05	8.6
1-MW-18-B-P-01	10.25

TABLE 4
SEQUENTIAL EXTRACTION

	U (mg/kg)	Ca (mg/kg)	Fe (mg/kg)	Mg (mg/kg)	Mn (mg/kg)	P (mg/kg)	Pb (mg/kg)	S (mg/kg)
2-MW-2-B-P-03								
Soluble	11.770	24.2000	10.3000	<1.00	<0.010	<1.00	<0.100	34.6000
Exchangeable	1.370	1080.0000	<.200		1.1500	<1.00	<0.100	27.3000
Carbonates	1052.000	151.0000	91.2000	7190.0000	3.4800	1320.0000	13.6000	<1.00
Fe-Mn Oxides	353.500	206.0000	2390.0000	352.0000	40.9000	21.2000	19.5000	28.9000
OM & Sulfides	56.340	94.6000	1152.0000	117.6000	8.8200	100.8000	9.0000	632.0000
Residual	7.005	63.0000	2600.0000	410.0000	13.6500	38.7500	3.8250	42.2500
1-MW-08-B-P-04								
Soluble	0.084	585.0000	<0.200	<1.00	<0.010	<1.00	<0.100	398.0000
Exchangeable	2.940	7370.0000	<0.200		<0.010	<1.00	<0.100	114.0000
Carbonates	149.000	11200.0000	712.0000	11300.0000	61.9000	140.0000	14.6000	298.0000
Fe-Mn Oxides	54.050	918.0000	1340.0000	971.0000	34.0000	28.5000	21.6000	12.9000
OM & Sulfides	6.200	220.0000	145.8000	141.0000	4.7800	48.8000	4.5600	133.4000
Residual	2.540	62.5000	3075.0000	380.0000	11.0750	30.2500	1.8750	24.6250
2-MW-03-B-P-03								
Soluble	75.470	20.5000	25.8000	<1.00	<0.010	14.3000	<0.100	40.4000
Exchangeable	10.750	548.0000	<0.200		<0.010	<1.00	<0.100	27.3000
Carbonates	3636.000	77.8000	64.2000	5780.0000	1.2800	111.0000	23.0000	<1.00
Fe-Mn Oxides	659.010	30.9000	990.0000	222.0000	1.0800	19.8000	18.9000	17.6000
OM & Sulfides	1.180	29.2000	492.0000	82.0000	1.8600	23.0000	6.7000	454.0000
Residual	16.697	24.8500	2725.0000	267.5000	8.7000	43.5000	1.7500	29.2500
2-MW-11-B-P-03								
Soluble	0.192	358.0000	<0.200	<1.00	<0.010	13.4000	<0.100	319.0000
Exchangeable	0.220	2290.0000	<0.200		<0.010	<1.00	<0.100	54.6000
Carbonates	1.090	2970.0000	515.0000	5970.0000	13.4000	98.6000	20.8000	86.2000
Fe-Mn Oxides	0.440	512.0000	3180.0000	422.0000	26.5000	22.9000	38.5000	23.0000
OM & Sulfides	1.166	123.8000	560.0000	68.2000	3.9800	26.0000	16.1200	322.0000
Residual	0.482	47.2500	1740.0000	173.7500	8.3000	21.6750	2.4000	23.8750
H 1-MW-09-B-P-04								
Soluble	0.372	542.0000	<0.200	<1.00	<0.010	11.9000	<0.100	301.0000
Exchangeable	0.697	2470.0000	<0.200		<0.010	<1.00	<0.100	58.2000
Carbonates	7.430	2330.0000	242.0000	7300.0000	18.9000	96.4000	8.9500	65.5000
Fe-Mn Oxides	1.870	272.0000	579.0000	444.0000	6.3100	19.4000	5.7400	<1.00
OM & Sulfides	0.346	68.8000	175.2000	69.4000	1.2600	<1.00	<0.100	128.6000
Residual	0.424	33.2500	1322.5000	217.0000	7.2250	13.1750	1.3000	8.6500
1-MW-17-B-P-05								
Soluble	0.220	119.0000	10.8000	<1.00	<0.010	15.3000	<0.100	44.1000
Exchangeable	0.486	949.0000	<0.200		17.0000	<1.00	<0.100	29.0000
Carbonates	16.280	795.0000	43.9000	4600.0000	56.0000	78.3000	2.6800	16.6000
Fe-Mn Oxides	6.510	1490.0000	1730.0000	908.0000	51.6000	22.3000	5.9900	<1.00
OM & Sulfides	96.200	246.0000	157.4000	168.6000	13.6600	<1.00	3.0400	<1.00
Residual	0.423	19.9250	6925.0000	392.5000	19.9750	95.0000	1.6750	6.2500
1-MW-18-B-P-01								
Soluble	0.535	509.0000	<0.200	<1.00	<0.010	14.0000	<0.100	211.0000
Exchangeable	1.580	2920.0000	<0.200		<0.010	12.1000	<0.100	72.6000
Carbonates	27.050	12500.0000	553.0000	11600.0000	50.1000	101.0000	88.8000	328.0000
Fe-Mn Oxides	9.080	1420.0000	2050.0000	1370.0000	30.6000	37.0000	72.4000	40.6000
OM & Sulfides	9.060	308.0000	522.0000	354.0000	8.7200	29.4000	19.7200	412.0000
Residual	2.127	40.0000	2725.0000	267.5000	12.3500	37.2500	4.0000	19.0500

= below detection limit

TABLE 5
Total Organic Carbon

Sample ID	TOC (mg/kg)
2-MW-2-B-P-03	45000
1-MW-08-B-P-04	13000
2-MW-11-B-P-03	5600
1-MW-09-B-P-04	38000
1-MW-17-B-P-05	5200
1-MW-18-B-P-01	30000
2-MW-03-B-DUP-04	36000

Laboratory QC	TOC (mg/kg)	Recovery/RPD
Method Blank	ND (<250)	
LCS	25000	106%

TABLE 6
Cation Exchange Capacity

Sample ID	CEC (meq/100g)
1-MW-09-B-Dup-04	5.96
2-MW-2-BP-03	12.18
1-MW-08-B-P-04	14.22
2-MW-11-BP-03	8.26
1-MW-09-B-P-04	5.65
2-MW-03-BP-03	10.16
1-MW-17-BP-05	5.44
1-MW-18-BP-01	10.27

TABLE 7

XRD Results
Qualitative Mineralogical Report

Sample ID	Phases	Qualitative Results
1-MW-18-B-P-01	Quartz	Major Phase
	Mica	Possible Phase
	Plagioclase Feldspar	Possible Phase
	Alkali Feldspar	Possible Phase
	Calcite	Possible Phase
	Dolomite	Possible Phase
1-MW-08-B-P-04	Quartz	Major Phase
	Mica	Trace Phase
	Plagioclase Feldspar	Trace Phase
	Alkali Feldspar	Possible Phase
	Clays	Possible Phase
1-MW-17-B-P-05	Quartz	Major Phase
	Mica	Trace Phase
	Alkali Feldspar	Trace Phase
	Plagioclase Feldspar	Possible Phase
	Dolomite	Possible Phase
2-MW-03-B-P-03	Quartz	Major Phase
	Plagioclase Feldspar	Trace Phase
	Mica	Possible Phase
	Alkali Feldspar	Possible Phase
	Halite	Possible Phase
	Clays	Possible Phase
2-MW-11-B-P-03	Quartz	Major Phase
	Mica	Possible Phase
	Plagioclase Feldspar	Possible Phase
	Alkali Feldspar	Possible Phase
	Dolomite	Possible Phase
	Calcite	Possible Phase
2-MW-02-B-P-03	Quartz	Major Phase
	Mica	Possible Phase
	Plagioclase Feldspar	Possible Phase
	Alkali Feldspar	Possible Phase
	Dolomite	Possible Phase
	Clays	Possible Phase
1-MW-09-B-P-04	Quartz	Major Phase
	Mica	Trace Phase
	Plagioclase Feldspar	Trace Phase
	Alkali Feldspar	Trace Phase
	Clays	Possible Phase

NOTES:
Major Phase = Relative intensity of most intense peak >30.
Minor Phase = Relative intensity of most intense peak >7 and <30.
Trace Phase = Relative intensity of most intense peak <7.
Possible Phase = Not confirmed by the presence of at least three peaks.

TABLE 8
DISTRIBUTION COEFFICIENT

2004 Samples

Sample ID	Kd	Groundwater
2-MW-2-BP-03	-4.1816	2BH026
1-MW-08-B-P-04	-18.611	2BH026
2-MW-11-B-P-03	4.6623	2BH026
1-MW-09-B-P-04	2.6273	2BH026
2-MW-03-B-P-03	-4.0278	2BH026
1-MW-17-B-P-05	-26.791	2BH026
1-MW-18-B-P-01	2.877	2BH026
2-MW-11-B-P-03-2b	5.4016	D07-M02B
2-MW-11-B-P-03-3s	41.434	3SB15
1-MW-09-B-P-04(2b)	3.1292	D07-M02B
1-MW-09-B-P-04-(3s)	5.3038	3SB15

2003 Samples

Sample ID	Kd	Groundwater
3-SS-28-R-0-01	-277.9	2BH026
5-SB-10-B-1-03	21779	2BH026
3-SB-19-B-1-03	5.2217	2BH026
3-SB-01-B-0-04	31.677	2BH026
2-BH-0250-2	1.0594	2BH026
2-BH-0250-2 (2b)	18.538	D07-M02B
2-BH-0250-2 (3s)	20.642	3SB15
1-BH-007-2-4	1837	2BH026
1-BH-0180-2	-7.7566	2BH026
1-BH-0180-2 (2b)	-7.3185	D07-M02B
1-BH-0180-2 (3s)	222.28	3SB15