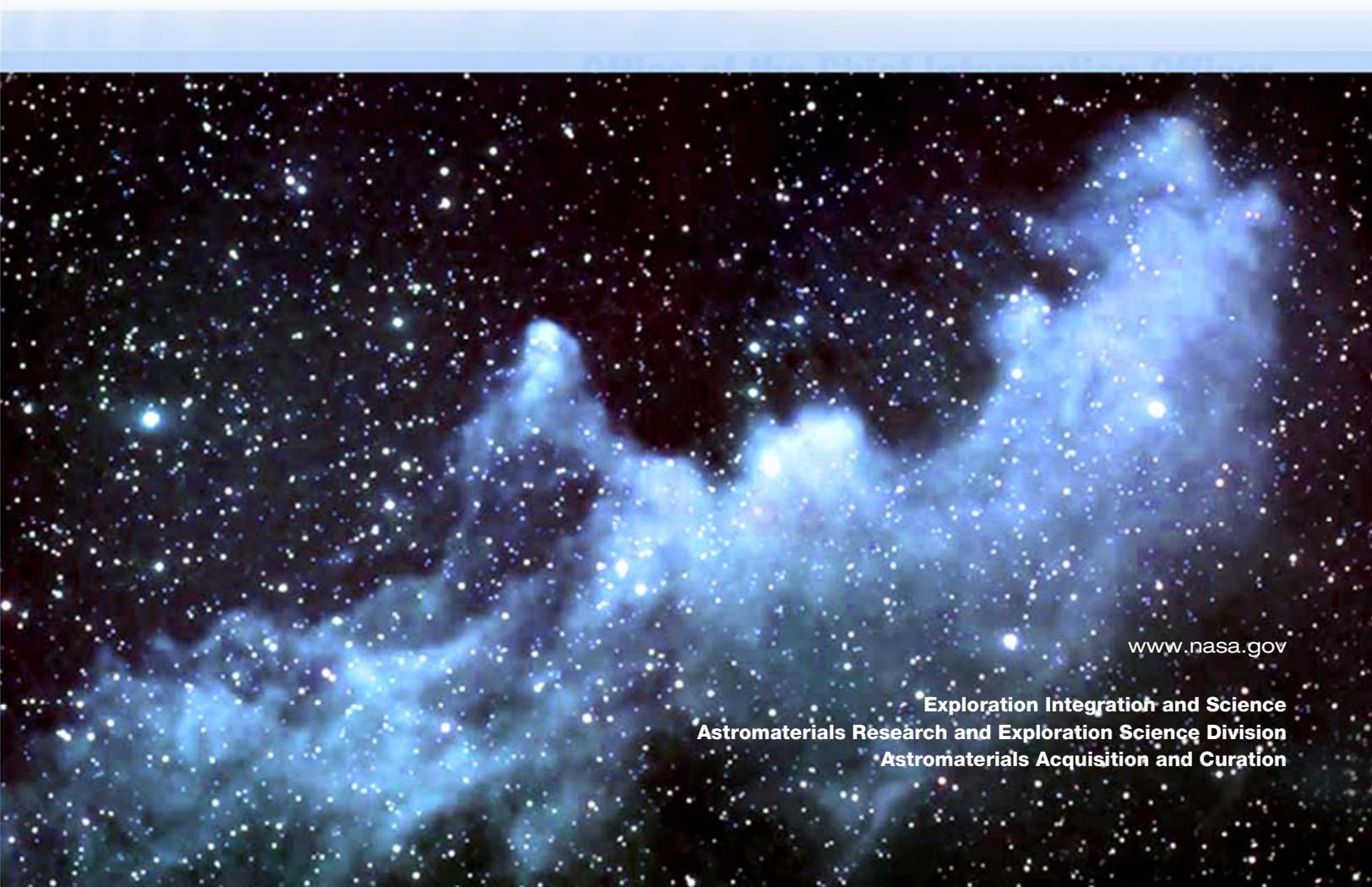


National Aeronautics and Space Administration



# Cosmic Dust Catalog Volume 19

Particles from Collectors U2153, U2158, and U2160



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Exploration Integration and Science  
Astromaterials Research and Exploration Science Division  
Astromaterials Acquisition and Curation



# Cosmic Dust Catalog

Volume 19

Particles from Collectors U2153, U2158, and  
U2160

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## Introduction

Since May 1981, the National Aeronautics and Space Administration (NASA) has used aircraft to collect cosmic dust (CD) particles from Earth's stratosphere. Specially designed dust collectors are prepared for flight and processed after flight in an ultraclean (Class-100) laboratory constructed for this purpose at the Lyndon B. Johnson Space Center (JSC) in Houston, Texas. Particles are individually retrieved from the collectors, examined and cataloged, and then made available to the scientific community for research. Cosmic dust thereby joins lunar samples and meteorites as an additional source of extraterrestrial materials for scientific study.

This catalog summarizes preliminary observations on particles retrieved from collection surfaces U2153, U2158, and U2160. These surfaces were flat plate collectors which were coated with silicone oil (dimethyl siloxane) and then flown aboard NASA ER-2 aircraft during a series of flights as follows:

- U2153: 15.1 hours of flight time on October 15 and 17, 2012, during the Draconid Showers
- U2158 and U2160: 23.2 hours of flight time over California during 2012

All of the collectors were installed in specially constructed wing pylons which ensured that the necessary level of cleanliness was maintained between periods of active sampling. During successive periods of high altitude (20 km) cruise, the collectors were exposed in the stratosphere by barometric controls and then retracted into sealed storage containers prior to descent.

## Processing of Particles

Particle mounts designed for the JEOL 100CX scanning transmission electron microscope (STEM) are currently the standard receptacles for CD particles in the JSC laboratory. Each mount consists of a graphite frame (size  $\sim 3 \times 6 \times 24$  mm) onto which a Nucleopore filter (0.4  $\mu\text{m}$  pore size) is attached. A conductive coat of carbon is vacuum evaporated onto the mount and then a microscopic reference pattern is "stenciled" onto the carbon-coated filter by vacuum evaporation of aluminum through an appropriately sized template. Particles are individually removed from collectors using glass-needle micromanipulators under a binocular stereo-microscope. Each particle is positioned on an aluminum-free area of a Freon-cleaned (Freon 113), carbon-coated filter and washed in place with hexane to remove silicone oil. Each mount is normally limited to 16 particles. All processing and storage of each particle is performed in a Class-100 clean room.

## Preliminary Examination of Particles

Each rinsed particle is examined, before leaving the Class-100 clean room processing area, with a petrographic research microscope equipped with transmitted, reflected and oblique light illuminators. At a magnification of 200-500X, size, shape, transparency, color, and luster are determined and recorded for each particle.

After optical description, each mount (with uncoated particles) is examined by scanning electron microscopy (SEM) and X-ray energy-dispersive spectrometry (EDS). Secondary-electron imaging of each particle was performed with an ISI SEM at an accelerating voltage of 15 kV. Images are therefore of relatively low contrast and resolution due to deliberate avoidance of conventionally applied conductive coats (carbon or gold-palladium) which might interfere with later elemental analyses of particles. EDS data are collected with the same SEM. Using an accelerating voltage of 15 kV, each particle is raster scanned and its X-ray spectrum recorded over the 0-10 keV range by counting for 30 sec. No system (artifact) peaks of significance appear in the spectra.

## Catalog Format

Each page in the main body of the catalog is devoted to one particle and consists of an SEM image, an EDS spectrum, and a brief summary of preliminary examination data obtained by optical microscopy. The unique identification number assigned to the particle appears at the top of the page. Sources of the descriptive data are as follows:

### SIZE

Size ( $\mu\text{m}$ ) is measured using the original SEM image and its known magnification factor. For an irregularly shaped particle, the minimum dimension in the plane of the field of view is located and determined; then a second (maximum) dimension is measured at a right angle to the first. For a spherical or equidimensional particle, only a single size is recorded.

### SHAPE

Shape is generalized to be spherical (S), equidimensional (E), or irregular (I).

### TRANSPARENCY

Transparency is determined by optical microscopy to be transparent (T), translucent (TL), or opaque (O). Significant variations in transparency within a particle are annotated on the SEM image.

### COLOR

Color is determined by optical microscopy using oblique (fiber optic, quartz halogen) illumination supplemented with normal reflected (tungsten-lamp) illumination.

### LUSTER

Luster is determined by optical microscopy using reflected normal (tungstenlamp) illumination and supplemented with oblique (fiber optic, quartz halogen) illumination. Commonly applied descriptions, adopted from mineralogical usage, include Dull (D),

Metallic (M), Submetallic (SM), Subvitreous (SV), Vitreous (V). Lusters transitional between categories or difficult to identify are indicated accordingly (Dull/Submetallic, etc.).

## TYPE

Type indicates a provisional first order identification of each particle based on its morphology (from SEM image), elemental composition (from EDS spectrum), and optical properties. We emphasize that, for catalog purposes, types are defined for their descriptive and curatorial utility, not as scientific classifications. These tentative categorizations, which reflect judgments based on the collective experience of the CDPET, should not be construed to be firm identifications and should not dissuade any investigator from requesting any given particle for detailed study and more complete identification. The precise identification of each particle in our inventory is beyond the scope and intent of our collection and Curation program. Indeed, the reliable identification and scientific classification of cosmic dust is one of many important research tasks that we hope this catalog will stimulate. We indicate particle "TYPE" only to aid the users of this catalog (especially those new to small particle analysis) in distinguishing possible cosmic dust particles from other particles which are invariably collected during stratospheric dust sampling. In this catalog, particles are organized according to their type. Categories used in this catalog are defined as follows:

**Cosmic (C):** Interplanetary dust (variety unspecified) or other extraterrestrial material. In the strict sense, "cosmic dust" refers only to those particles which have not been modified during passage from interplanetary space to Earth's stratosphere. In this catalog, though, particle type "Cosmic" is used to conveniently group together all particles which are judged to be of extraterrestrial origin, including those that have apparently experienced strong ablatational heating or melting. Type "Cosmic" particles are provisionally identified as those having one of the three following sets of attributes:

1. Irregular to spherical, opaque, dark-colored particles composed mostly of Fe with minor S and/or Ni.
2. Irregular to spherical, translucent to opaque, dark-colored particles containing various proportions of Mg, Si, and Fe with traces of S and/or Ni.
3. Irregular to faceted or blocky, transparent to translucent particles containing mostly Mg, Si, and Fe but with traces S and/or Ni.

Category (a) and (b) particles commonly display either complex, porous aggregate type morphologies or distinctively spherical shapes and dull to metallic lusters which distinguish them from terrestrial minerals. Their EDS spectra are reminiscent of those exhibited by meteoritic Fe-NiS minerals, or combinations of Fe-Ni-S phases with olivine and/or pyroxene. Category (c) particles display morphologies and EDS spectra which suggest that they are fragments of olivine or pyroxene crystals, neither of which are significant components of stratospheric volcanic ash. Particles which do not fall easily into categories (a), (b), or (c) but which possess some of the same attributes may be classified here as "Cosmic?".

**TCA:** Terrestrial contamination (artificial or man-made). Particles included in the "TCA" category are commonly irregular in shape (though a few may be spherical) and may be transparent, translucent, or opaque. Their EDS spectra commonly show Al, Fe, or Si as the principal peaks but with a variety of minor peaks including those of Cd, Ti, V, Cr, Mn, Ni, Cu, or Zn and at abundances which are frequently much greater than

those expected in common minerals. However, such compositions are similar to those expected for certain metal alloys. In some cases, a high intensity (relative to intensities of characteristic X-ray peaks) of continuum radiation occurs in the EDS spectrum, suggesting that low atomic number elements not detectable by the EDS (e.g., H, C, N, O) are abundant in the particle. Such "TCA" particles are tacitly inferred to be synthetic carbon based materials. (This category probably includes particles produced by or derived from aircraft operation or collector hardware, or possibly spacecraft debris. However, some of these particles are worthy of additional research and may represent true extraterrestrial "low Z" material).

**TCN:** Terrestrial contamination (natural). "TCN" particles may be transparent to opaque and may exhibit a variety of colors. However, they are commonly irregular in shape and distinctively rich in Si and Al with minor abundances of Na, K, Ca, or Fe. Some Fe-S particles are classified as TCN despite the fact that they may well be extraterrestrial. This action is due to the lack of conclusive investigations regarding these particular particles. Many particles containing only low-Z elements are also classified TCN for the same reason. Morphologies and EDS spectra of most "TCN" particles compare favorably with respective properties of silica polymorphs, feldspar, or silicic volcanic glass, three materials which are principal components of stratospheric volcanic ash. In addition, platy or porous aggregate-type particles of light color and Si, Al rich composition may be silicic clay minerals, common phases in Earth's surface soils. Irregular, reddish Fe rich particles may also be products of terrestrial rock weathering. Recognition of these and other phases as "TCN" particles is based mostly on CDPET's collective mineralogical experience and comparison with reference samples. Less commonly, the "TCN" category may include distinctive particles with apparently non-random shapes which are rich in low atomic number elements (as inferred from their EDS spectra having high levels of continuum x radiation and relatively small peaks for characteristic X-rays). Those rare particles are distinguished from "TCA" particles by their unusual, organized morphologies and probably represent biological contaminants.

**AOS:** Aluminum or aluminum oxide sphere. An AOS is transparent, subvitreous, vitreous to metallic in luster, colorless to pale yellow and at least approximately spherical. However, shape may range from nearly perfect sphericity to pronounced ellipticity and surface texture may range from very smooth to rough. Other spheres or irregularly shaped material may be attached to its surface. Al is the distinctively dominant (or only) peak in its EDS spectrum. A sphere displaying the attributes of an AOS except with major elements in addition to Al may be listed as "AOS?" or "?". Transparent Al rich particles of irregular shape would probably be listed as "TCA". Most AOS particles are products of solid fuel rocket exhausts.

Again, this system for provisional classification of particles is presented only as a first order attempt to distinguish particles which are probably extraterrestrial in origin from those which are probably contaminants. All particles will require careful research examination before they can be satisfactorily identified.

## COMMENTS

Comments are included for particles with special features or histories. Any large "cluster" particles, which have broken apart on the collector, have small portions present in the catalog as different "sibling" grains; the comments reflect these relationships. For example,

any particle with a cluster number designation in the comments field represents a much larger parent particle remaining on the collection plate, which is also available for allocation in part or in whole.

## **SAMPLE REQUESTS**

Scientists desiring to perform detailed research on particles described in this catalog should apply by email to:

**[michael.e.zolensky@nasa.gov](mailto:michael.e.zolensky@nasa.gov)**

Sample requests should refer to specific particle identification numbers and should describe the research being proposed as well as the qualifications and facilities of the investigator making the request. Publication reprints are frequently useful in sample allocation considerations. Additionally, requests for particles not yet passed through preliminary examination will be considered if the requester can demonstrate a strong need for them. NASA will arrange for a review of the scientific merits of each request and will inform the requester of the results. Approval of a sample request does not imply or include funding for the proposed research. Questions about NASA funding should be directed to:

### **Discipline Scientist, Solar System Workings Program**

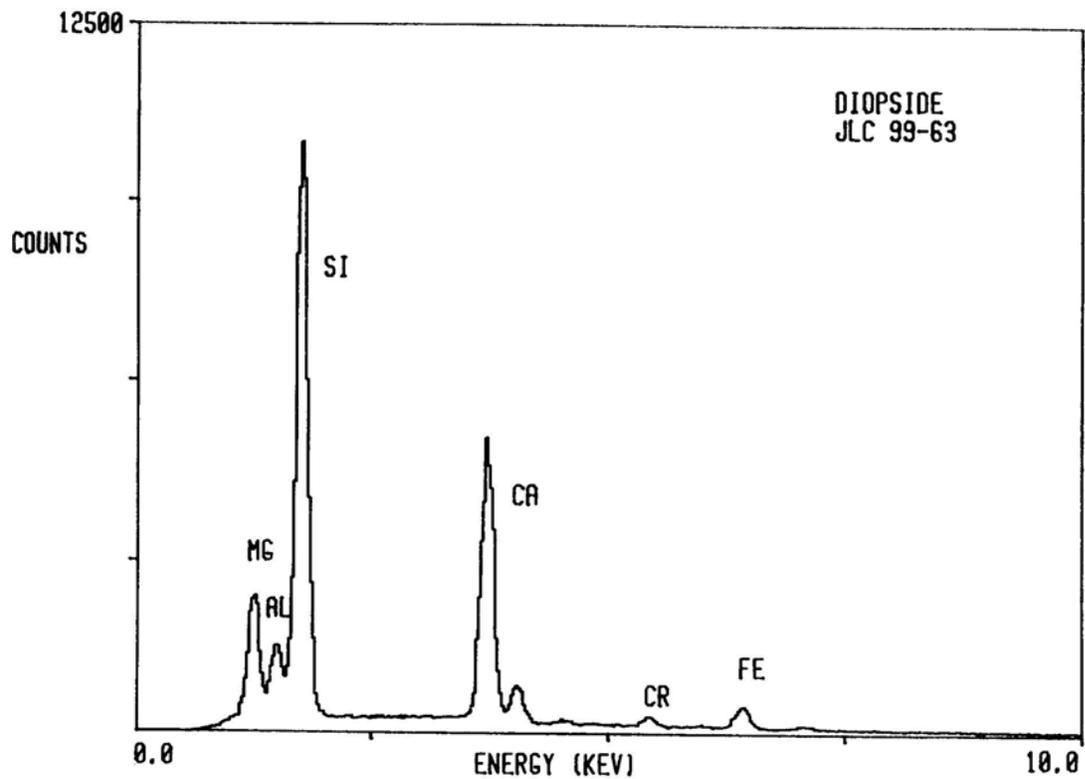
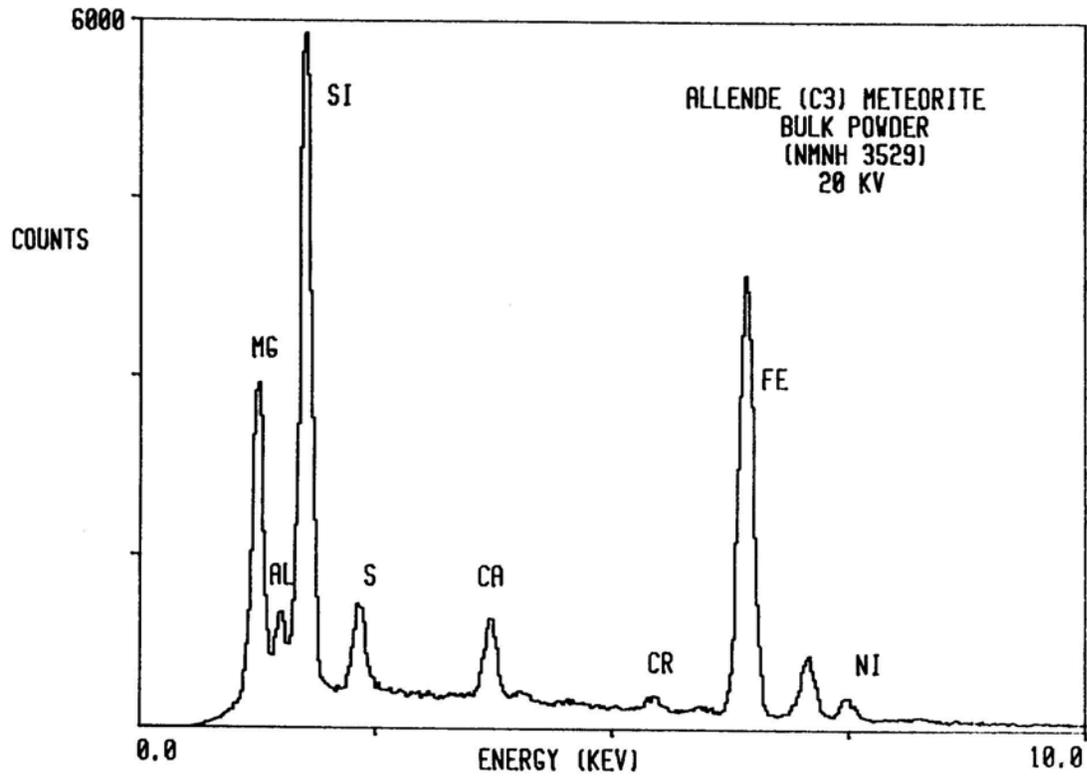
NASA Headquarters  
Washington, DC 20546 U.S.A.

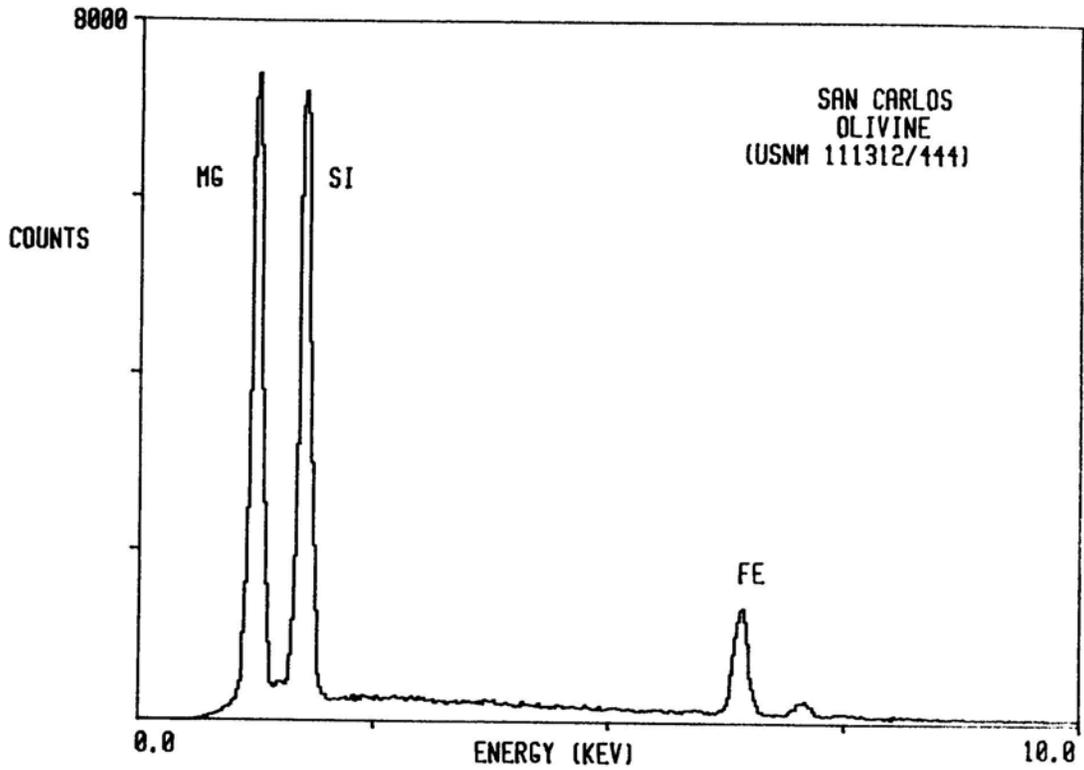
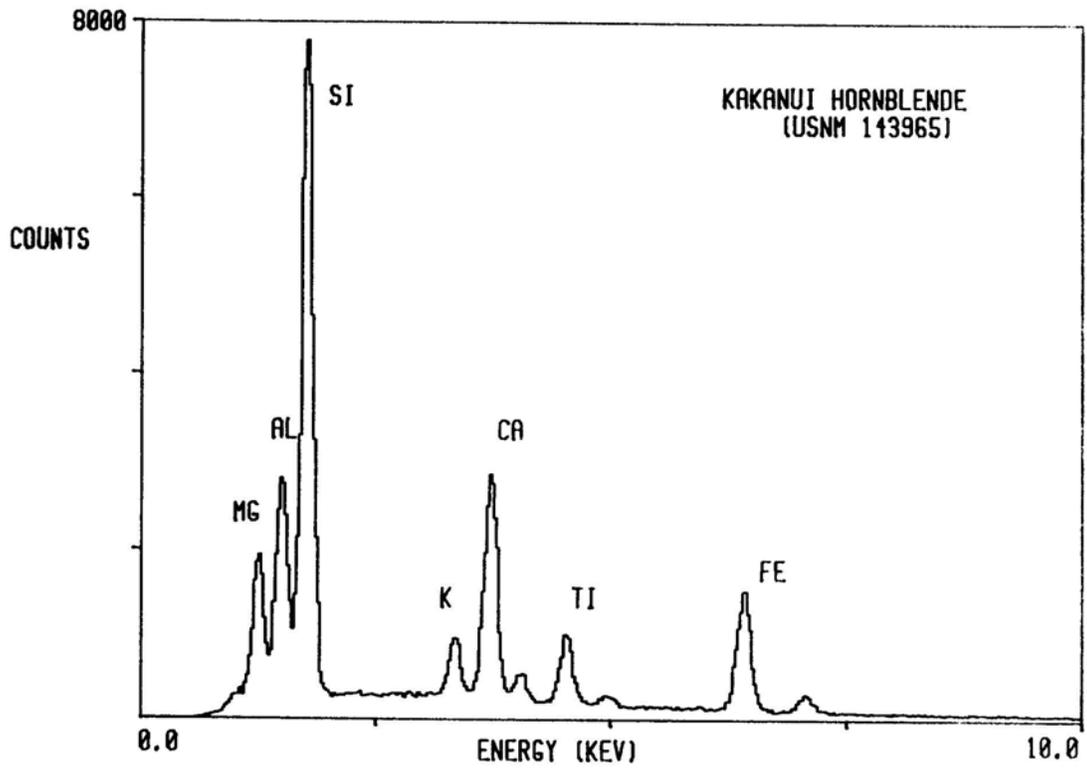
Although foreign scientists are welcome to request samples, NASA cannot provide funds to be spent outside the U.S.A. by citizens of other countries.

## **Acknowledgements**

The ER-2 flight personnel at NASA/Dryden Research Center performed the loading and unloading of the cosmic dust collectors on the ER-2 aircraft and provided flight log data and other critical assistance.

# Standard Spectra







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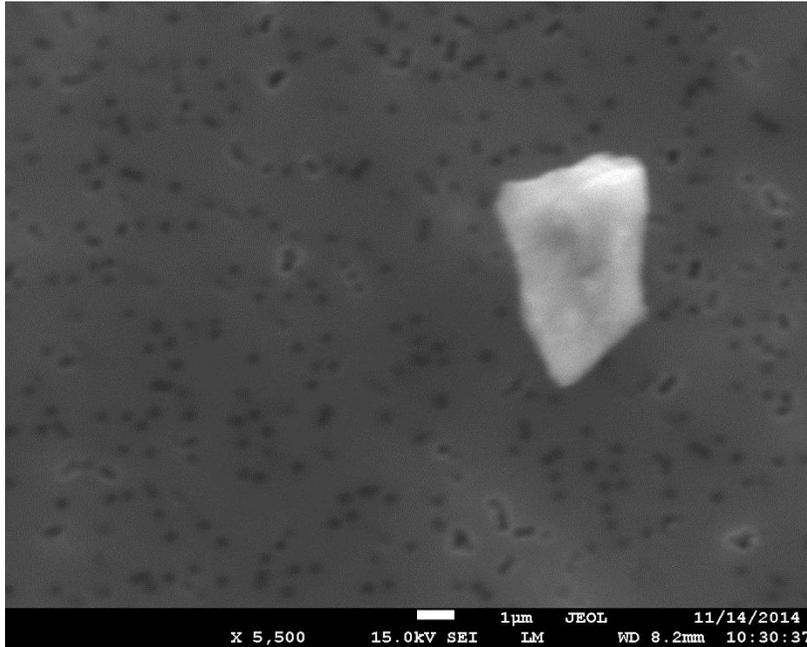
# Particle Descriptions

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## Cosmic and Possibly Cosmic Samples (C and C? Types)

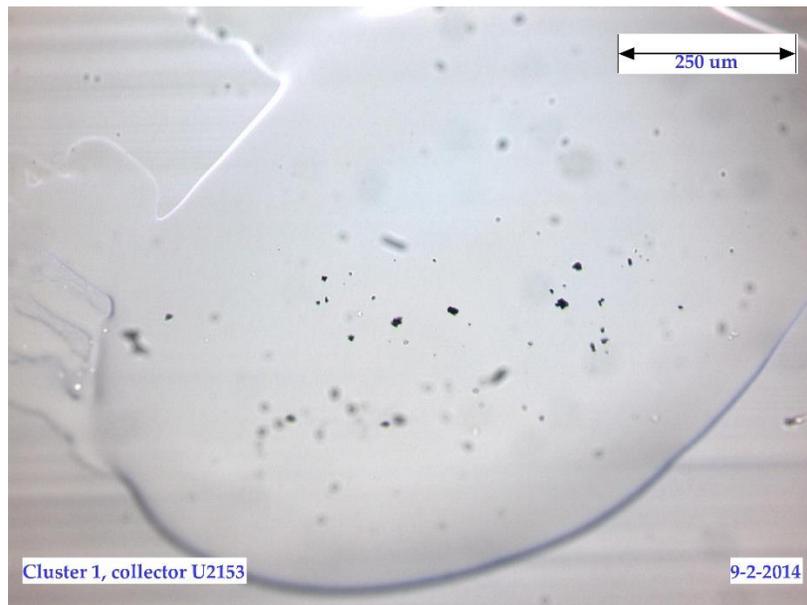


## U2153 A15



- Particle Size:** 7x5 µm
- Shape:** Equidimensional
- Transparency:** Opaque to Subvitreous
- Color:** Black
- Luster:** Pearly to Subvitreous
- Particle Type:** Possibly Cosmic or Natural Terrestrial Contamination
- Cluster No.:** 1
- Comments:** Chondritic CP-IDPs have been found in this cluster.

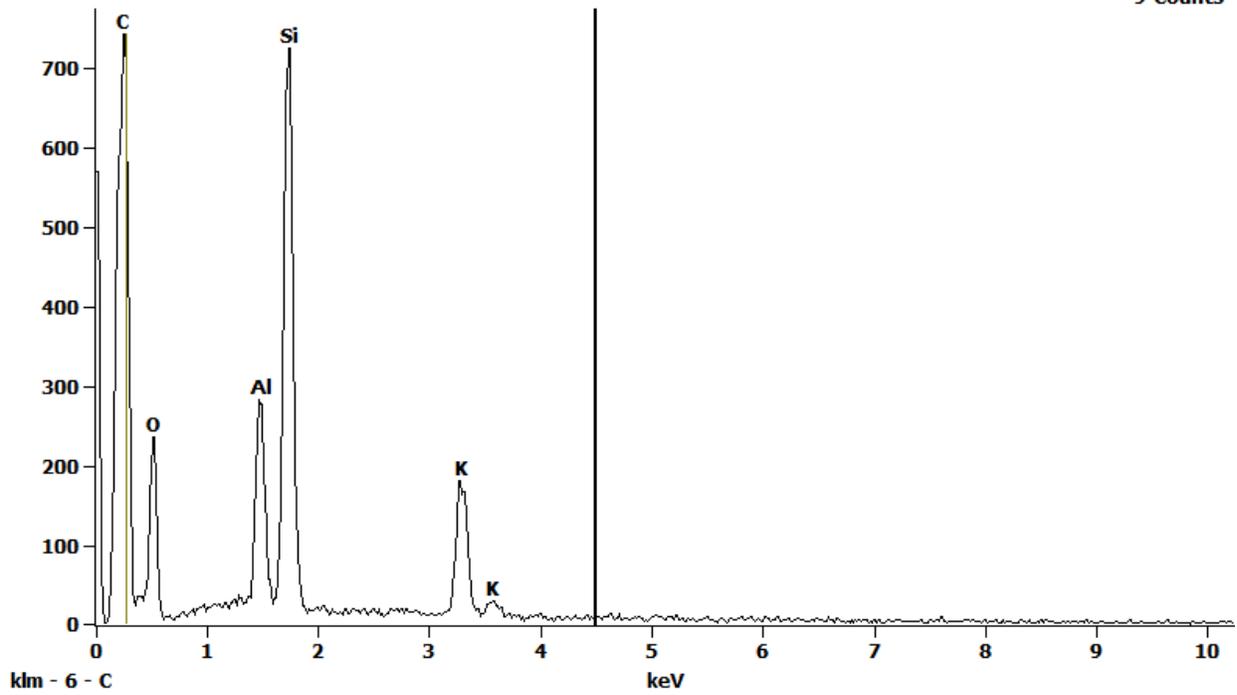
## Cluster of Origin: U2153 Cluster 1



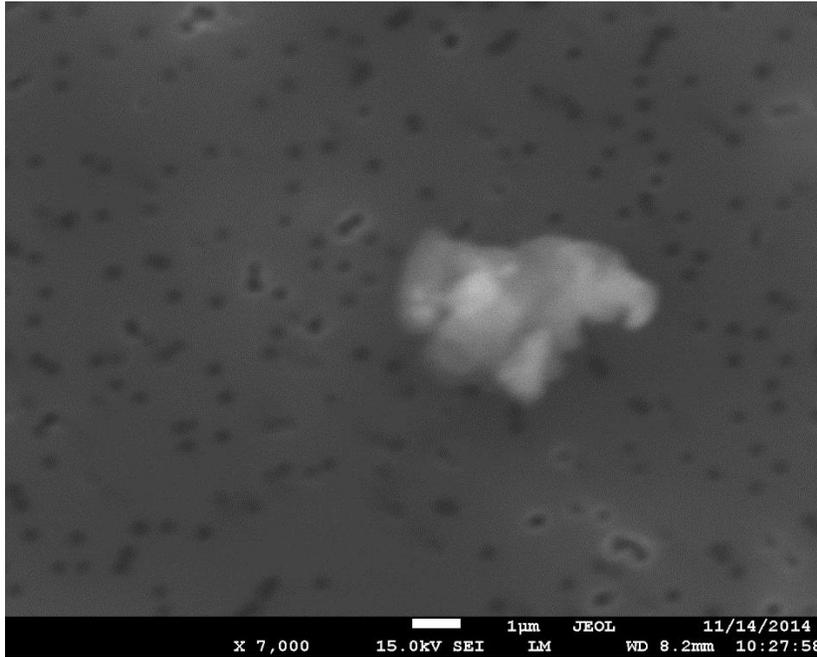
Full scale counts: 742

IDP(39)

Cursor: 4.500 keV  
9 Counts

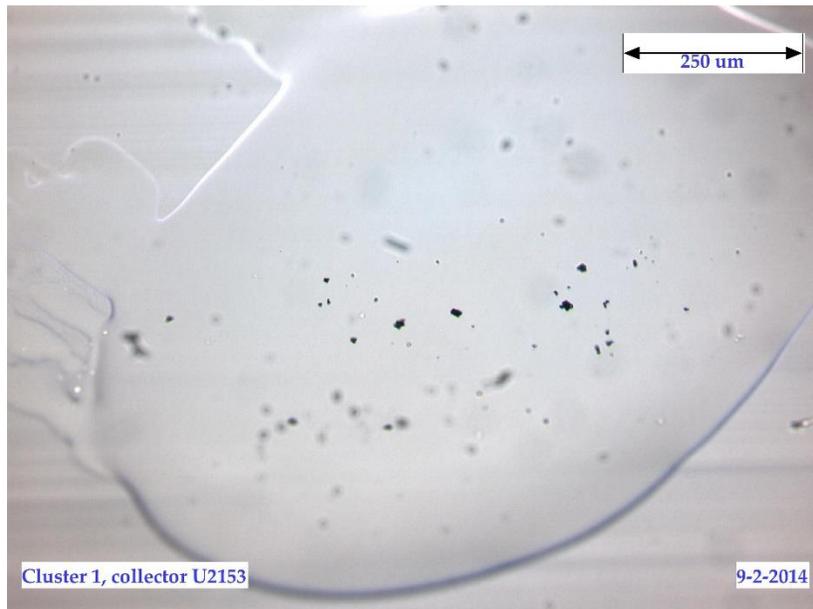


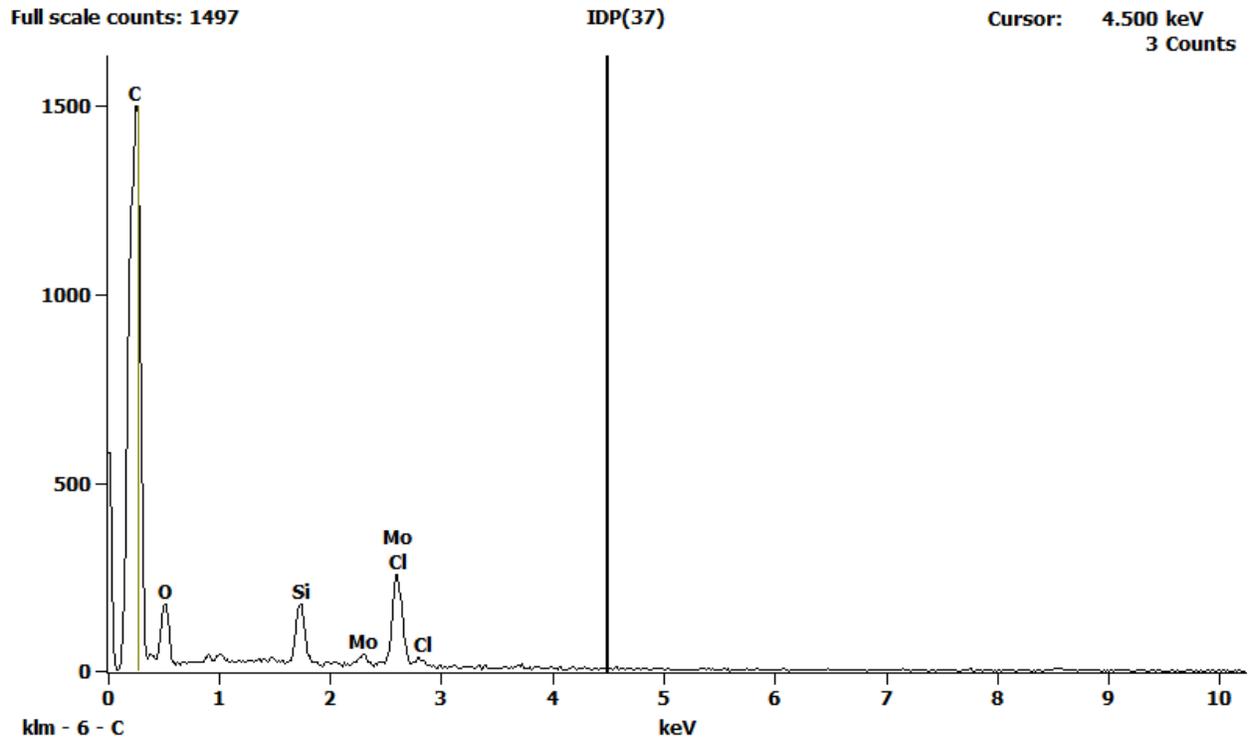
## U2153 A16



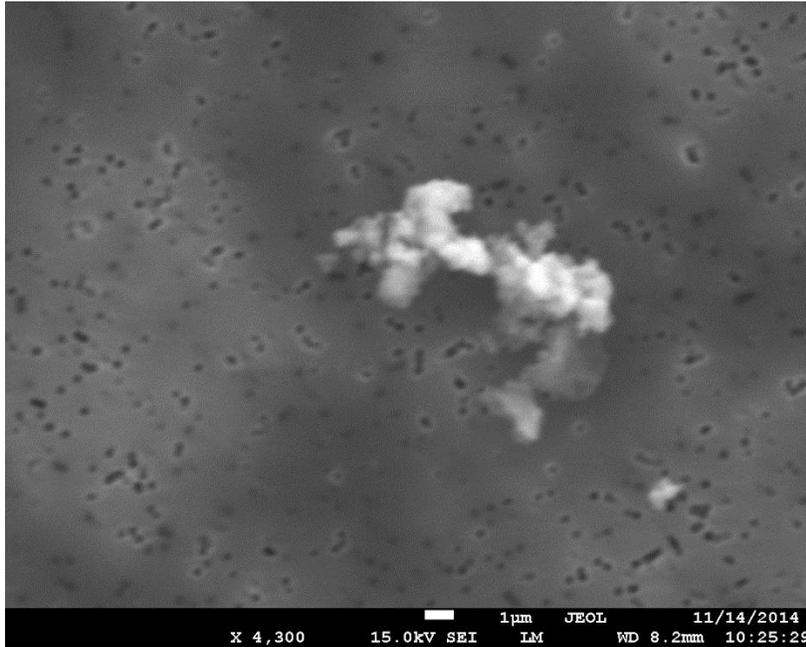
**Particle Size:** 7x4 µm  
**Shape:** Irregular  
**Transparency:** Opaque to Translucent  
**Color:** Black  
**Luster:** Pearly to Dull  
**Particle Type:** Possibly Cosmic or Natural Terrestrial Contamination  
**Cluster No.:** 1  
**Comments:** Chondritic CP-IDPs have been found in this cluster

## Cluster of Origin: U2153 Cluster 1





## U2153 A17



**Particle Size:** 6x4 µm

**Shape:** Irregular

**Transparency:** Opaque to Translucent

**Color:** Black, Gray

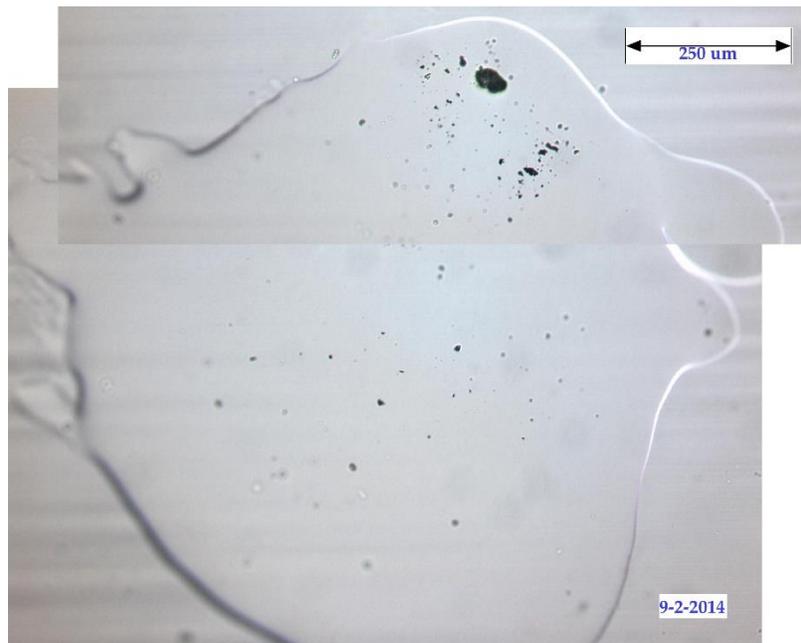
**Luster:** Dull

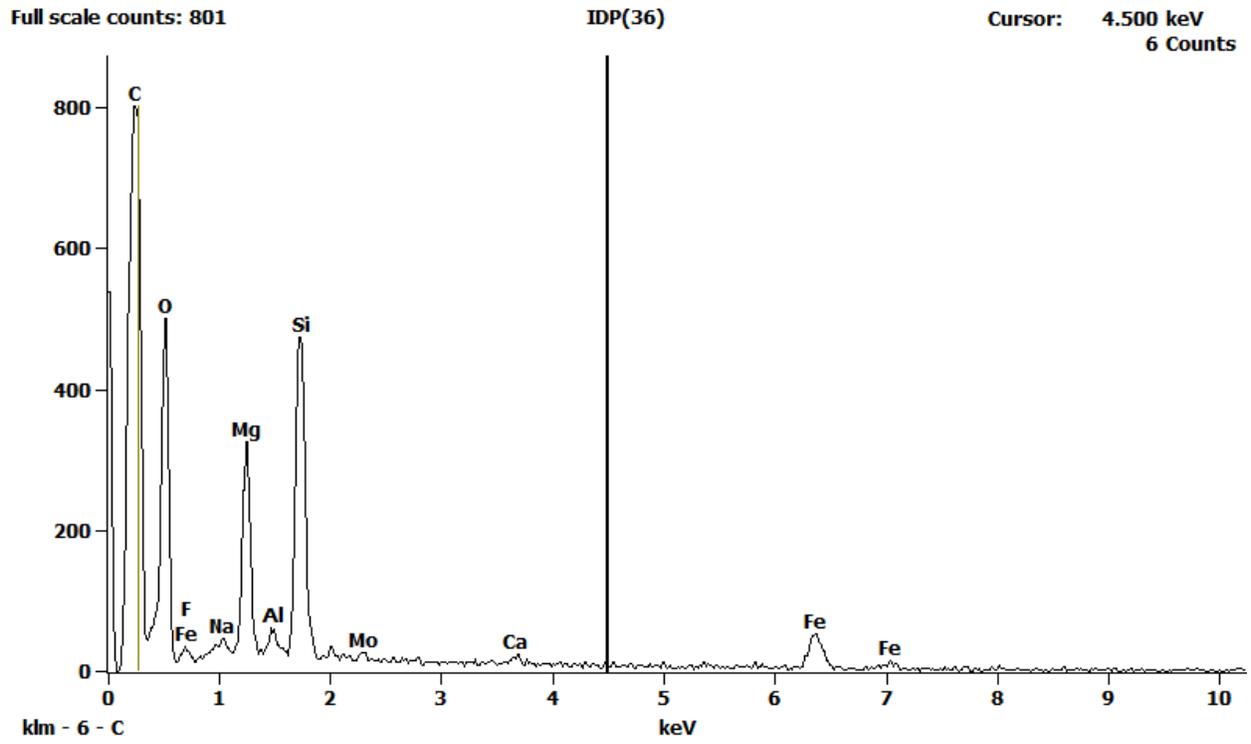
**Particle Type:** Possibly Cosmic or Natural Terrestrial Contamination

**Cluster No.:** 2

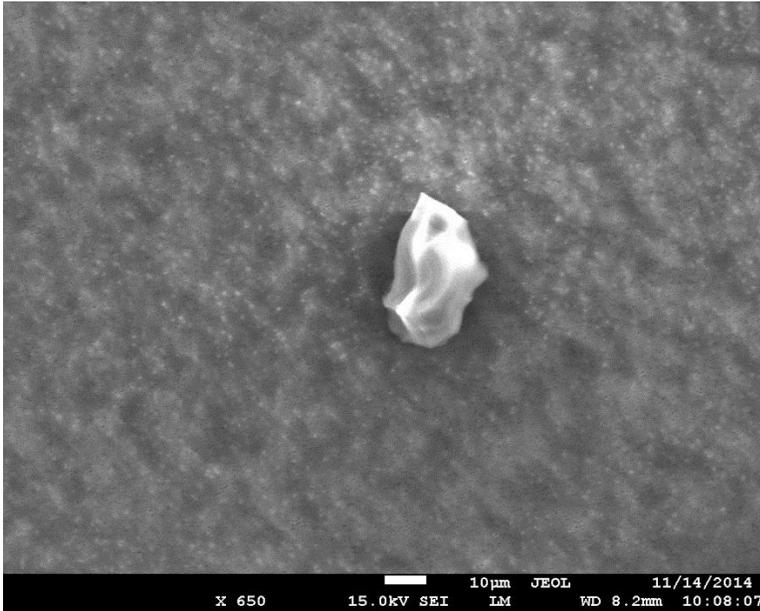
**Comments:** Chondritic hydrated and hybrid IDPs have been found in this cluster

## Cluster of Origin: U2153 Cluster 2





## U2153 A21



**Particle Size:** 20x30 µm

**Shape:** Equidimensional

**Transparency:** Opaque to Subvitreous

**Color:** Gray

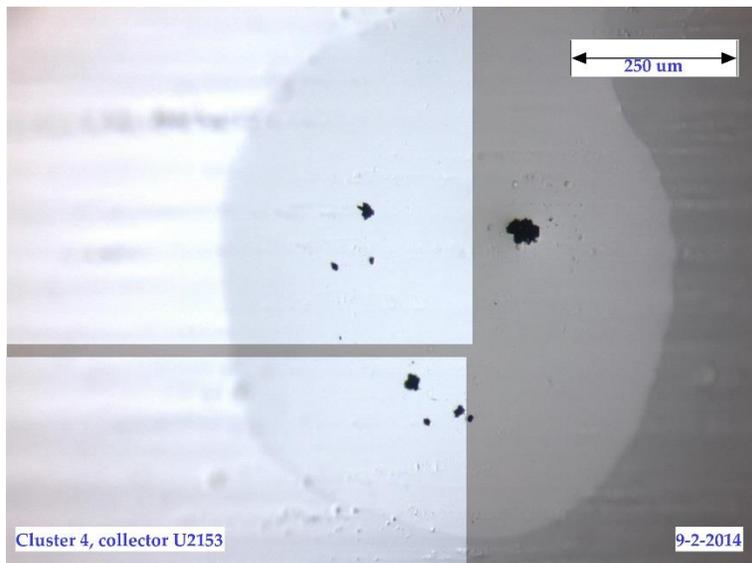
**Luster:** Pearly to Subvitreous

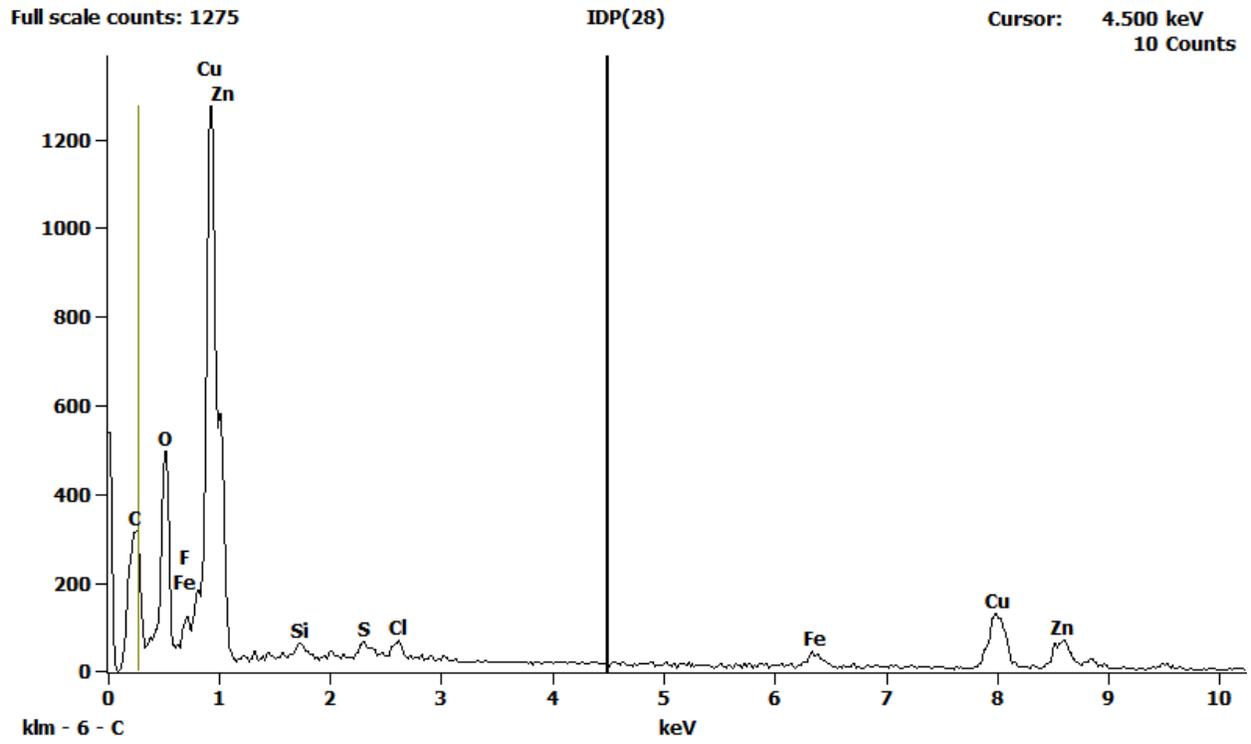
**Particle Type:** Cosmic

**Cluster No.:** 4

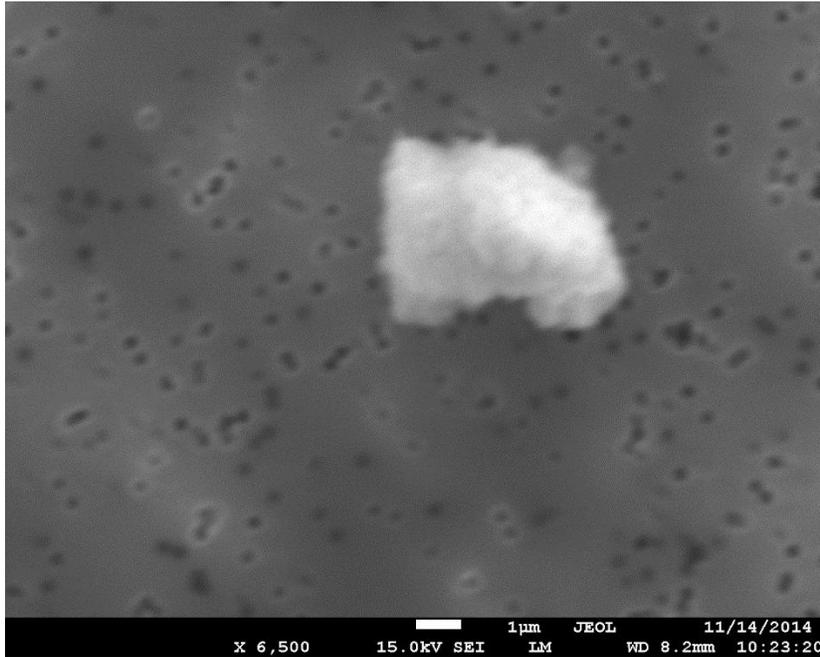
**Comments:** Chondritic hydrated IDPs and unusual amorphous assemblages with GEMS found in this cluster.

## Cluster of Origin: U2153 Cluster 4



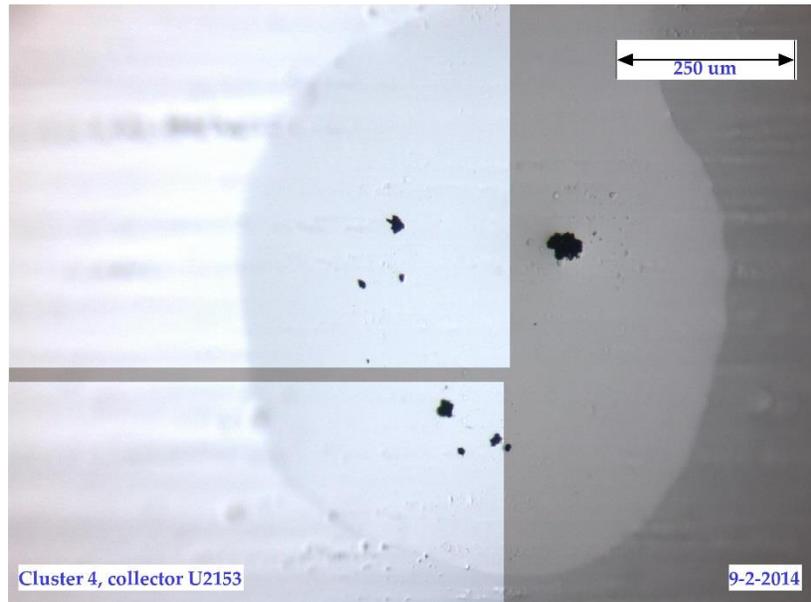


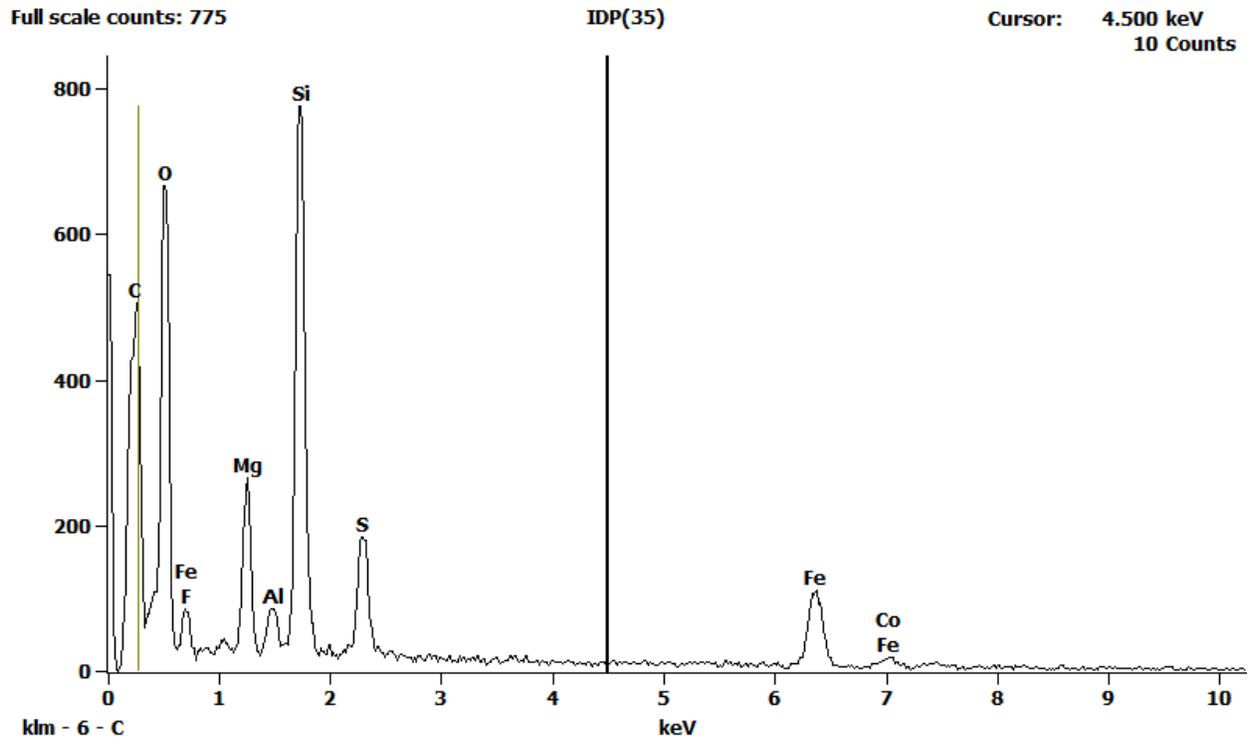
## U2153 A22



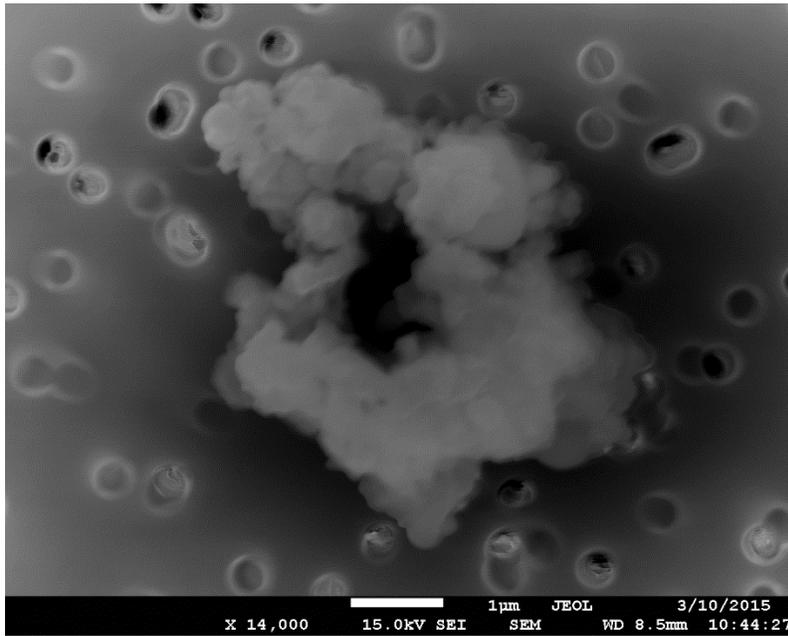
**Particle Size:** 6x5 µm  
**Shape:** Equidimensional  
**Transparency:** Opaque to Subvitreous  
**Color:** Black  
**Luster:** Pearly to Subvitreous  
**Particle Type:** Possibly Cosmic  
**Cluster No.:** 4  
**Comments:** Chondritic hydrated IDPs and unusual amorphous assemblages with GEMS found in this cluster.

## Cluster of Origin: U2153 Cluster 4



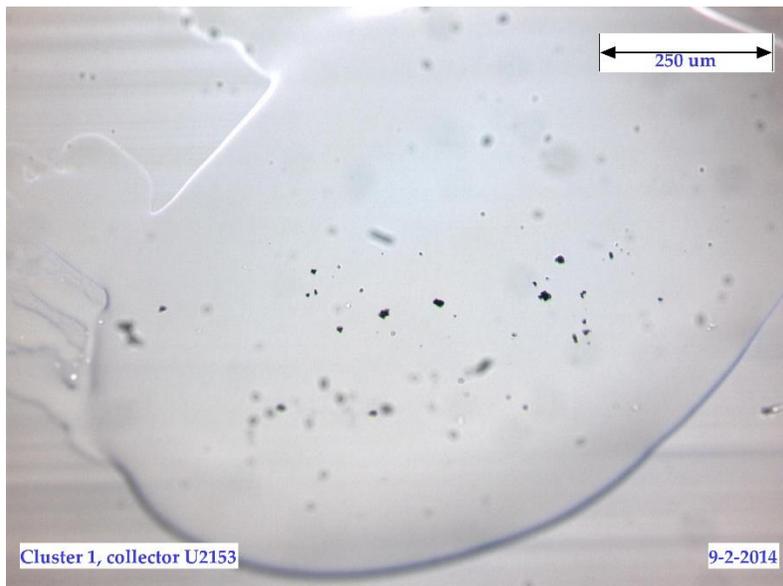


## U2153 B2



**Particle Size:** 7.5 µm  
**Shape:** Irregular to Equidimensional  
**Transparency:** Opaque to Subvitreous  
**Color:** Black  
**Luster:** Pearly to Dull  
**Particle Type:** Possibly Cosmic  
**Cluster No.:** 1  
**Comments:**

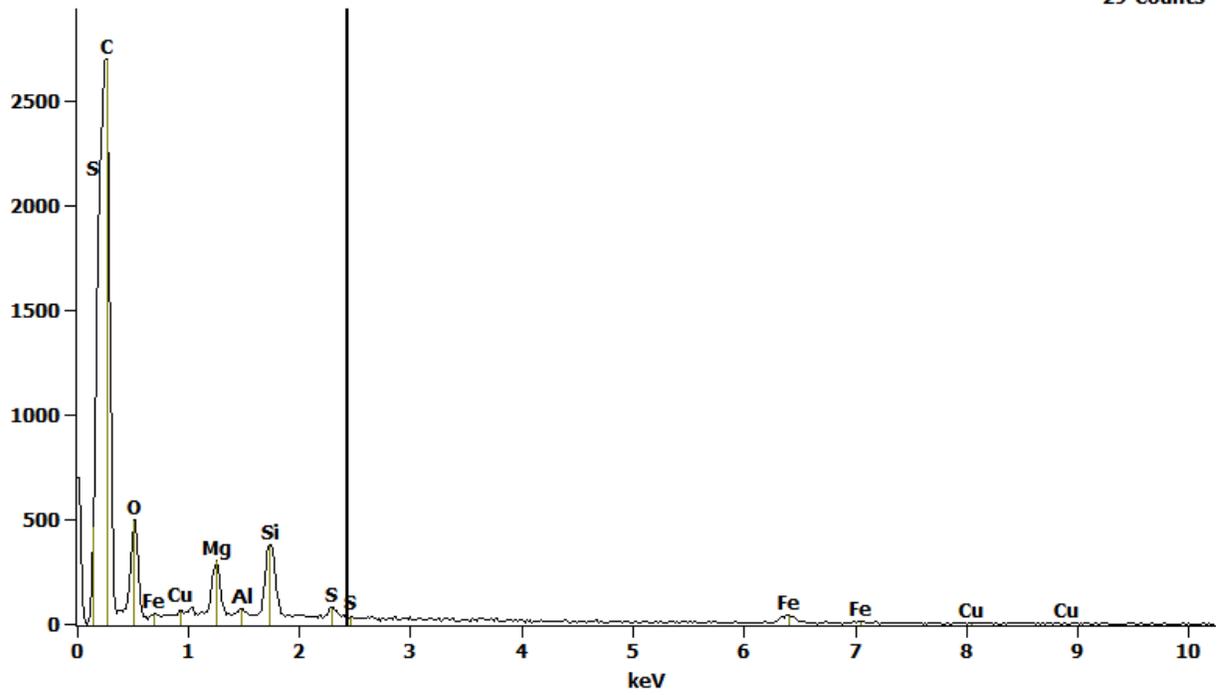
## Cluster of Origin: U2153 Cluster 1



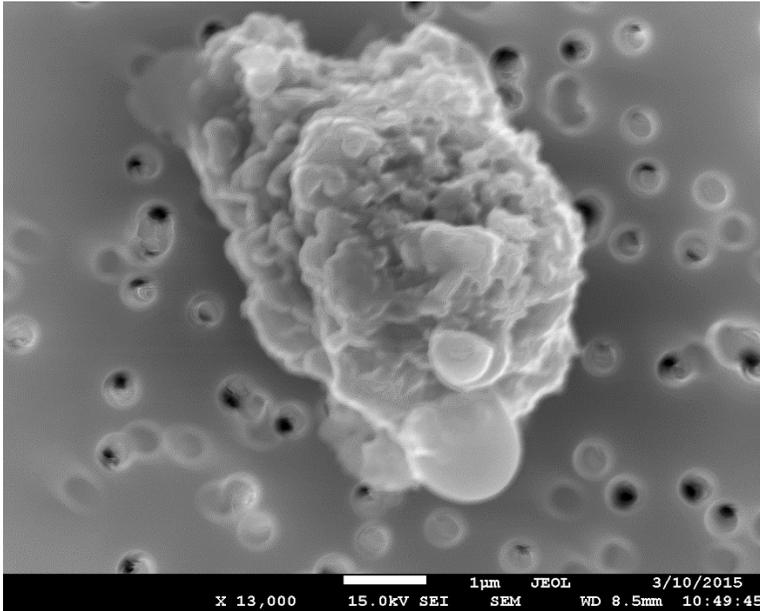
Full scale counts: 2695

U2153B2

Cursor: 2.429 keV  
29 Counts

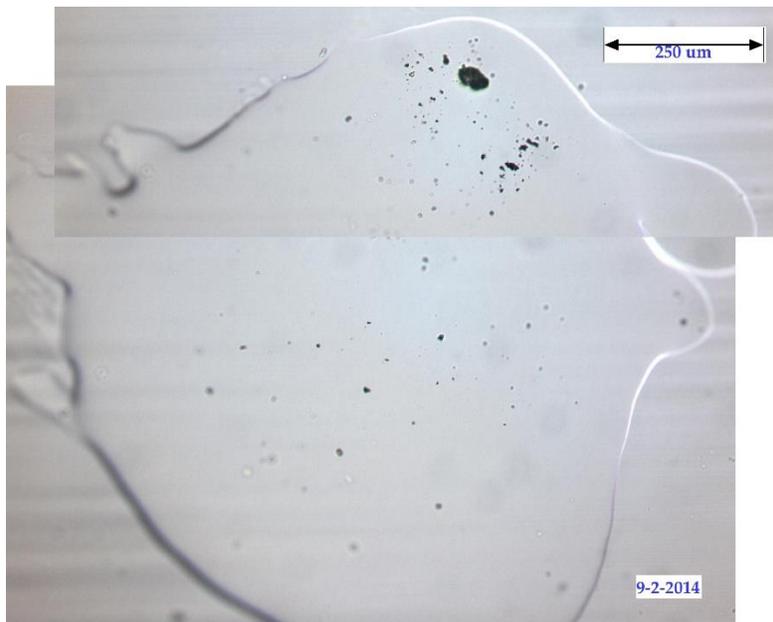


## U2153 B3



**Particle Size:** 4x6 µm  
**Shape:** Equidimensional to Irregular  
**Transparency:** Opaque to Subvitreous  
**Color:** Black  
**Luster:** Pearly to Subvitreous  
**Particle Type:** Cosmic  
**Cluster No.:** 2  
**Comments:**

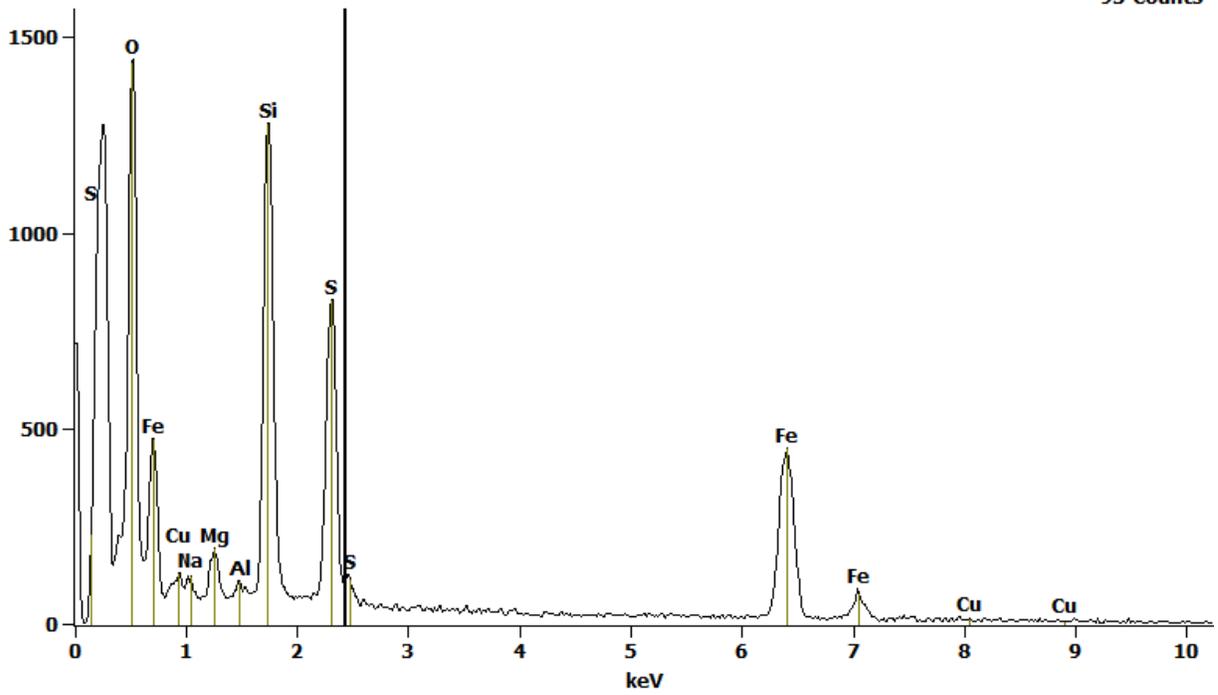
## Cluster of Origin: U2153 Cluster 2



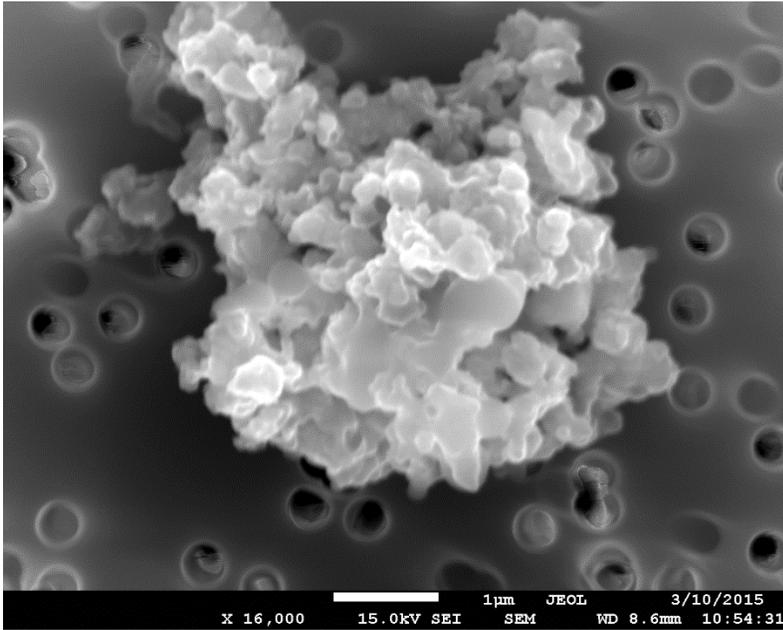
Full scale counts: 1443

U2153B3

Cursor: 2.429 keV  
93 Counts

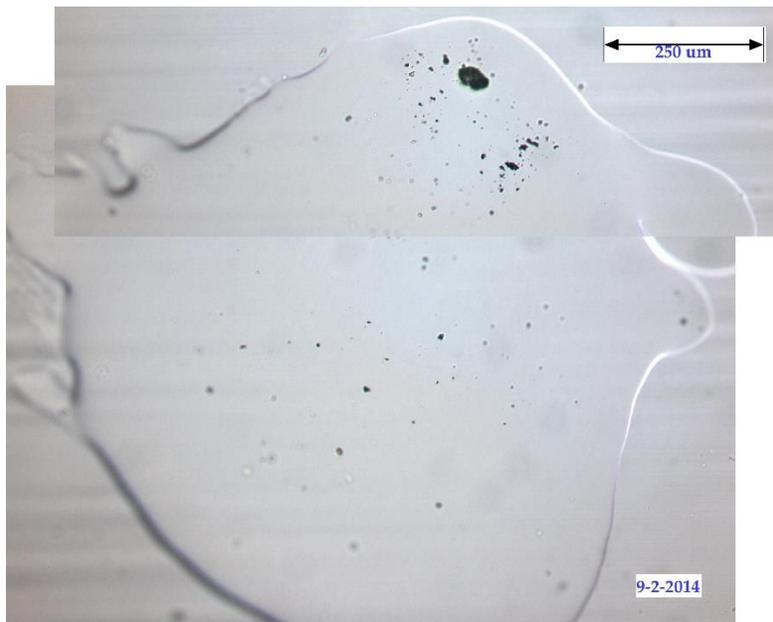


## U2153 B4



**Particle Size:** 4x5 μm  
**Shape:** Irregular to Equidimensional  
**Transparency:** Translucent to Opaque  
**Color:** Black  
**Luster:** Pearly to Dull  
**Particle Type:** Possibly Cosmic  
**Cluster No.:** 2  
**Comments:**

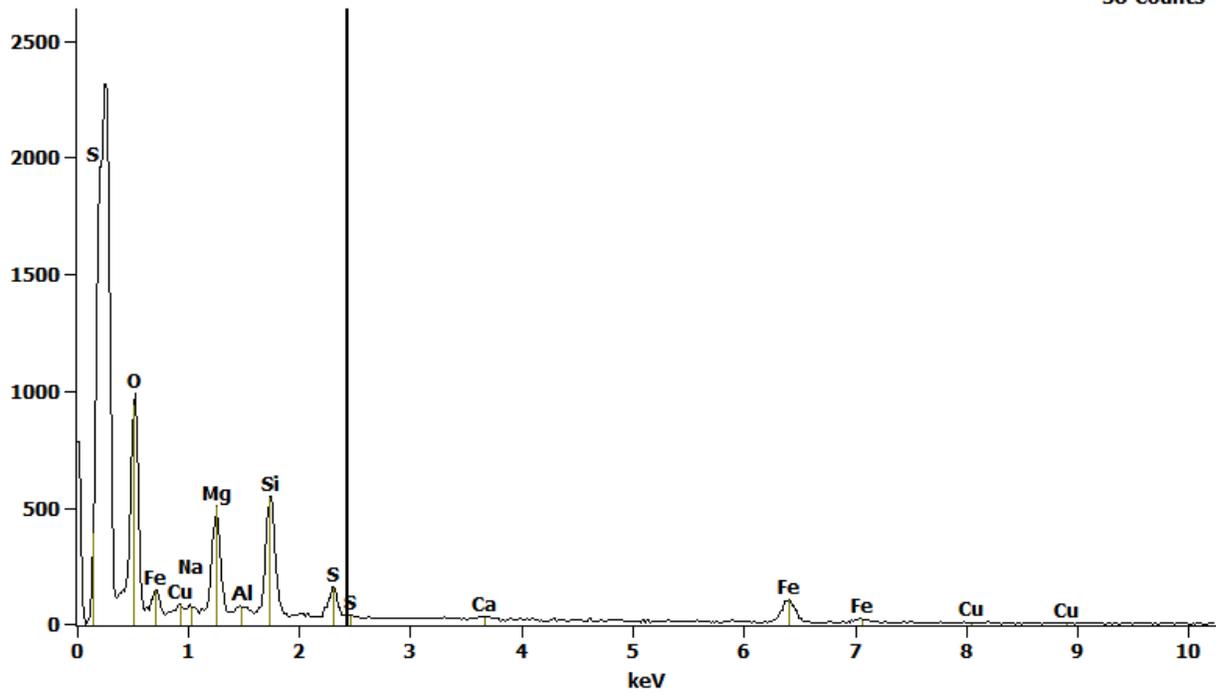
## Cluster of Origin: U2153 Cluster 2



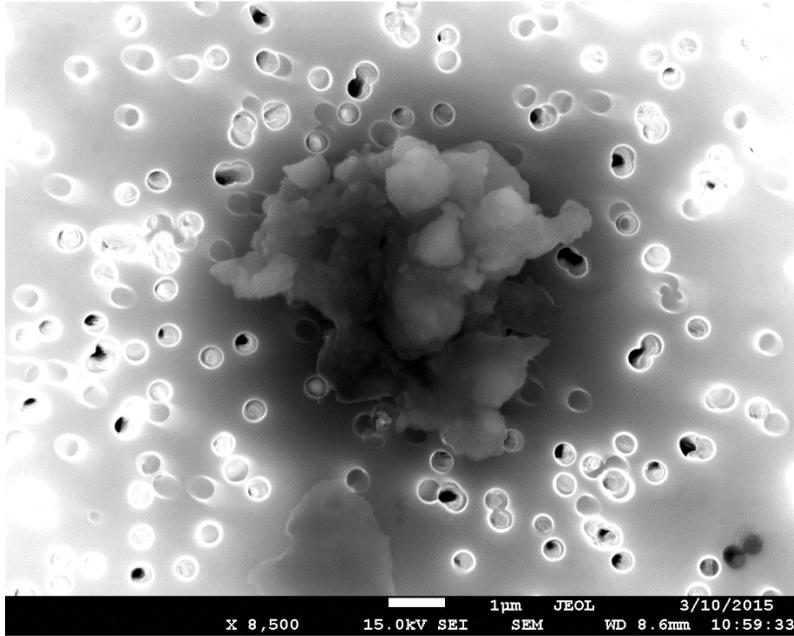
Full scale counts: 2314

U2153 B4

Cursor: 2.429 keV  
38 Counts



## U2153 B5



**Particle Size:** 9 µm

**Shape:** Equidimensional to Spherical

**Transparency:** Opaque to Subvitreous

**Color:** Black

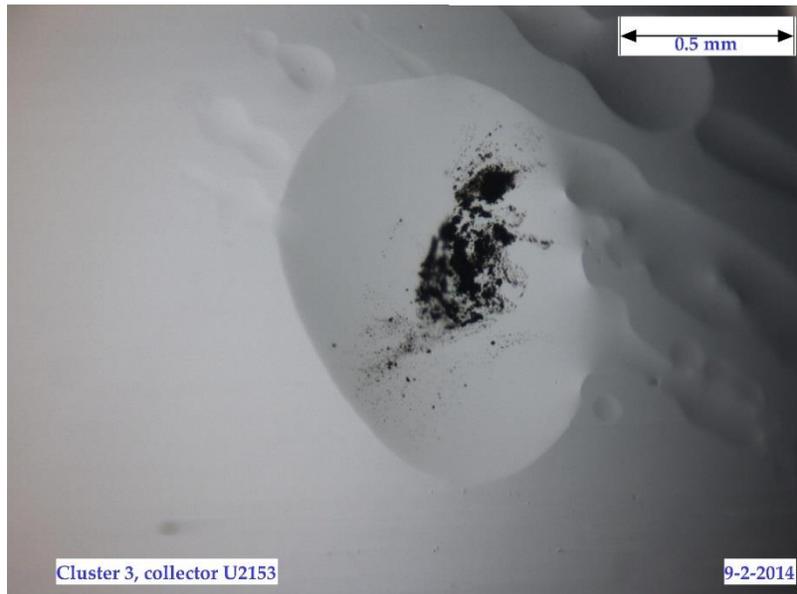
**Luster:** Pearly to Dull

**Particle Type:** Possibly Cosmic

**Cluster No.:** 3

**Comments:**

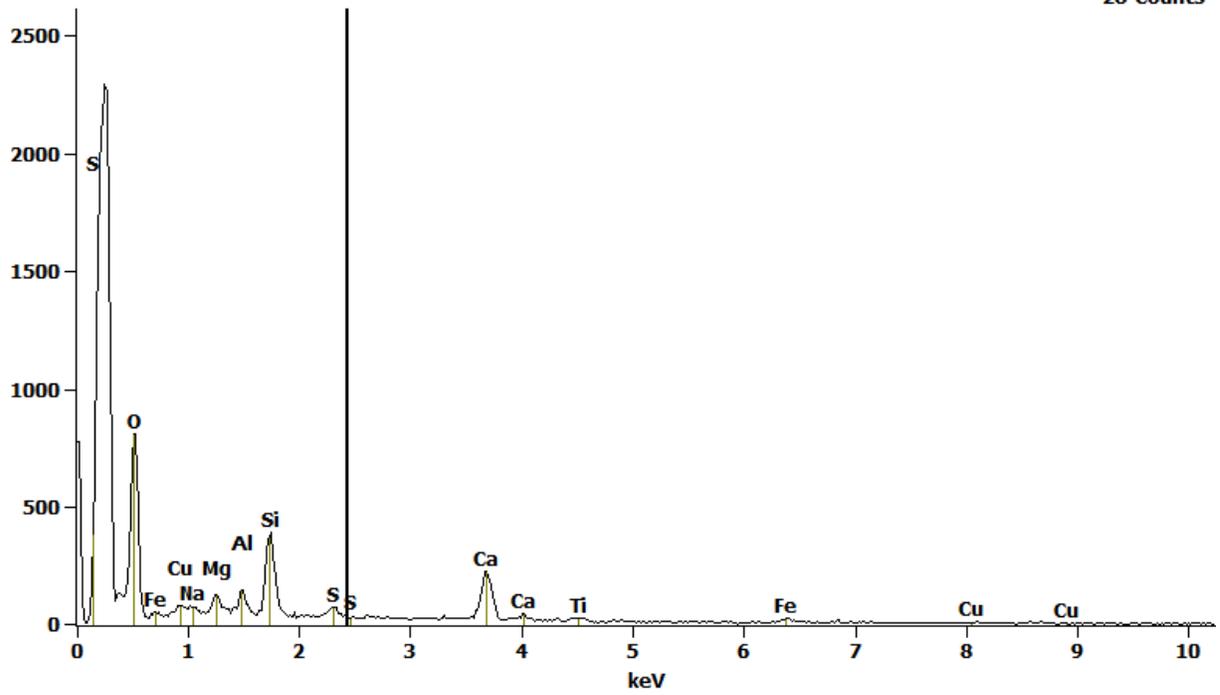
## Cluster of Origin: U2153 Cluster 3



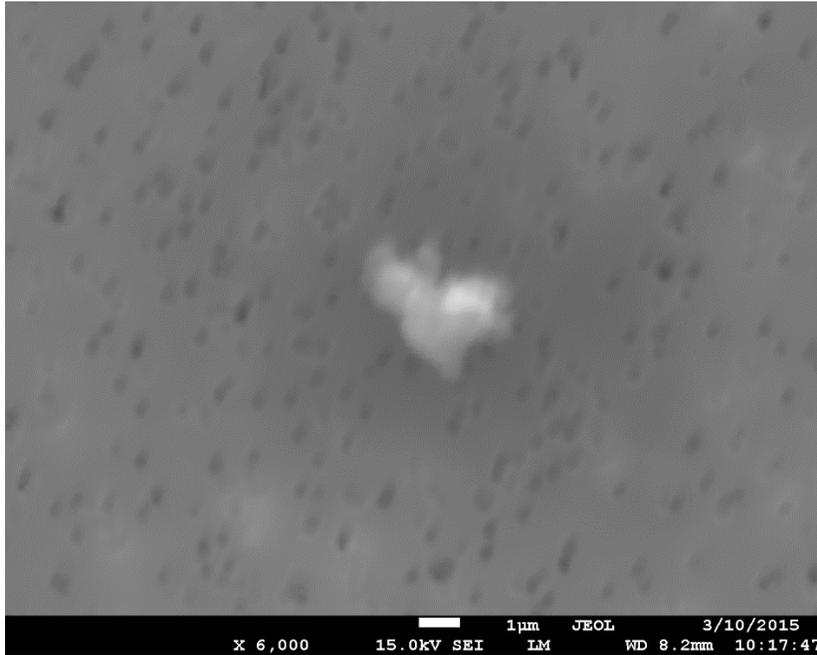
Full scale counts: 2294

U2153B5

Cursor: 2.429 keV  
28 Counts

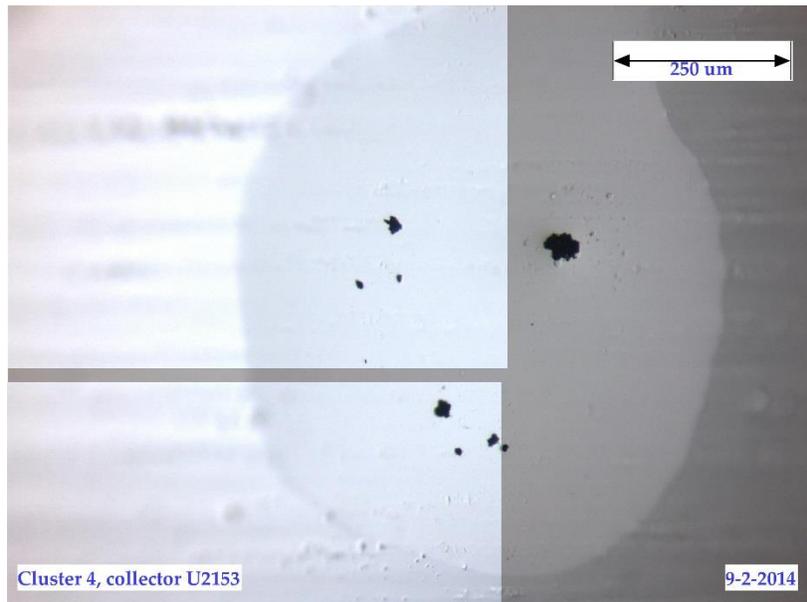


## U2153 C2



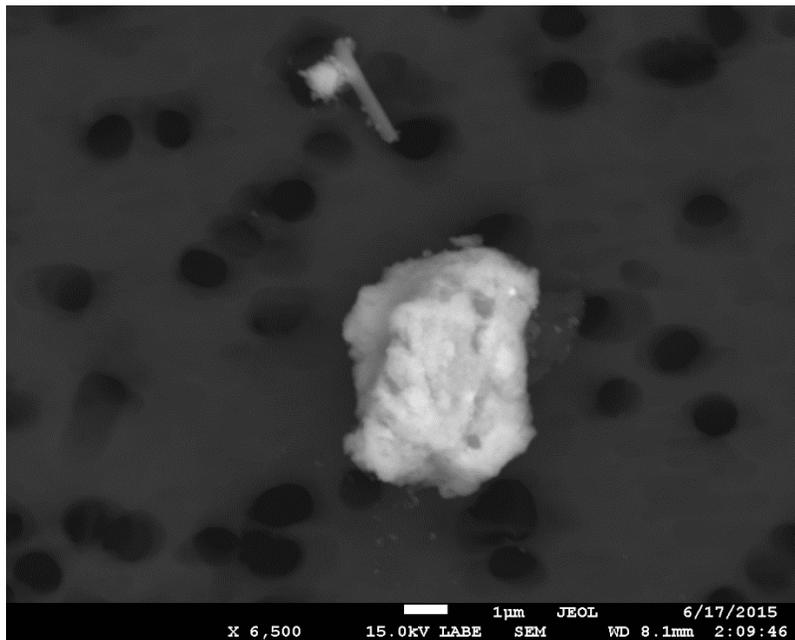
**Particle Size:** 3 µm  
**Shape:** Equidimensional to Irregular  
**Transparency:** Opaque to Subvitreous  
**Color:** Black  
**Luster:** Pearly to Dull  
**Particle Type:** Possibly Cosmic  
**Cluster No.:** 4  
**Comments:**

## Cluster of Origin: U2153 Cluster 4





## U2158 A15



**Particle Size:** 5x7.5 µm

**Shape:** Equidimensional

**Transparency:** Opaque

**Color:** Brown, Red

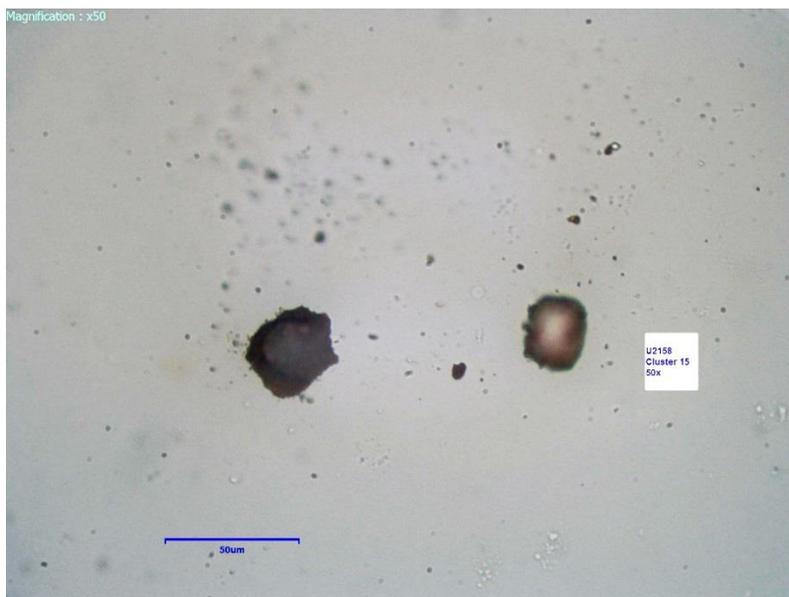
**Luster:** Pearly to Dull

**Particle Type:** Possibly Cosmic

**Cluster No.:** 15

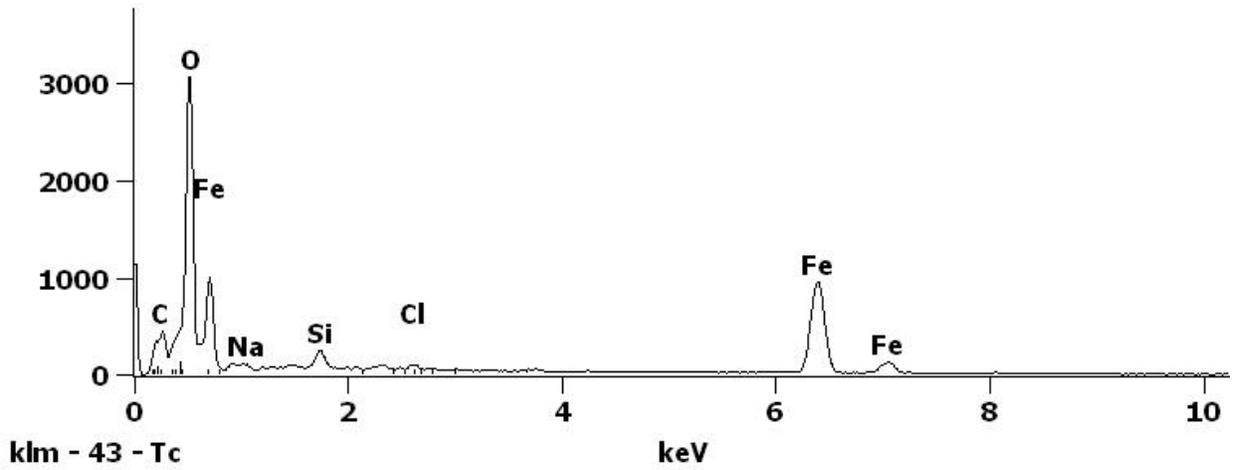
**Comments:**

## Cluster of Origin: U2158 Cluster 15



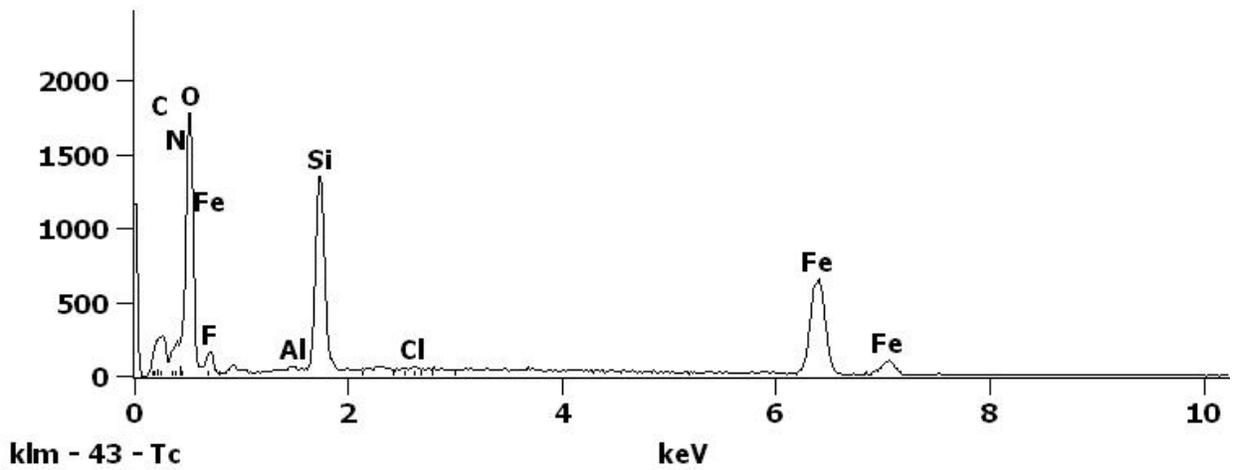
Full scale counts: 3060

A15(1)\_pt1



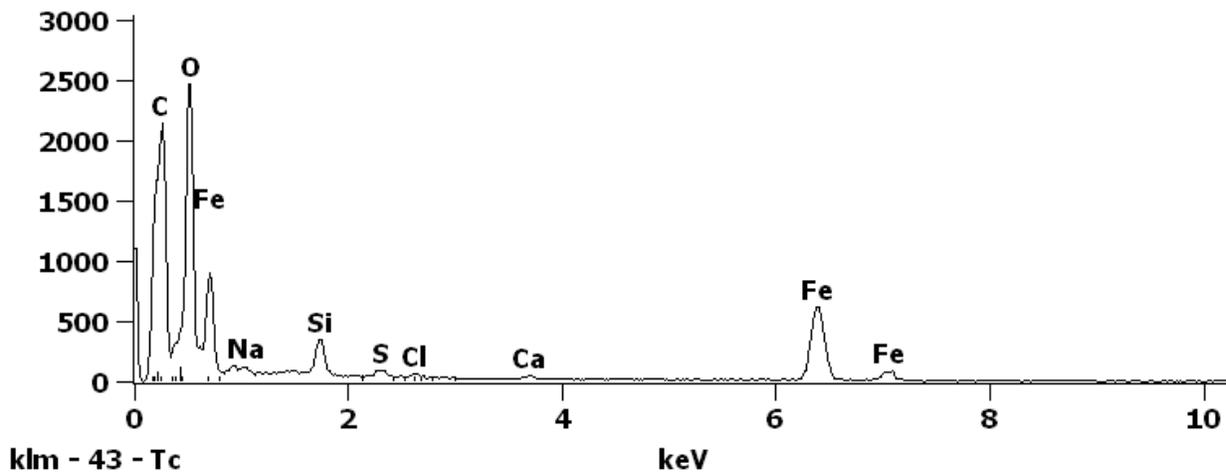
Full scale counts: 1776

A15(1)\_pt2



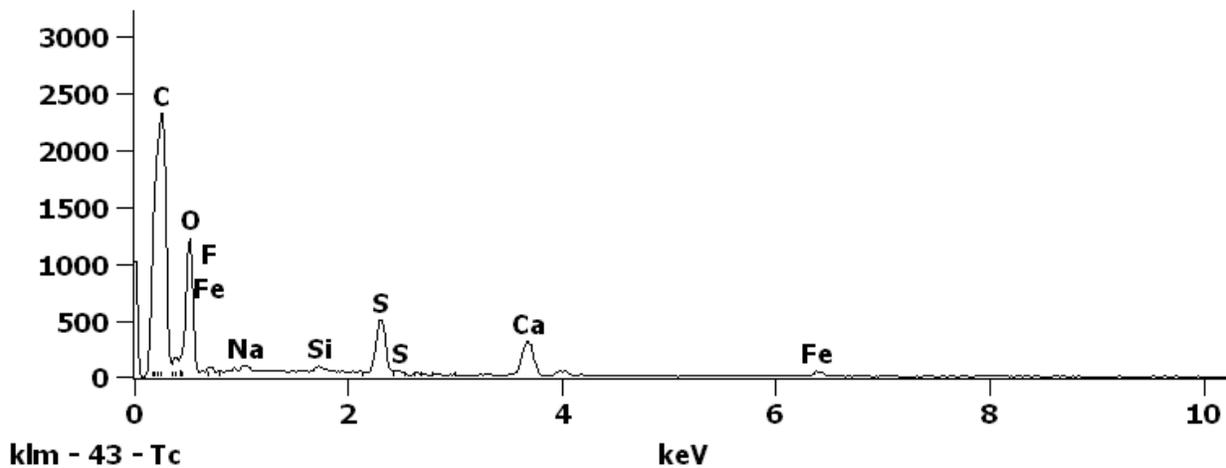
Full scale counts: 2462

A15(1)\_pt3

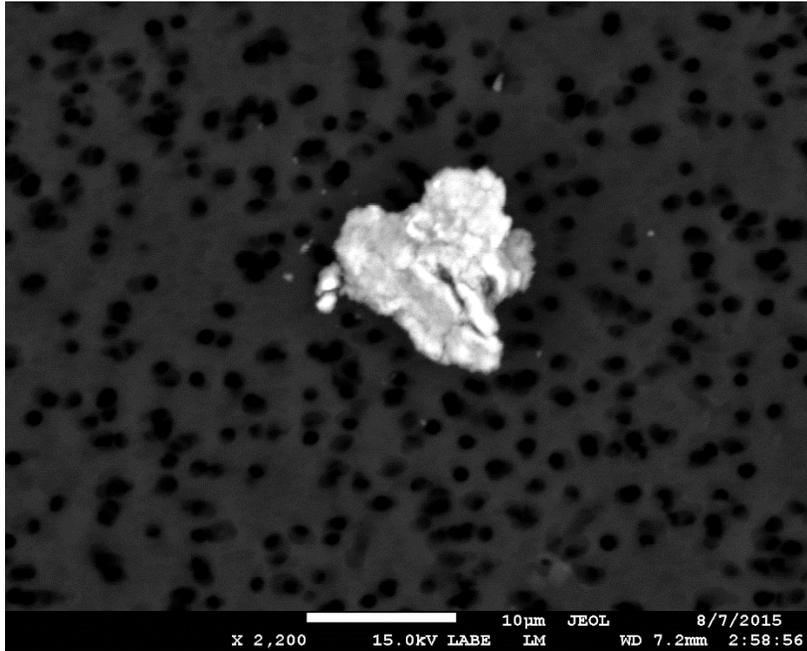


Full scale counts: 2324

A15(1)\_pt4



## U2158 A16



**Particle Size:** 10x12  $\mu\text{m}$

**Shape:** Irregular

**Transparency:** Opaque

**Color:** Black

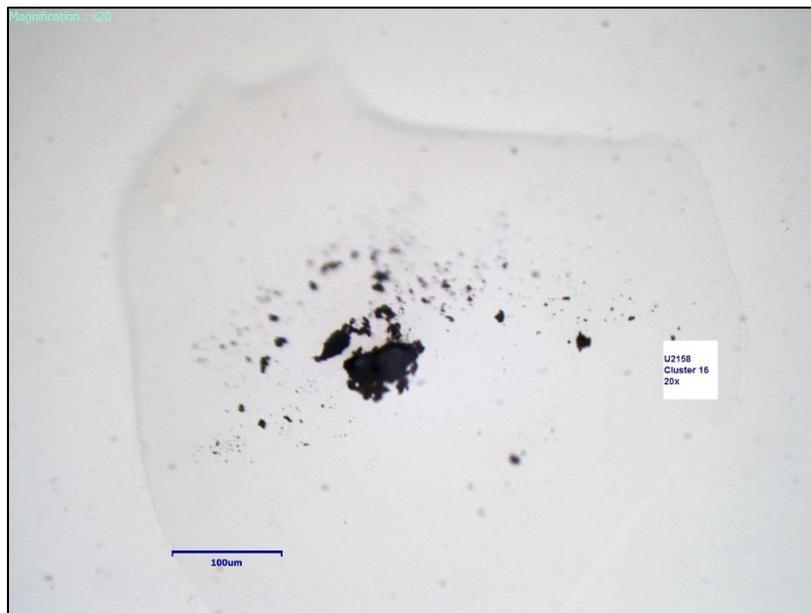
**Luster:** Dull

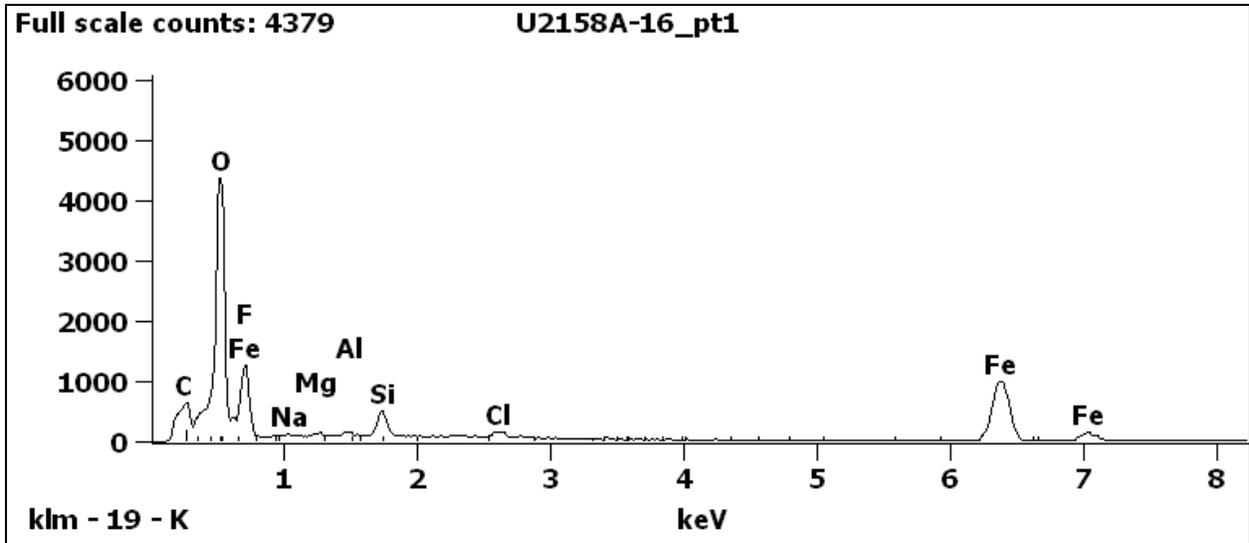
**Particle Type:** Possibly Cosmic

**Cluster No.:** 16

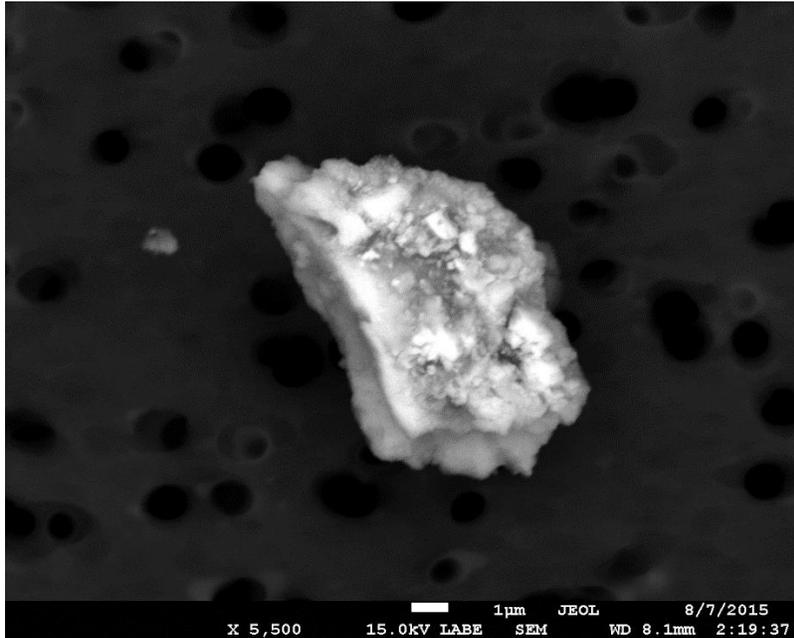
**Comments:**

## Cluster of Origin: U2158 Cluster 16





## U2158 A17



**Particle Size:** 6x10 µm

**Shape:** Equidimensional

**Transparency:** Translucent

**Color:** Brown, Black, Red

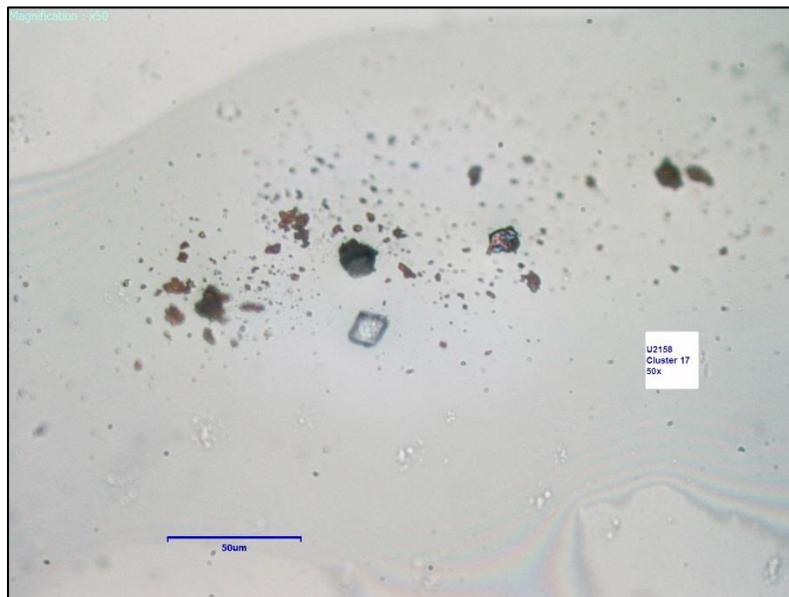
**Luster:** Pearly to Vitreous

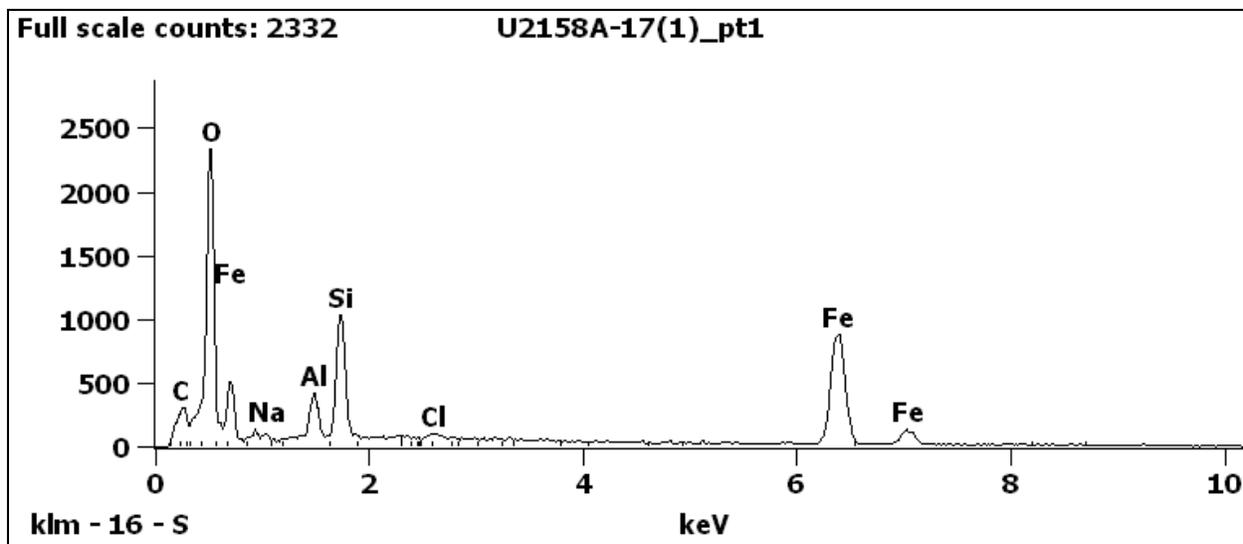
**Particle Type:** Possibly Cosmic

**Cluster No.:** 17

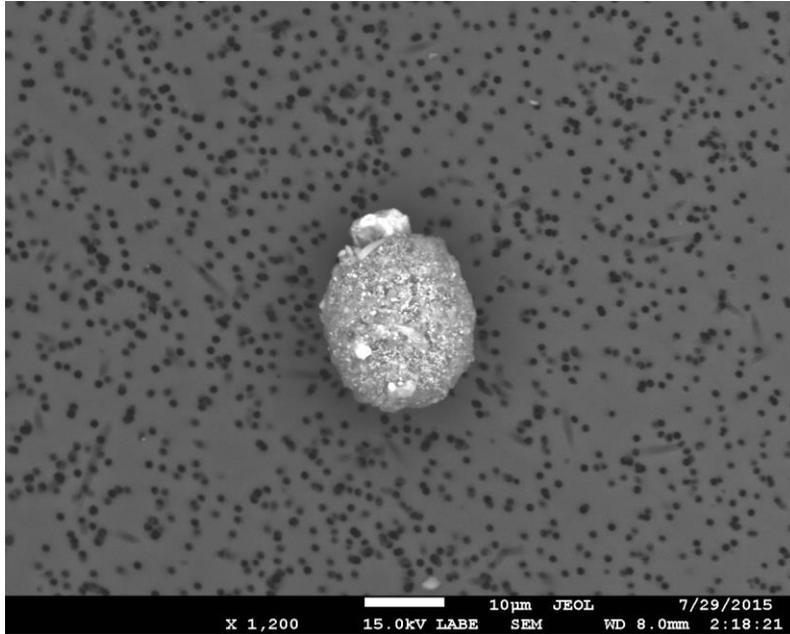
**Comments:**

## Cluster of Origin: U2158 Cluster 17





## U2158 B1



**Particle Size:** 22 µm

**Shape:** Spherical

**Transparency:** Opaque

**Color:** Black

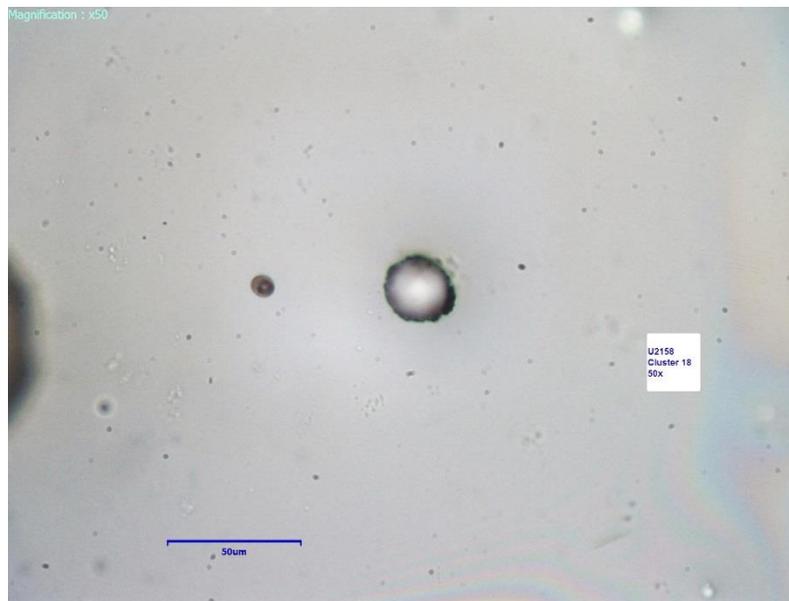
**Luster:** Pearly

**Particle Type:** Possibly Cosmic

**Cluster No.:** 18

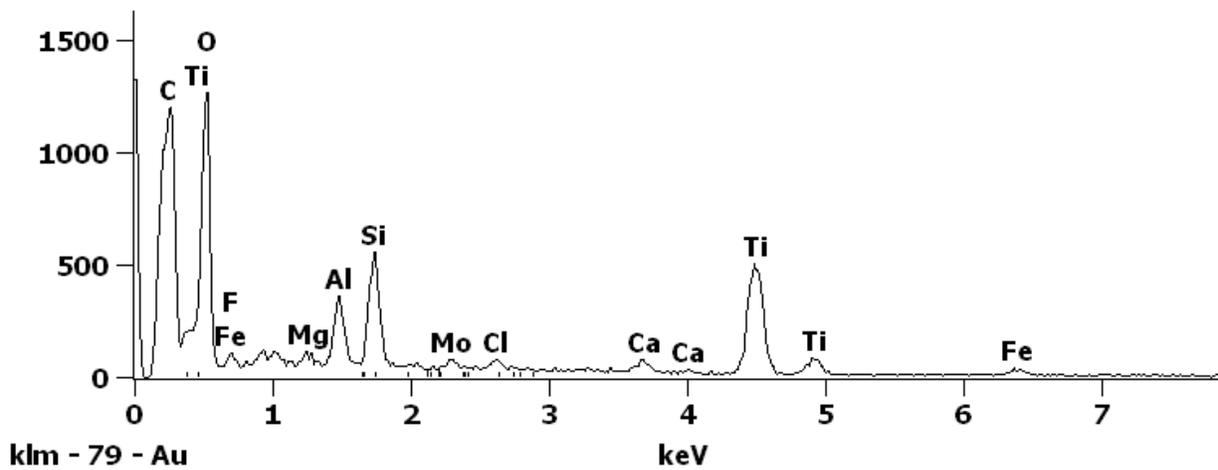
**Comments:**

## Cluster of Origin: U2158 Cluster 18



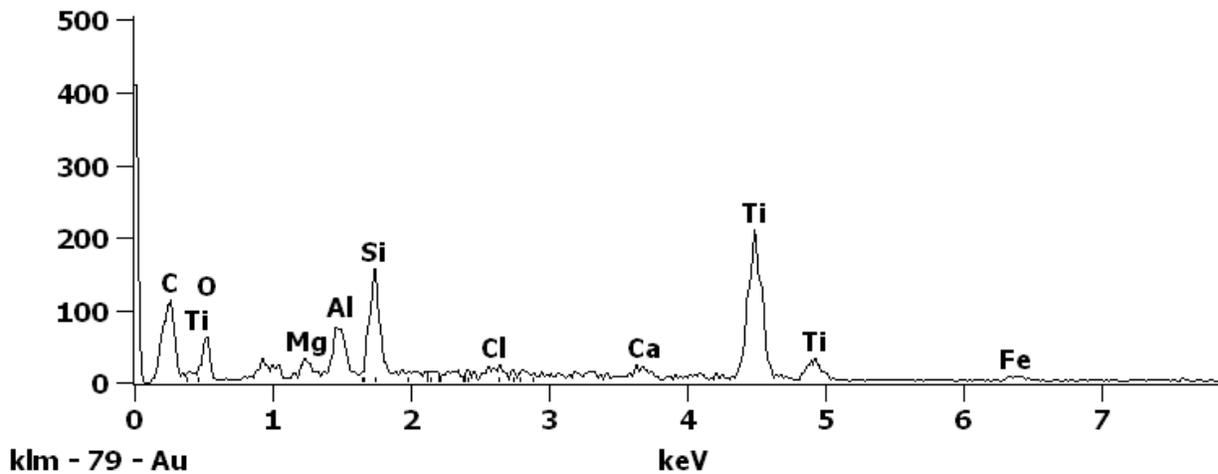
Full scale counts: 1323

U2158B(1)\_pt1

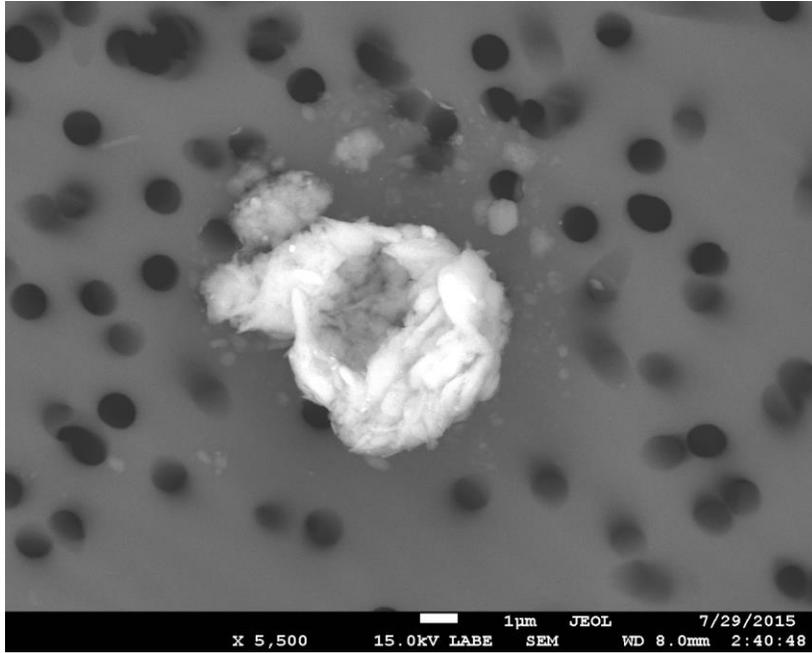


Full scale counts: 410

U2158B(1)\_pt2

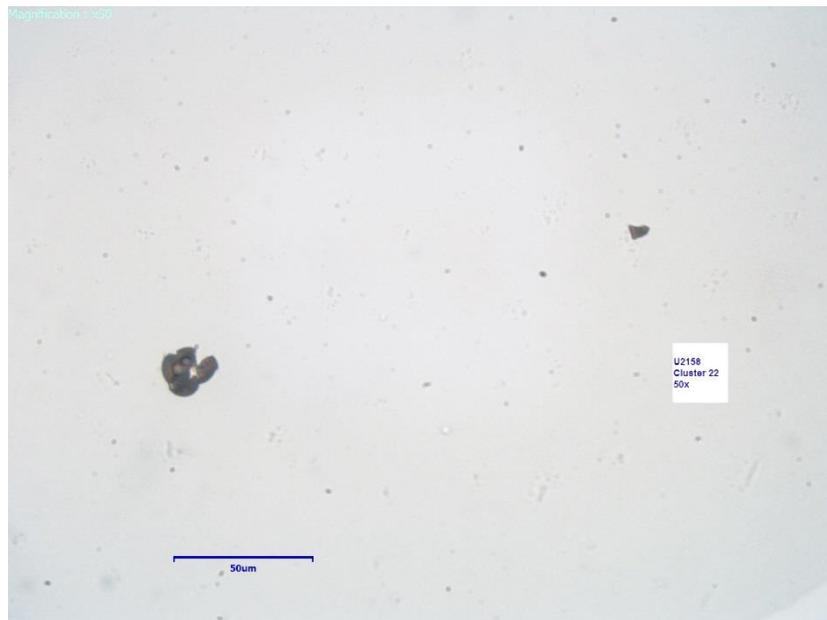


## U2158 B5



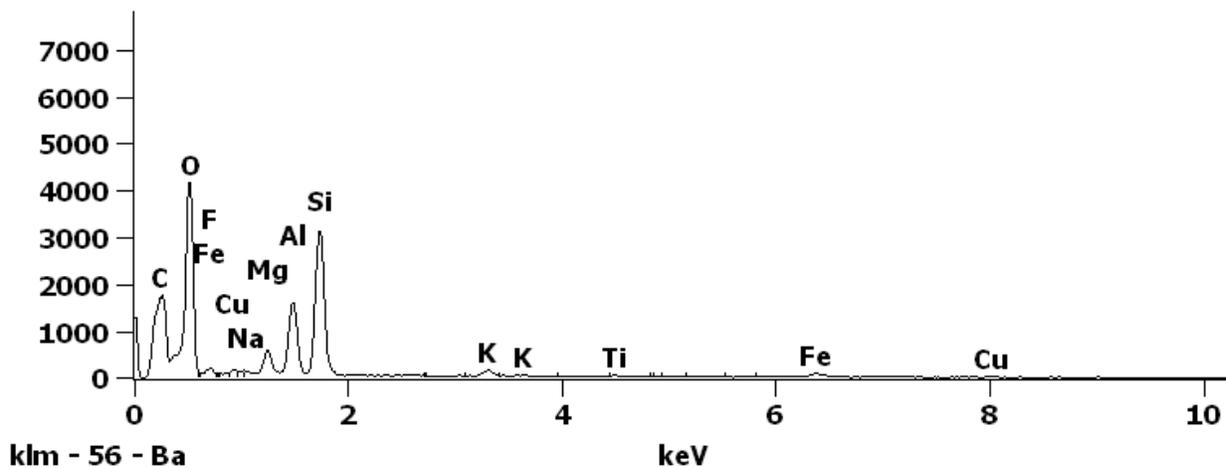
**Particle Size:** 8 µm  
**Shape:** Equidimensional  
**Transparency:** Opaque  
**Color:** Brown  
**Luster:** Dull  
**Particle Type:** Possibly Cosmic  
**Cluster No.:** 22  
**Comments:**

## Cluster of Origin: U2158 Cluster 22



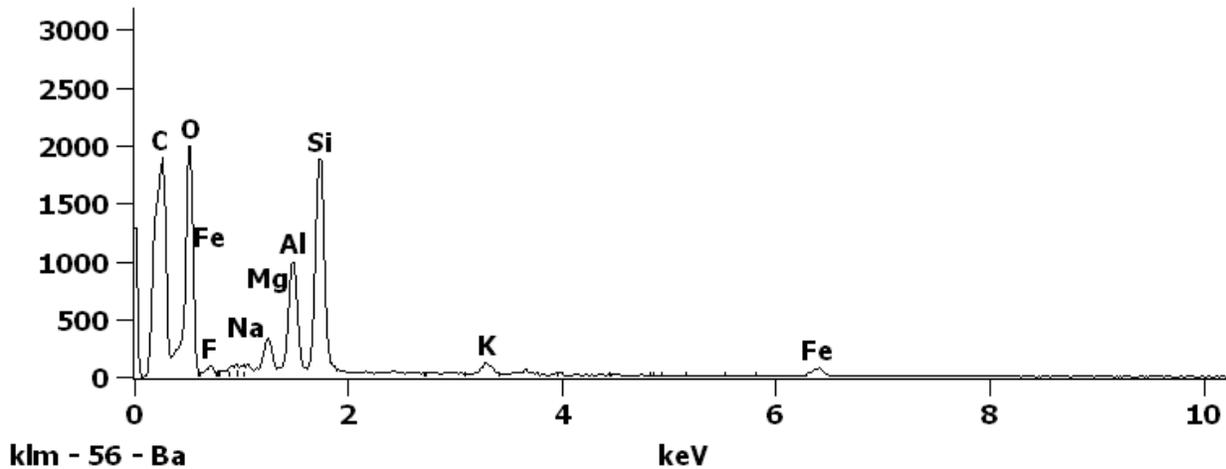
Full scale counts: 4165

U2158B(5)\_pt1

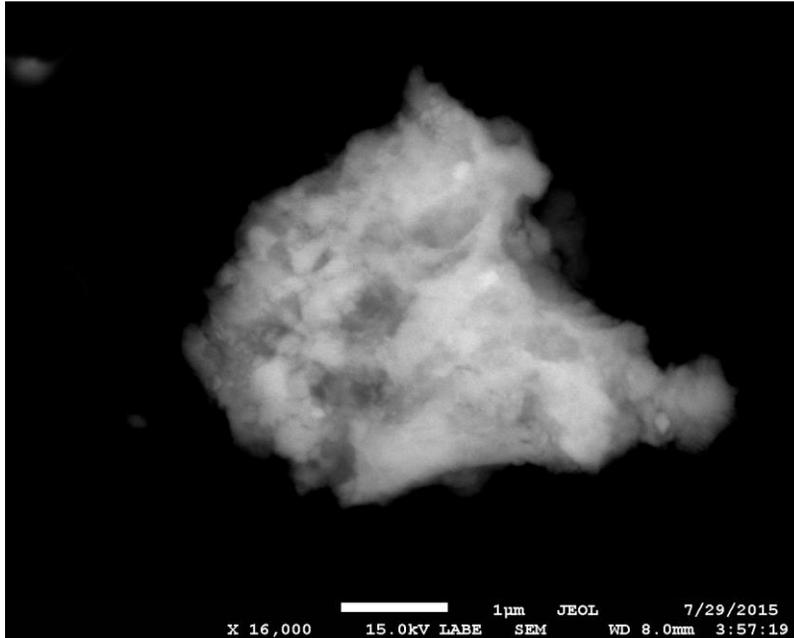


Full scale counts: 1992

U2158B(5)\_pt2

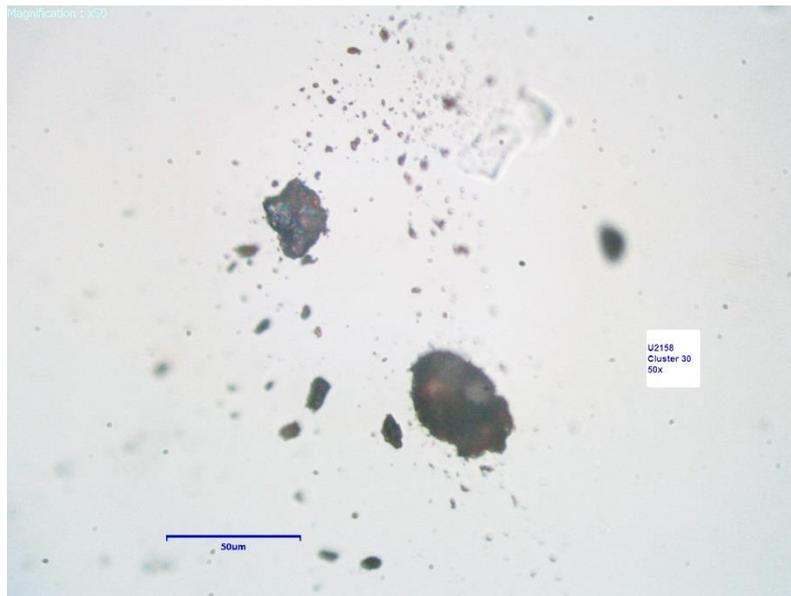


## U2158 B13



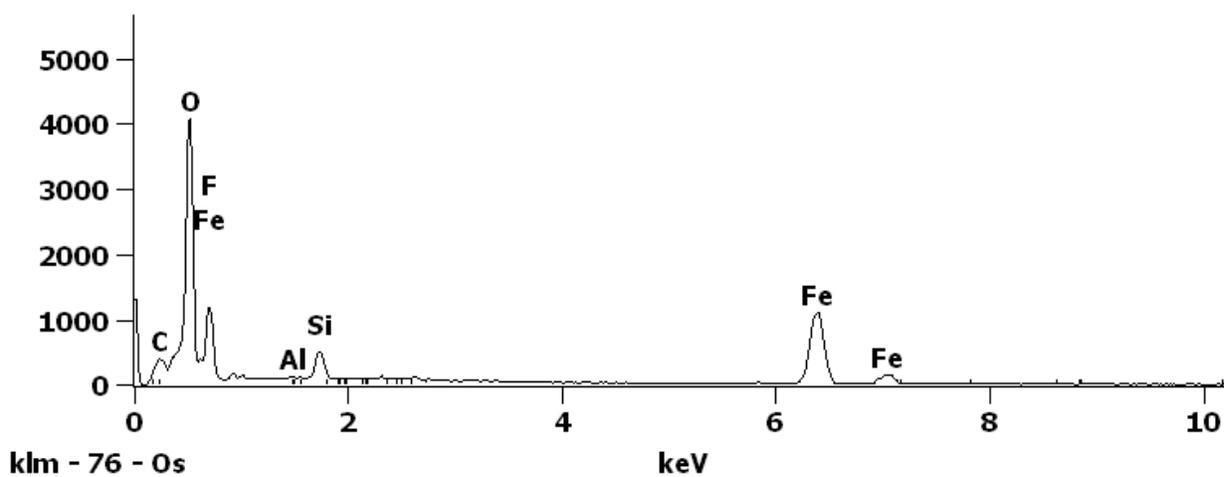
**Particle Size:** 7 µm  
**Shape:** Equidimensional  
**Transparency:** Translucent to Opaque  
**Color:** Red, Green, Brown  
**Luster:** Pearly to Vitreous  
**Particle Type:** Possibly Cosmic  
**Cluster No.:** 30  
**Comments:**

## Cluster of Origin: U2158 Cluster 30

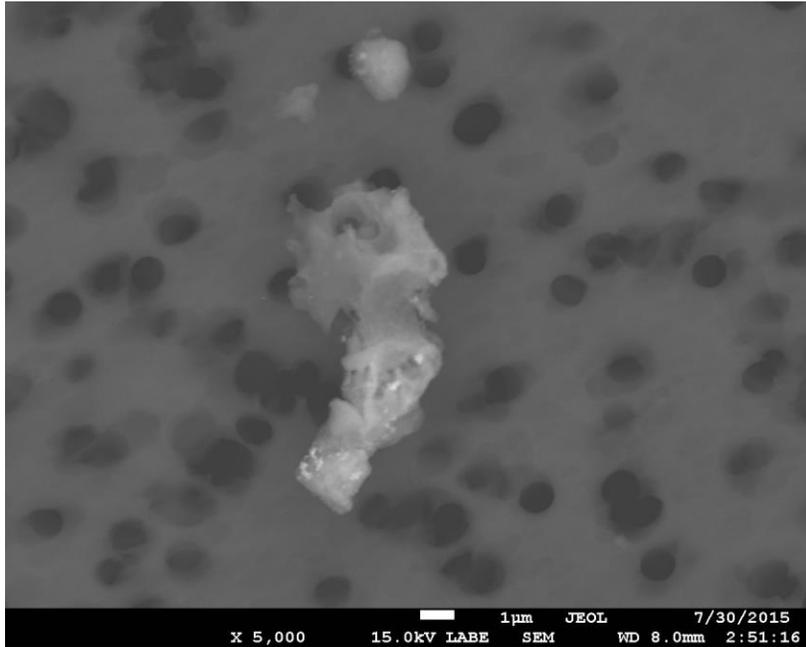


Full scale counts: 4071

U2158B(13)\_pt1

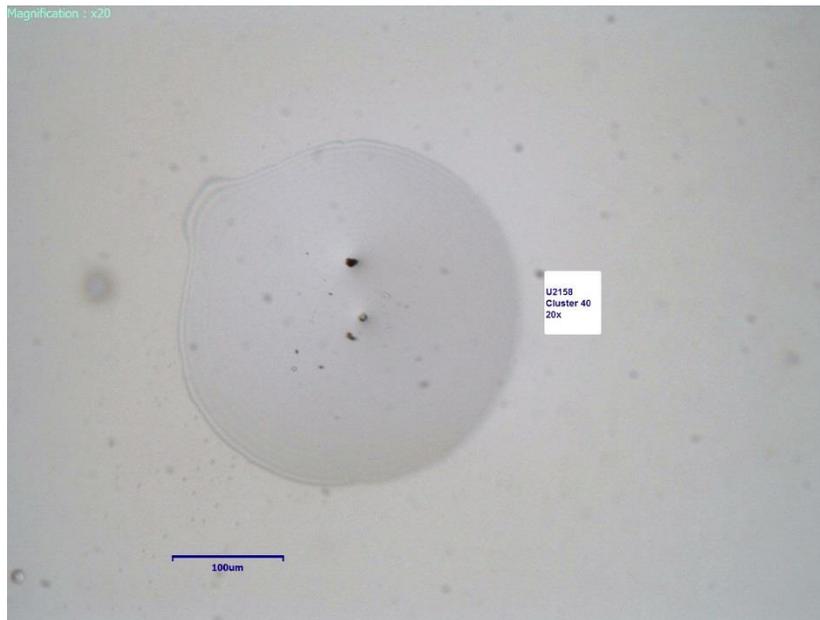


## U2158 C5



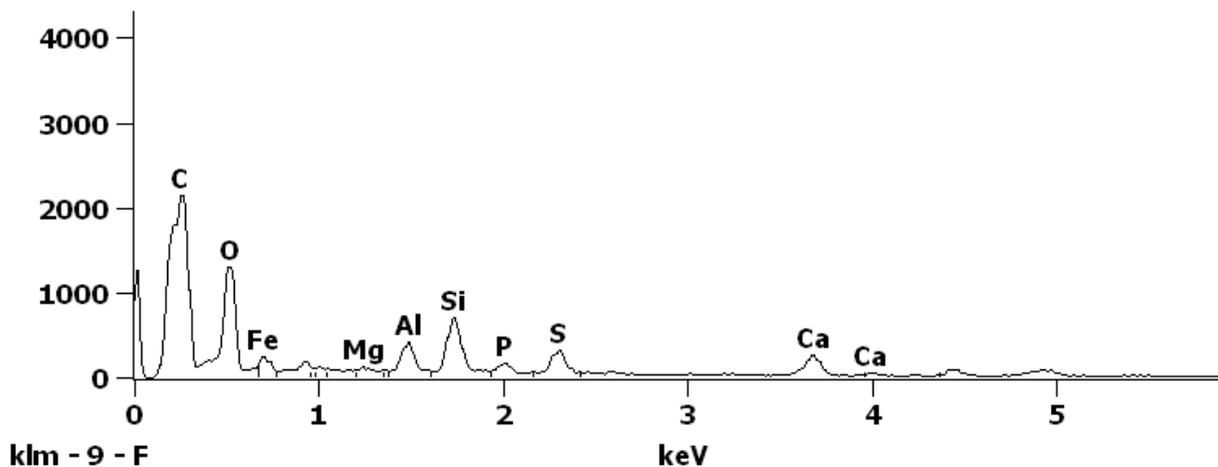
**Particle Size:** 11 µm  
**Shape:** Irregular to Equidimensional  
**Transparency:** Transparent to Translucent  
**Color:** Brown, Clear  
**Luster:** Pearly to Subvitreous  
**Particle Type:** Possibly Cosmic  
**Cluster No.:** 40  
**Comments:**

## Cluster of Origin: U2158 Cluster 40



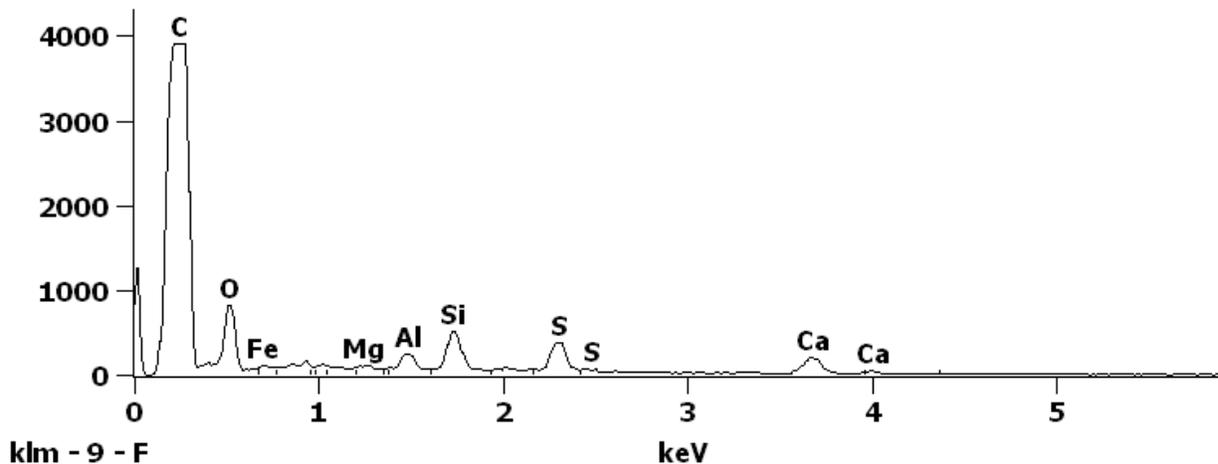
Full scale counts: 3901

U2158C(5)\_pt1



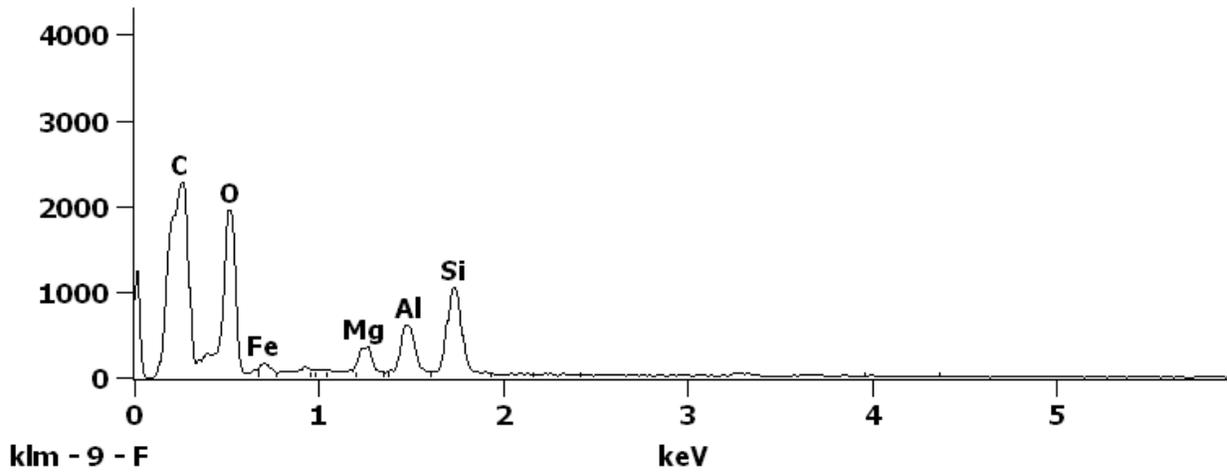
Full scale counts: 3901

U2158C(5)\_pt2

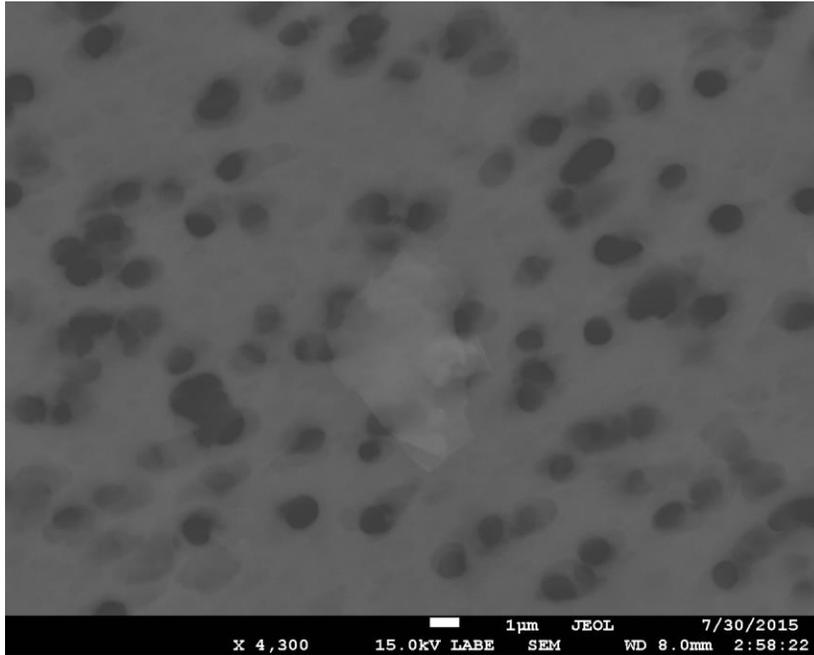


Full scale counts: 3901

U2158C(5)\_pt3

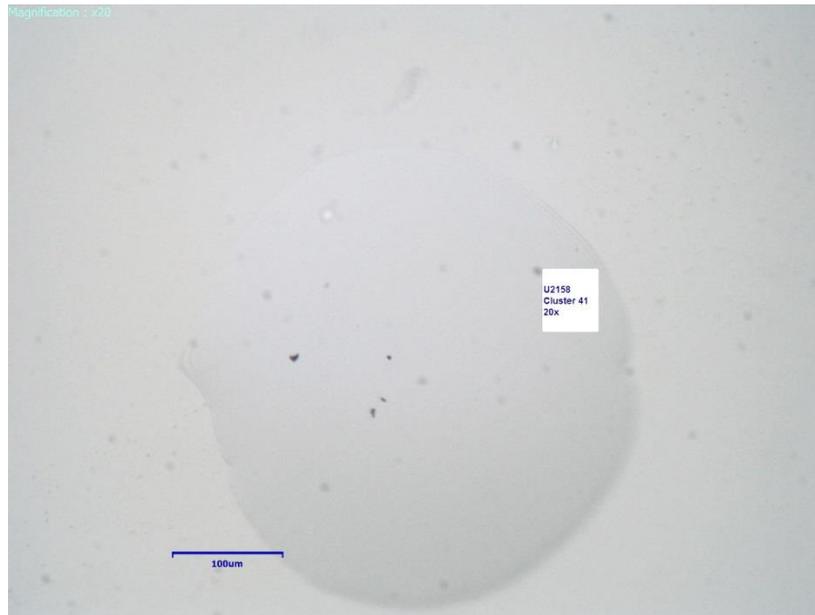


## U2158 C6



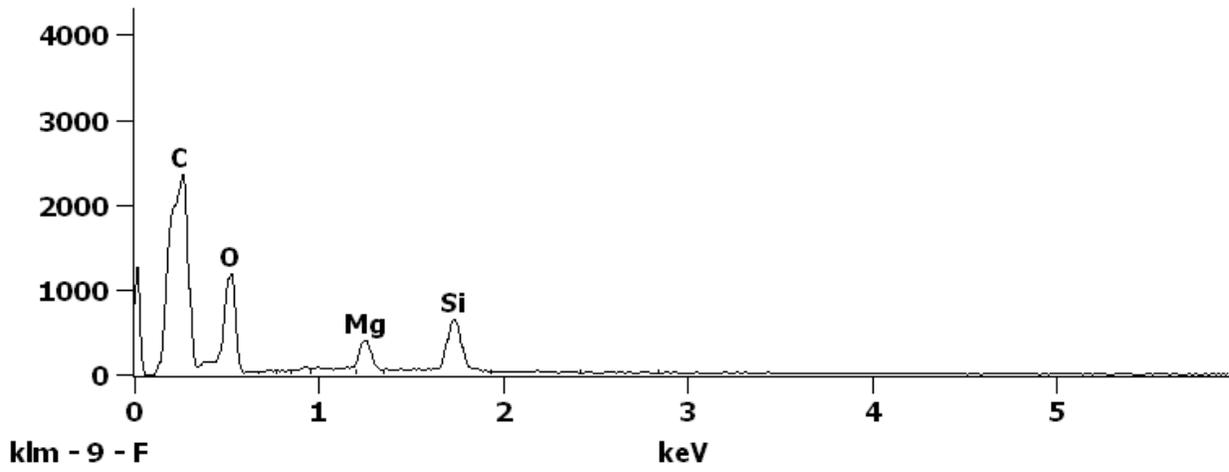
**Particle Size:** 13 μm  
**Shape:** Equidimensional to Irregular  
**Transparency:** Opaque  
**Color:** Black  
**Luster:** Dull  
**Particle Type:** Possibly Cosmic  
**Cluster No.:** 41  
**Comments:**

## Cluster of Origin: U2158 Cluster 41

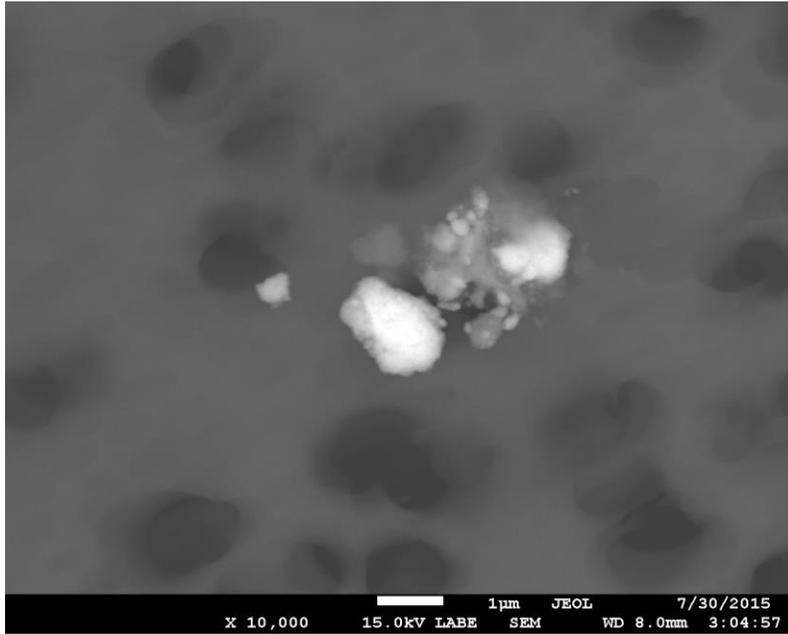


Full scale counts: 3901

U2158C(6)\_pt1

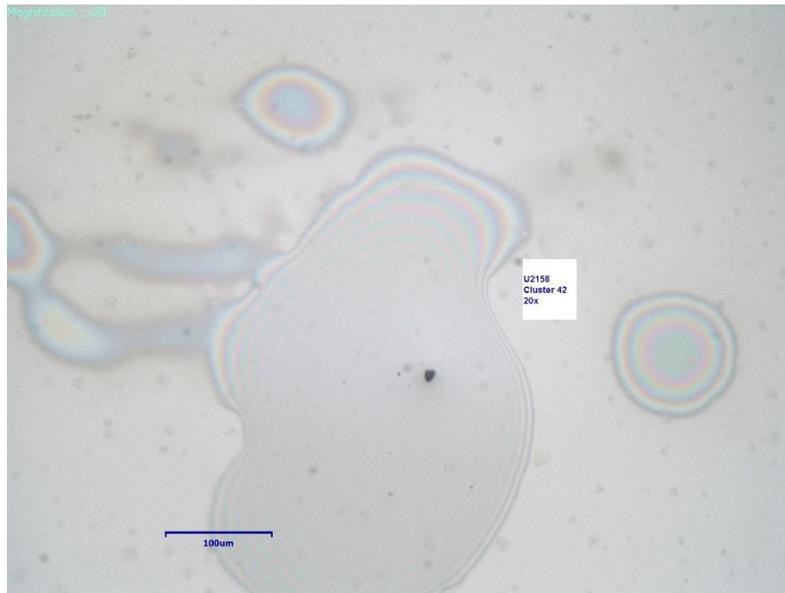


## U2158 C7



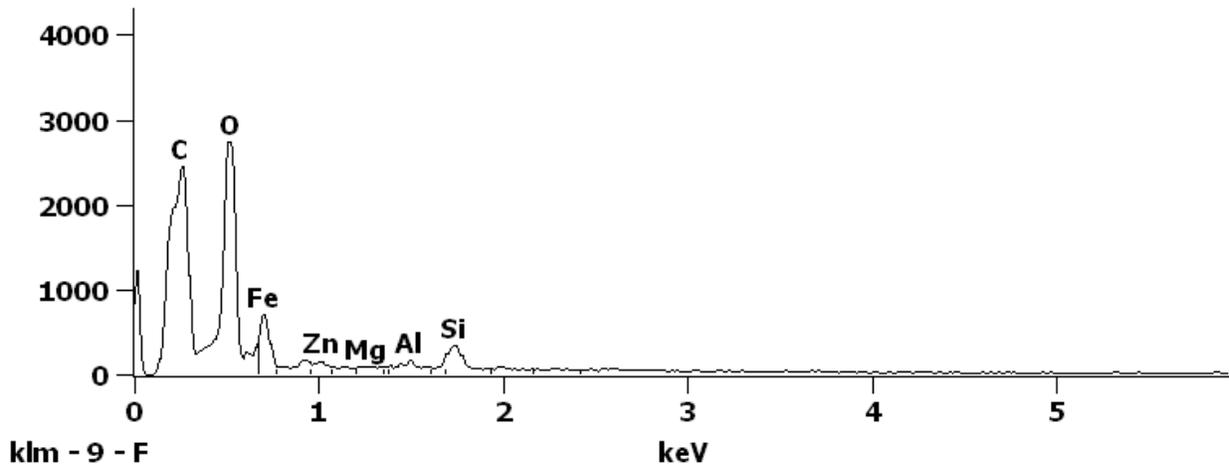
**Particle Size:** 11 µm  
**Shape:** Irregular  
**Transparency:** Opaque  
**Color:** Black  
**Luster:** Dull  
**Particle Type:** Possibly Cosmic  
**Cluster No.:** 42  
**Comments:**

## Cluster of Origin: U2158 Cluster 42



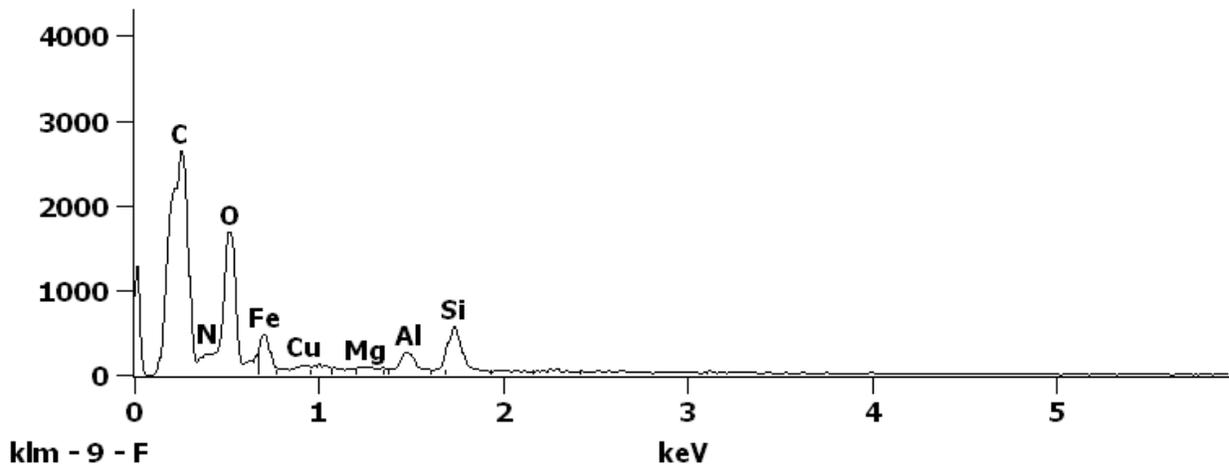
Full scale counts: 3901

U2158C(7)\_pt1

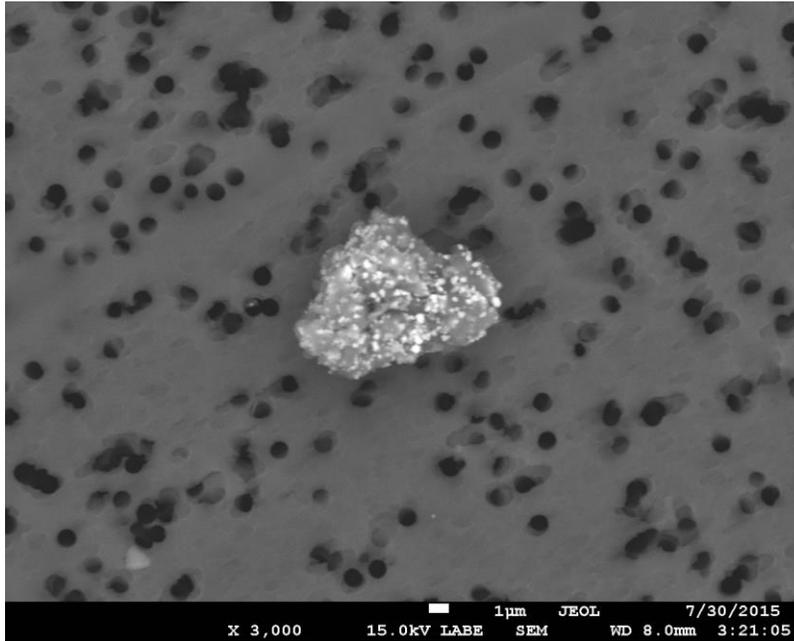


Full scale counts: 3901

U2158C(7)\_pt2

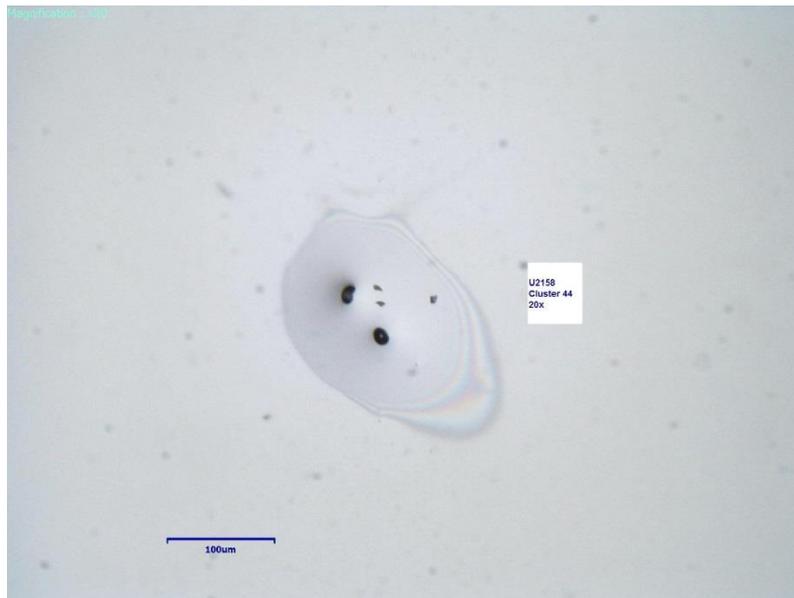


## U2158 C9



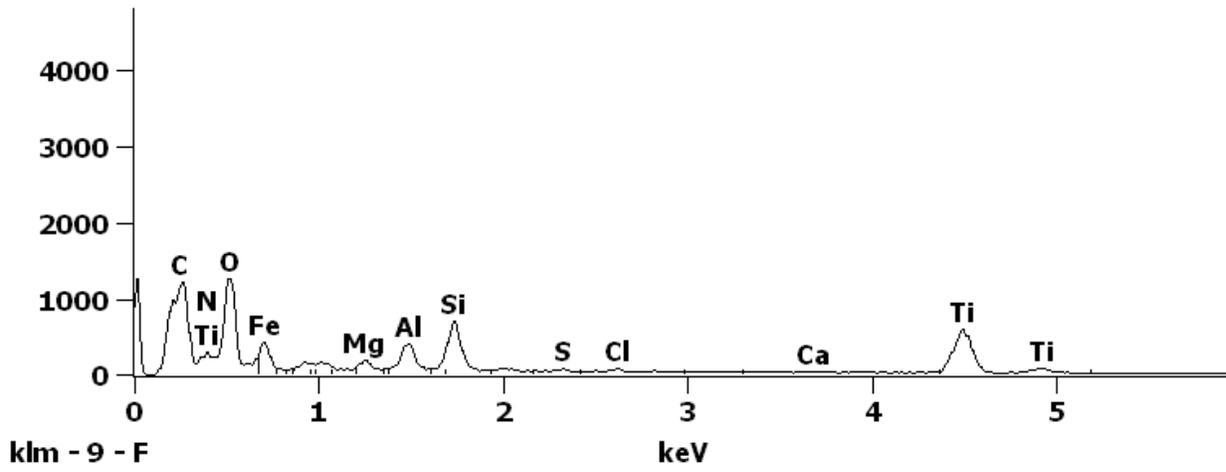
**Particle Size:** 15 µm  
**Shape:** Irregular  
**Transparency:** Opaque  
**Color:** Black, Green  
**Luster:** Pearly  
**Particle Type:** Possibly Cosmic  
**Cluster No.:** 44  
**Comments:**

## Cluster of Origin: U2158 C9

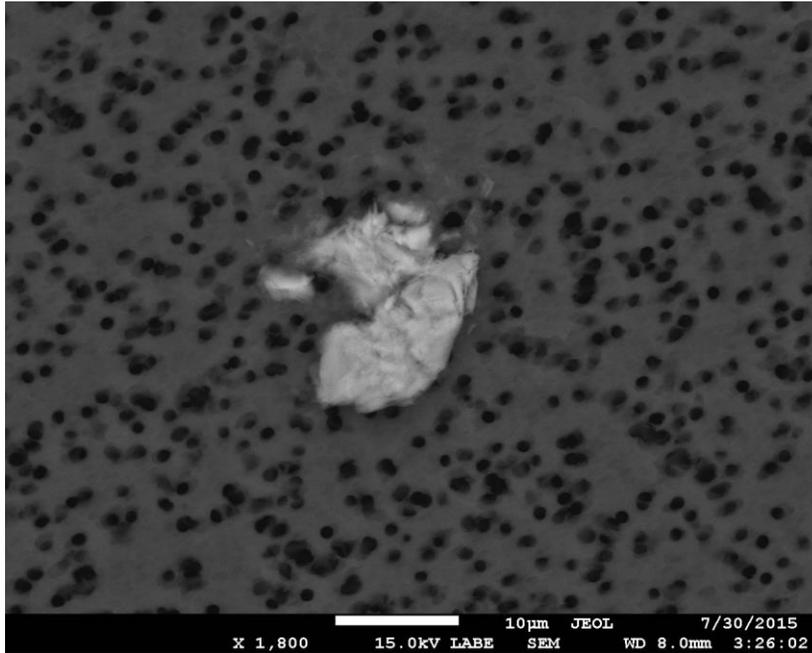


Full scale counts: 3901

U2158C(9)\_pt1

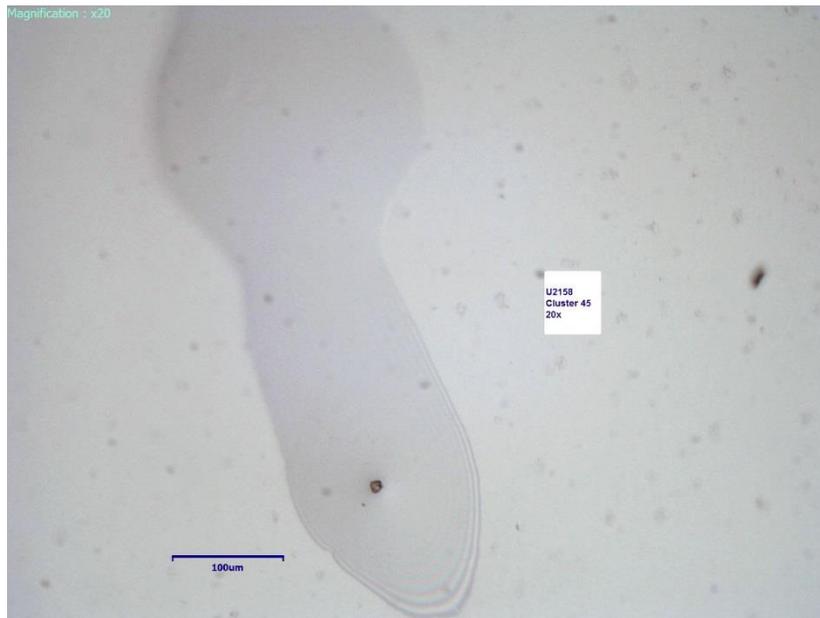


## U2158 C10

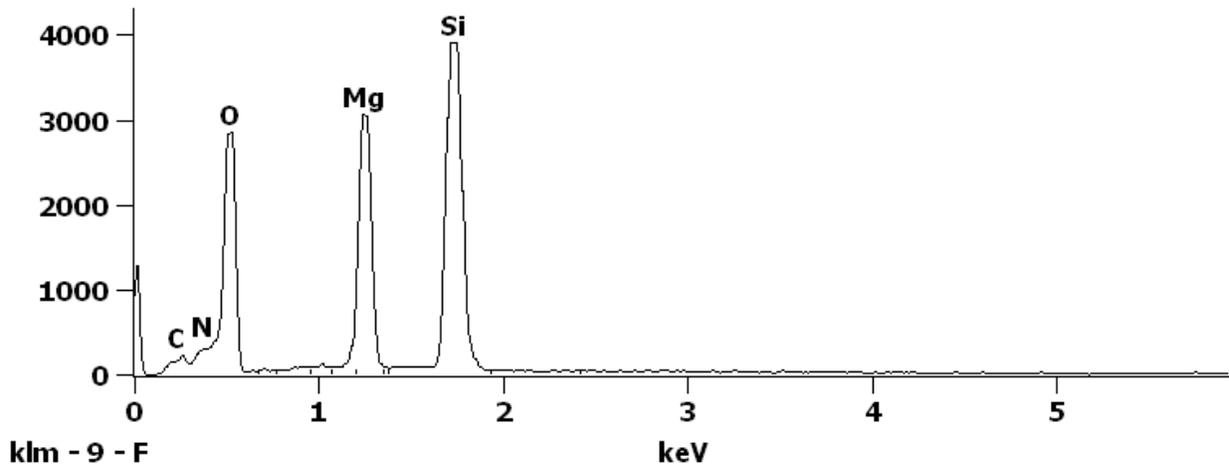


**Particle Size:** 15 µm  
**Shape:** Irregular  
**Transparency:** Translucent  
**Color:** Clear, Yellow, Green  
**Luster:** Subvitreous  
**Particle Type:** Possibly Cosmic  
**Cluster No.:** 45  
**Comments:**

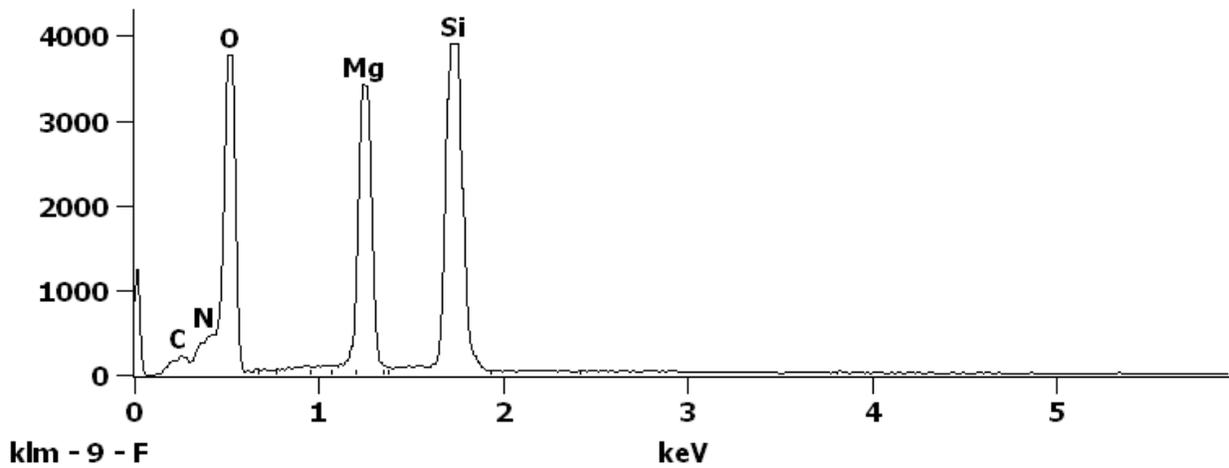
## Cluster of Origin: U2158 Cluster 45



Full scale counts: 3901 U2158C(10)\_pt1



Full scale counts: 3901 U2158C(10)\_pt2

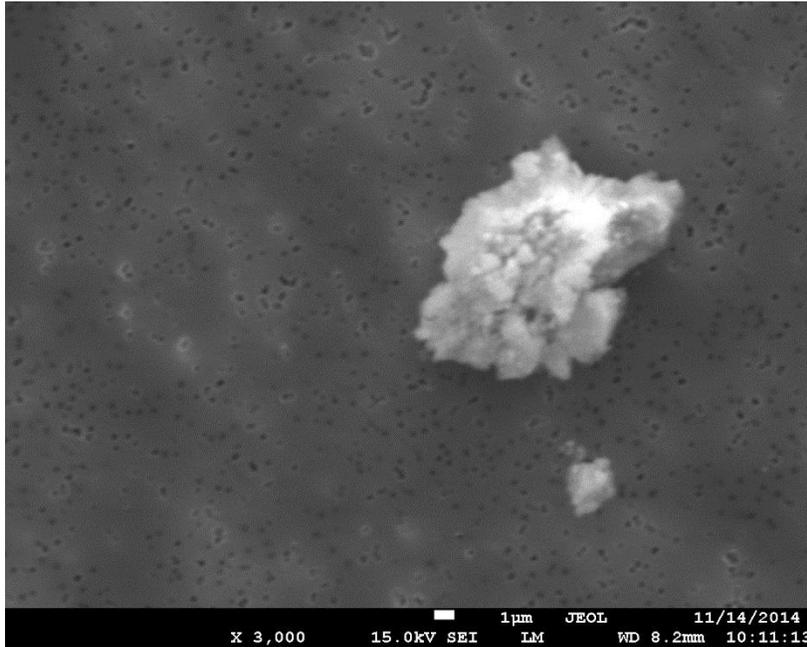


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**Artificial Terrestrial Contamination (TCA Type)**

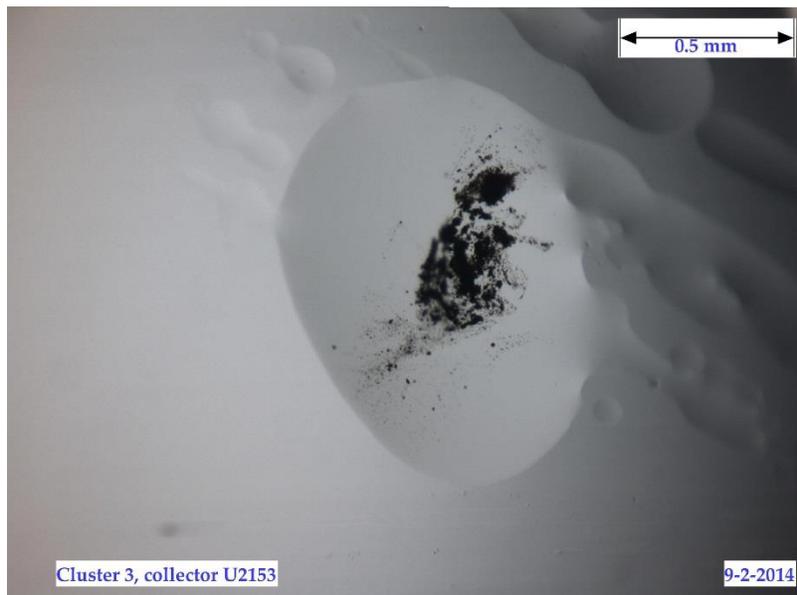


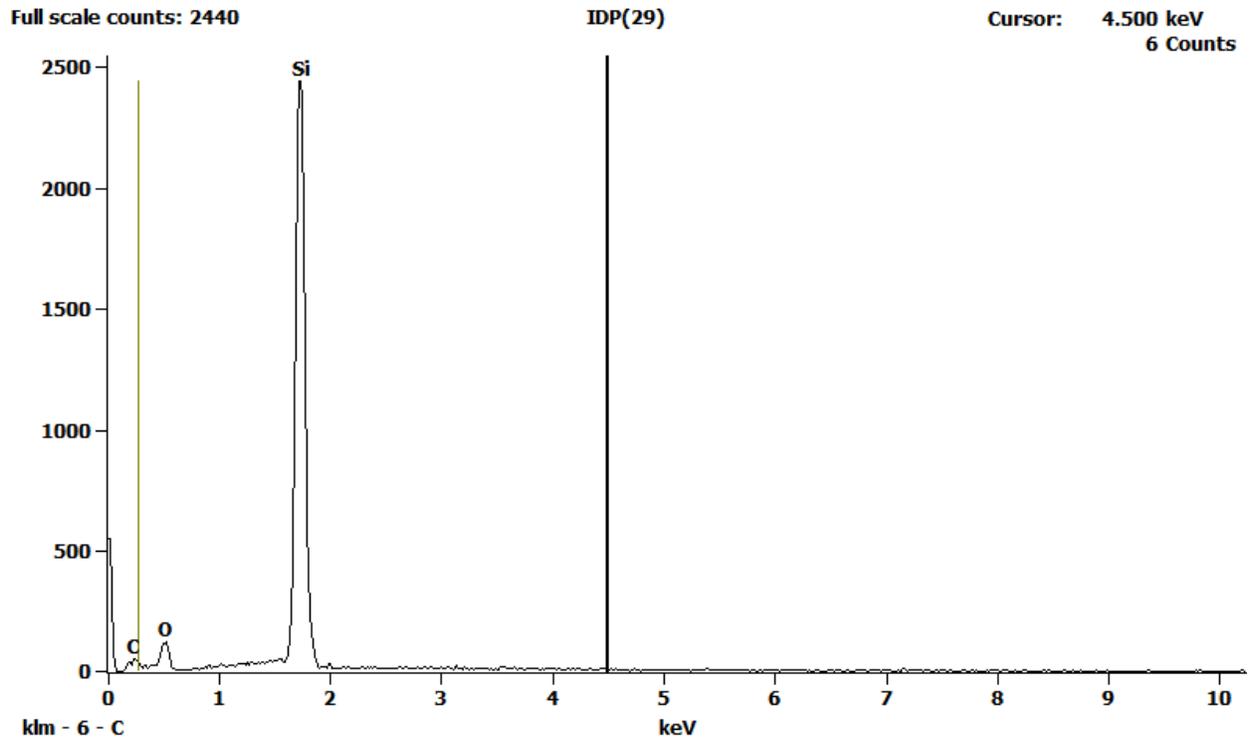
## U2153 A20



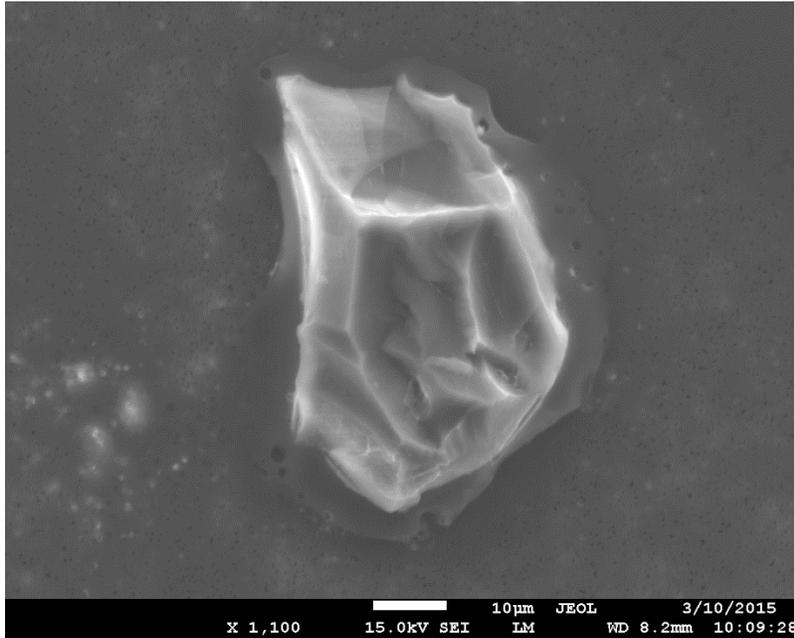
**Particle Size:** 25x15 µm  
**Shape:** Irregular  
**Transparency:** Translucent to Opaque  
**Color:** Gray  
**Luster:** Pearly to Subvitreous  
**Particle Type:** Artificial Terrestrial Contamination  
**Cluster No.:** 3  
**Comments:** Cu-sulfide+Fe metal

## Cluster of Origin: U2153 Cluster 3





## U2153 C1



**Particle Size:** 20x40  $\mu\text{m}$

**Shape:** Equidimensional to Irregular

**Transparency:** Opaque to Subvitreous

**Color:** Black

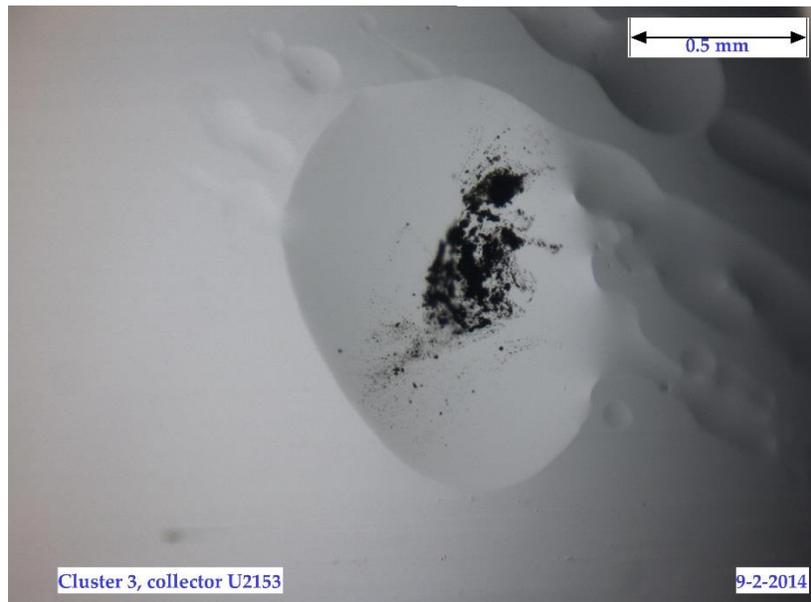
**Luster:** Pearly to Dull

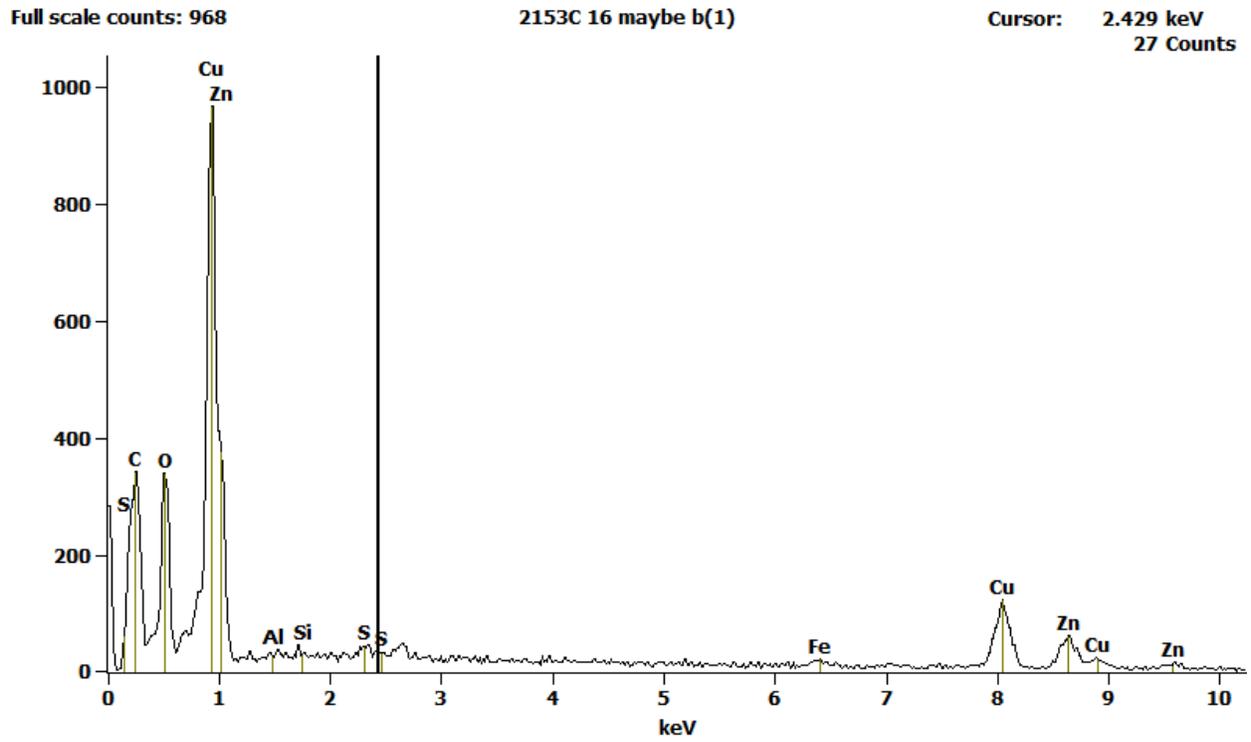
**Particle Type:** Artificial Terrestrial Contamination

**Cluster No.:** 3

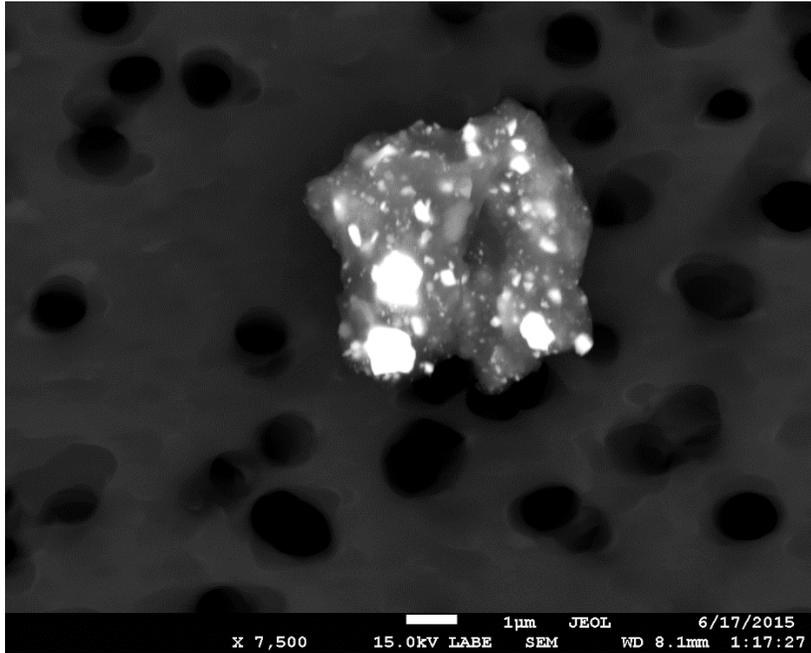
**Comments:**

## Cluster of Origin: U2153 Cluster 3



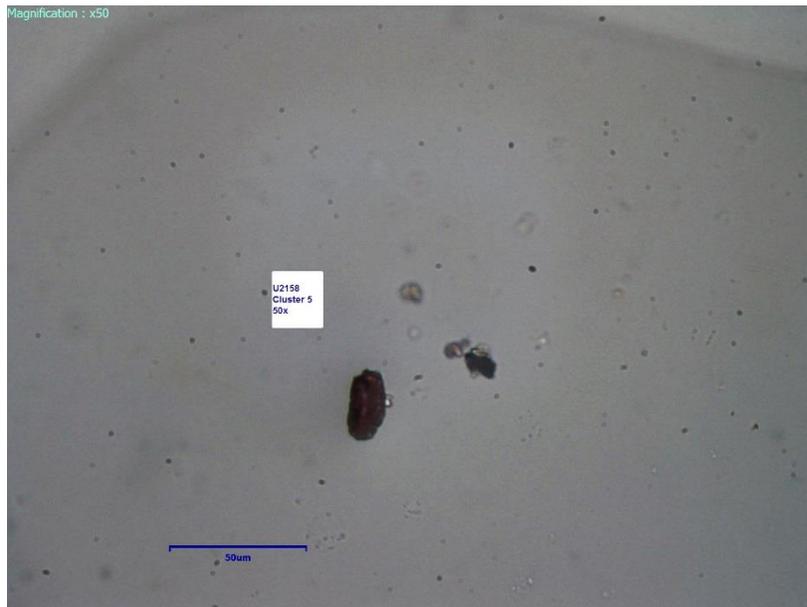


## U2158 A5



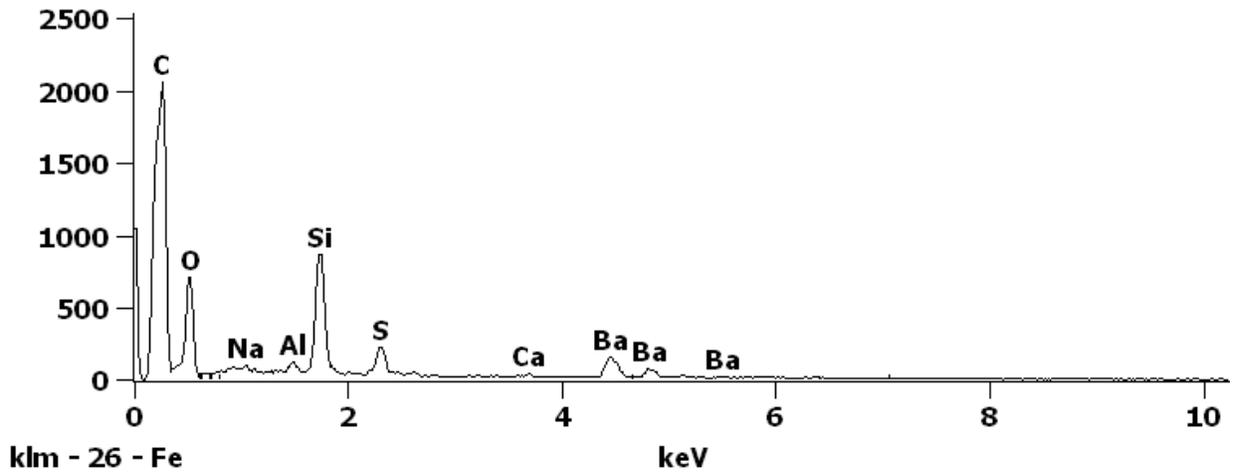
**Particle Size:** 5 µm  
**Shape:** Equidimensional to Irregular  
**Transparency:** Translucent to Transparent  
**Color:** Clear, Red  
**Luster:** Pearly to Vitreous  
**Particle Type:** Artificial Terrestrial Contamination  
**Cluster No.:** 5  
**Comments:**

## Cluster of Origin: U2158 Cluster 5



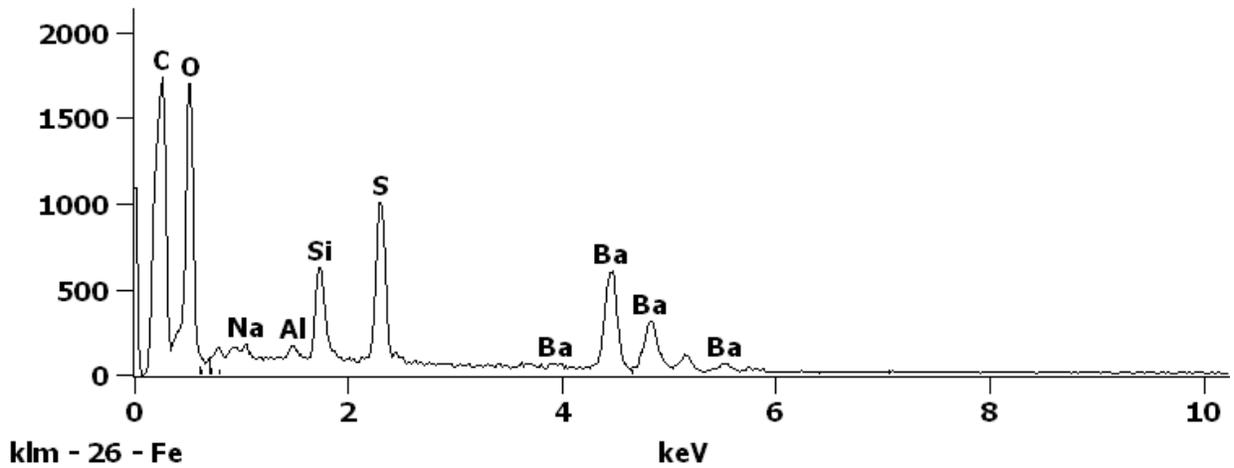
Full scale counts: 2058

A5(1)\_pt1



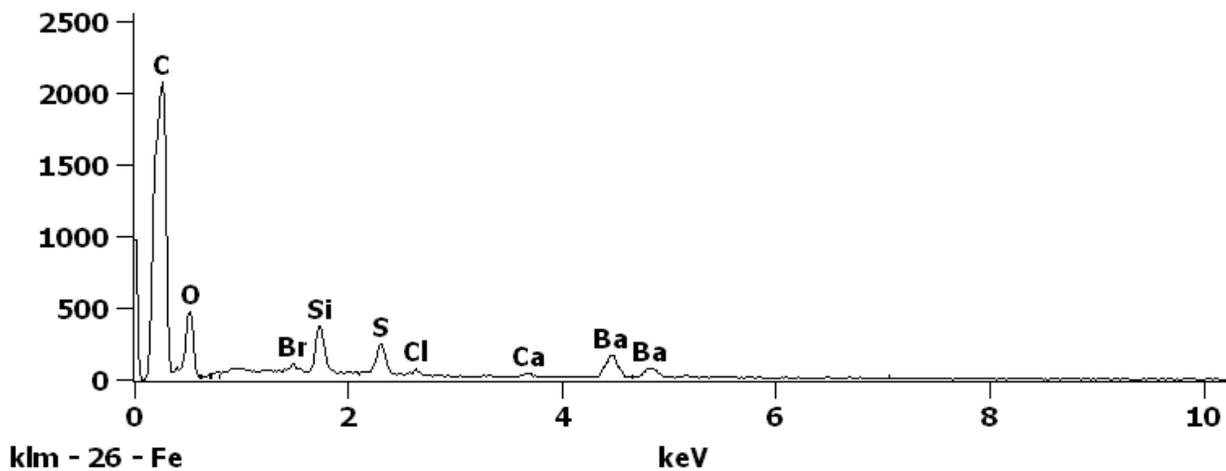
Full scale counts: 1736

A5(1)\_pt2



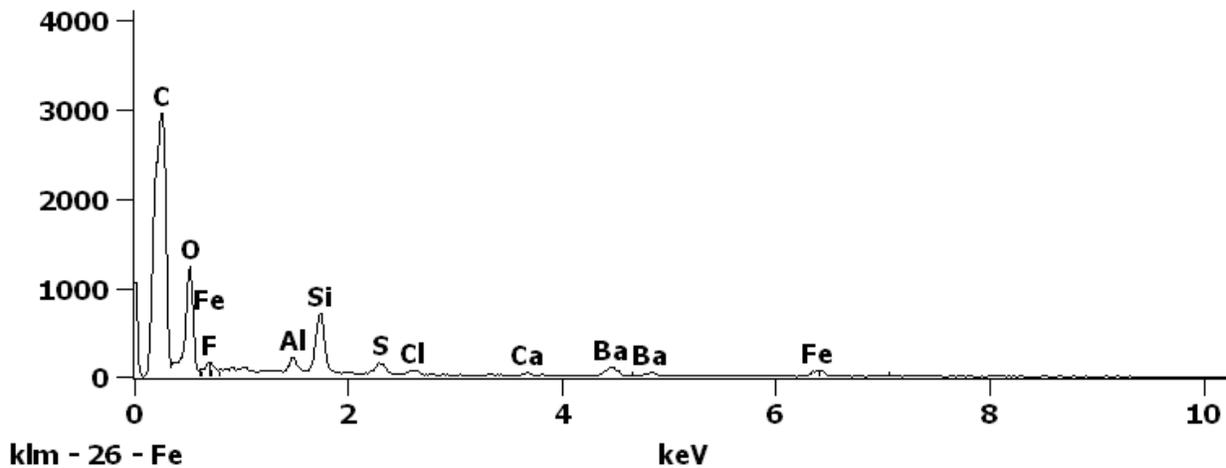
Full scale counts: 2072

A5(1)\_pt3

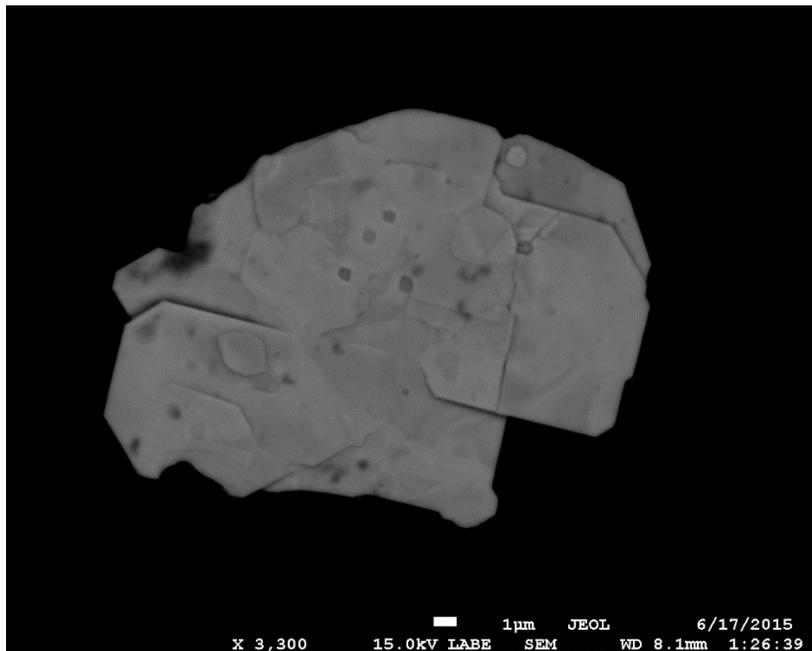


Full scale counts: 2957

A5(1)\_pt4



## U2158 A6



**Particle Size:** 20x25 µm

**Shape:** Equidimensional

**Transparency:** Translucent to Transparent

**Color:** Multiple

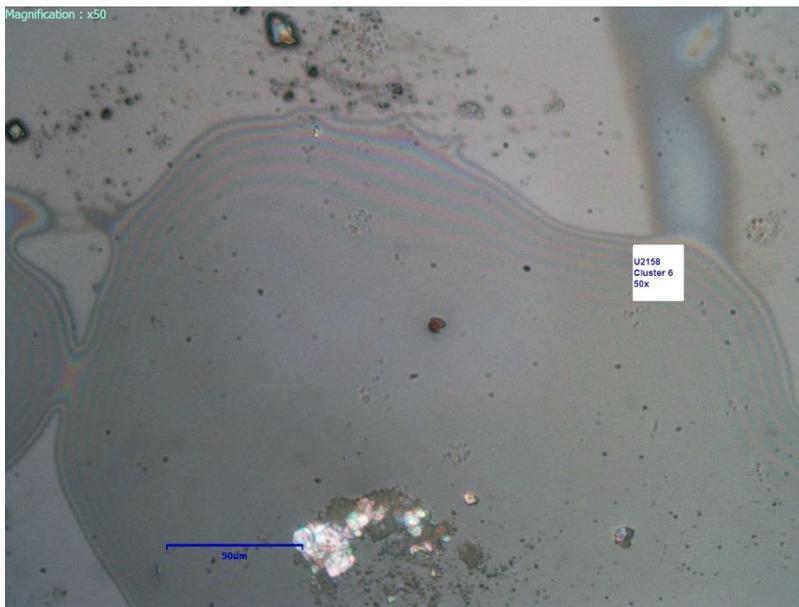
**Luster:** Pearly to Vitreous

**Particle Type:** Artificial Terrestrial Contamination

**Cluster No.:** 6

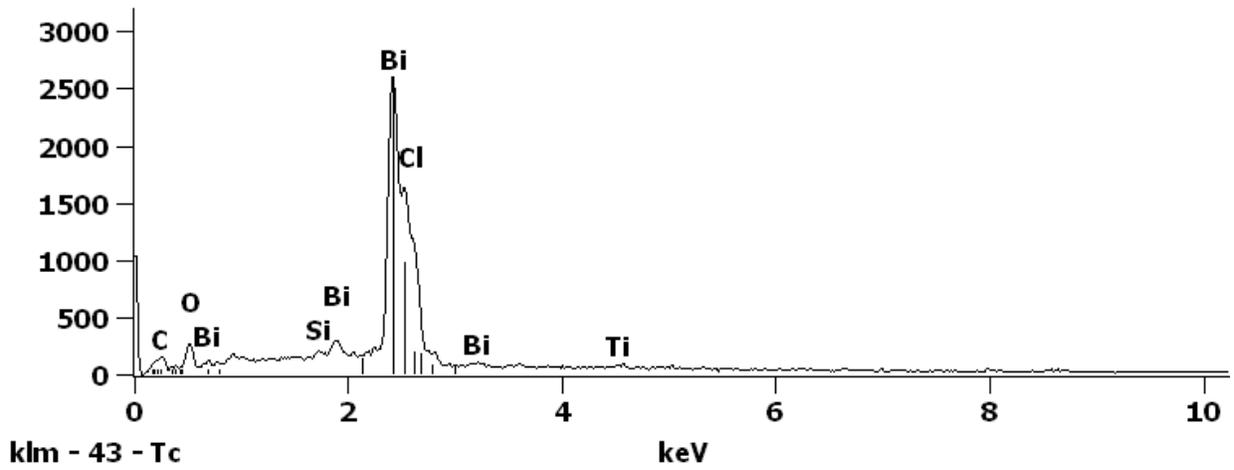
**Comments:**

## Cluster of Origin: U2158 Cluster 6



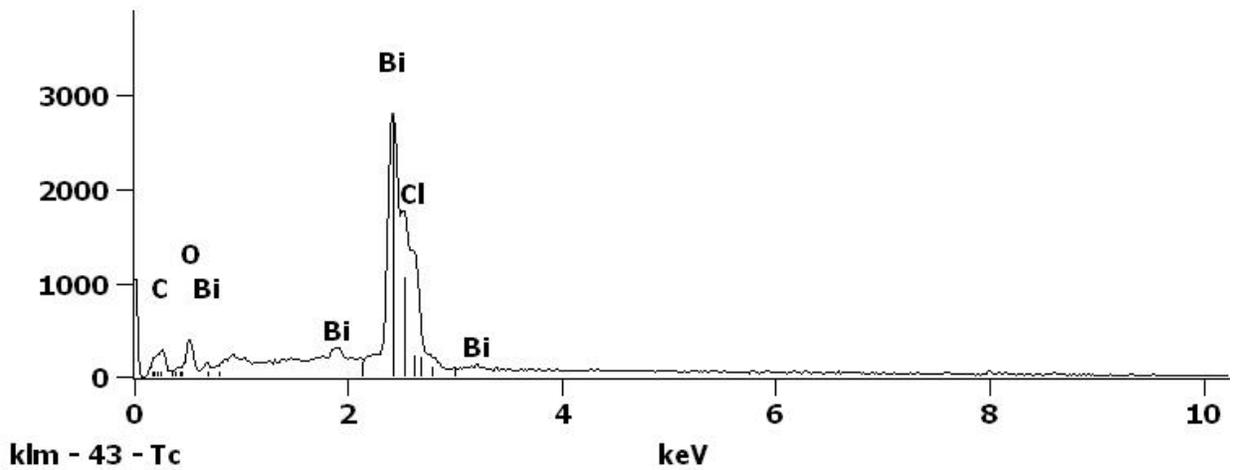
Full scale counts: 2599

A6(1)\_pt2

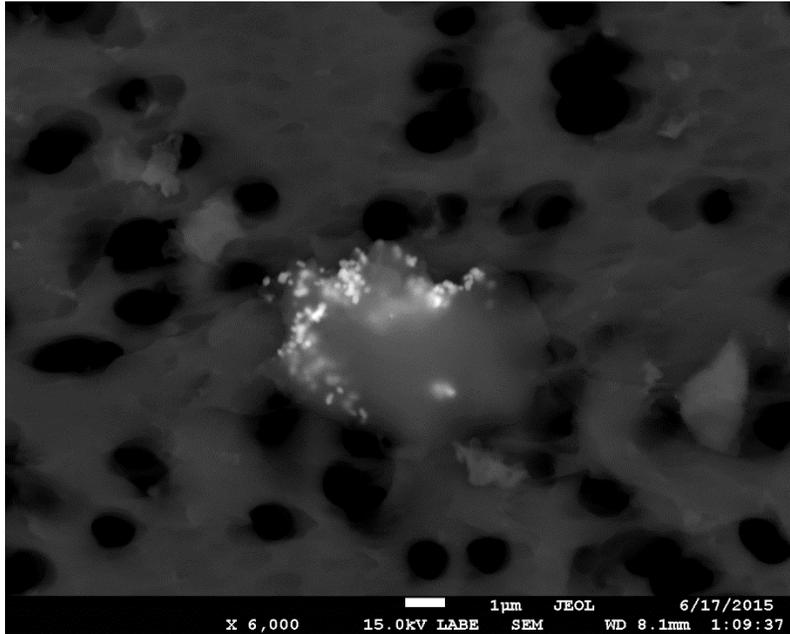


Full scale counts: 2805

A6(1)\_pt3

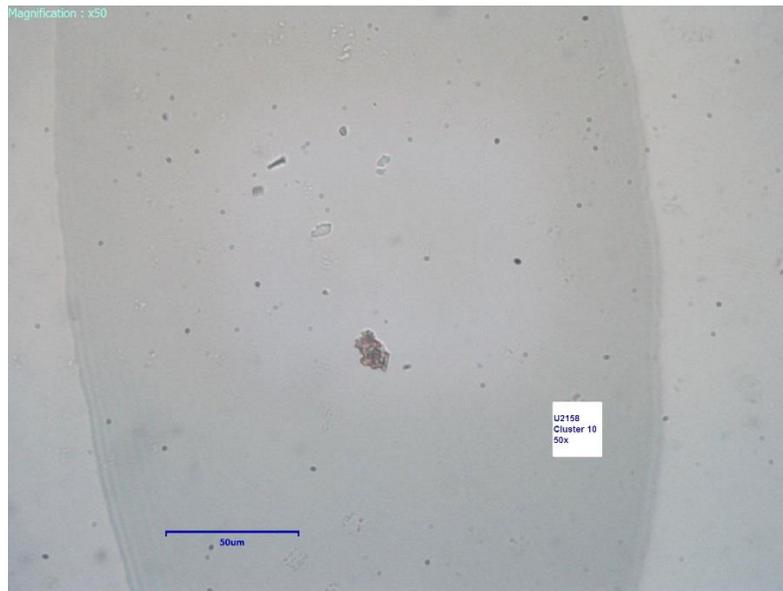


## U2158 A10



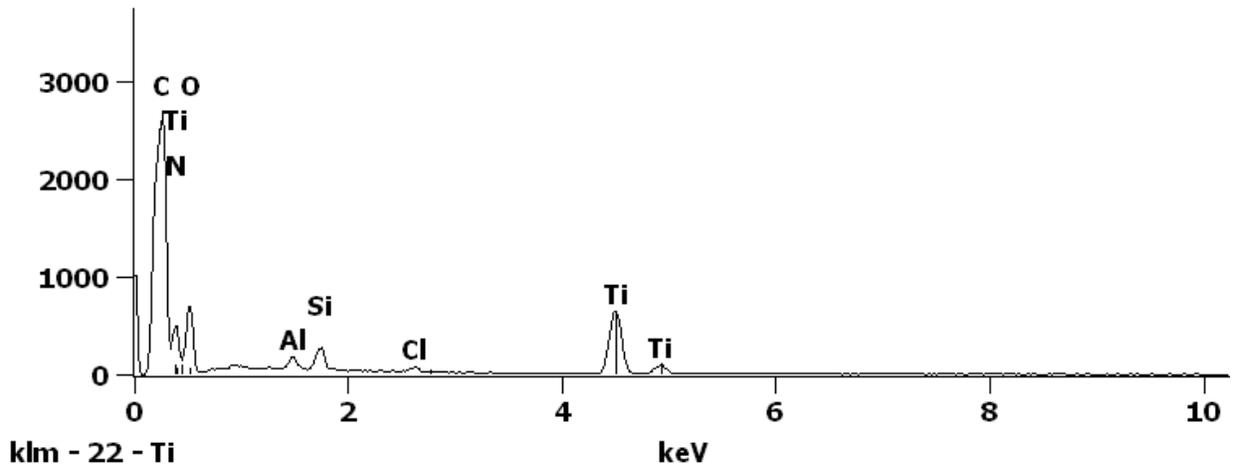
**Particle Size:** 10 µm  
**Shape:** Irregular  
**Transparency:** Transparent to Translucent  
**Color:** Clear, Green, Ruby  
**Luster:** Pearly to Vitreous  
**Particle Type:** Artificial Terrestrial Contamination  
**Cluster No.:** 10  
**Comments:**

## Cluster of Origin: U2158 Cluster 10

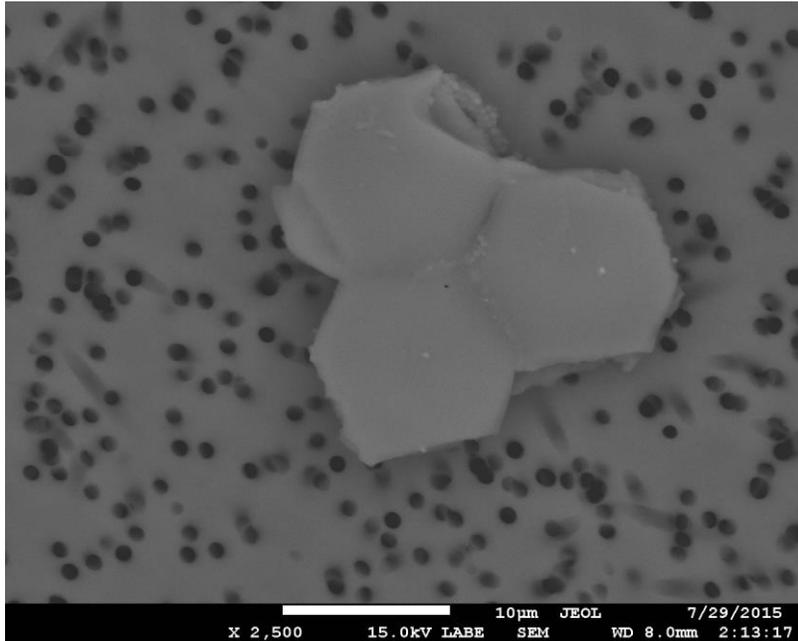


Full scale counts: 2697

A10(1)\_pt1



## U2158 B2



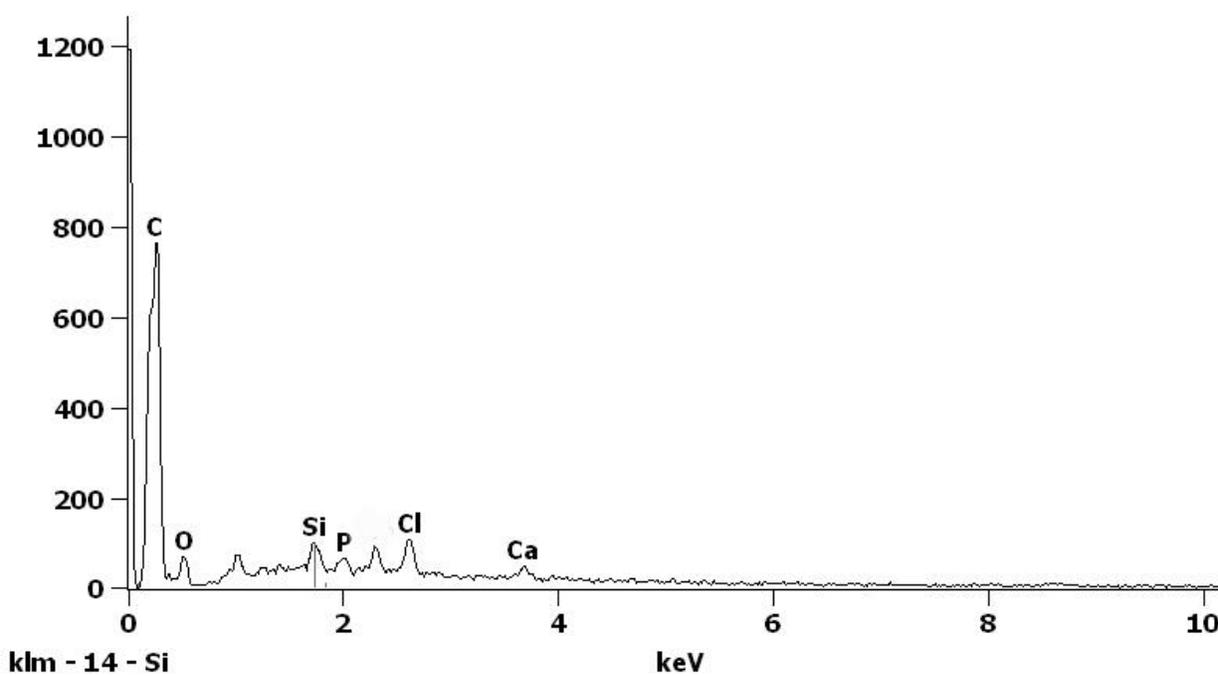
**Particle Size:** 26 µm  
**Shape:** Equidimensional  
**Transparency:** Transparent to Opaque  
**Color:** Red  
**Luster:** Dull  
**Particle Type:** Artificial Terrestrial Contamination  
**Cluster No.:** 19  
**Comments:**

## Cluster of Origin: U2158 Cluster 19

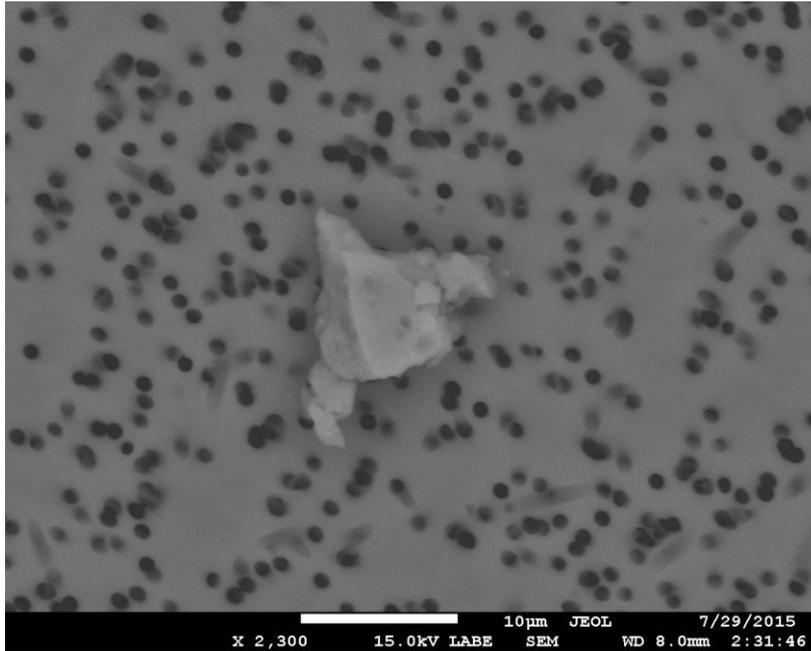


Full scale counts: 1192

U2158B(2)

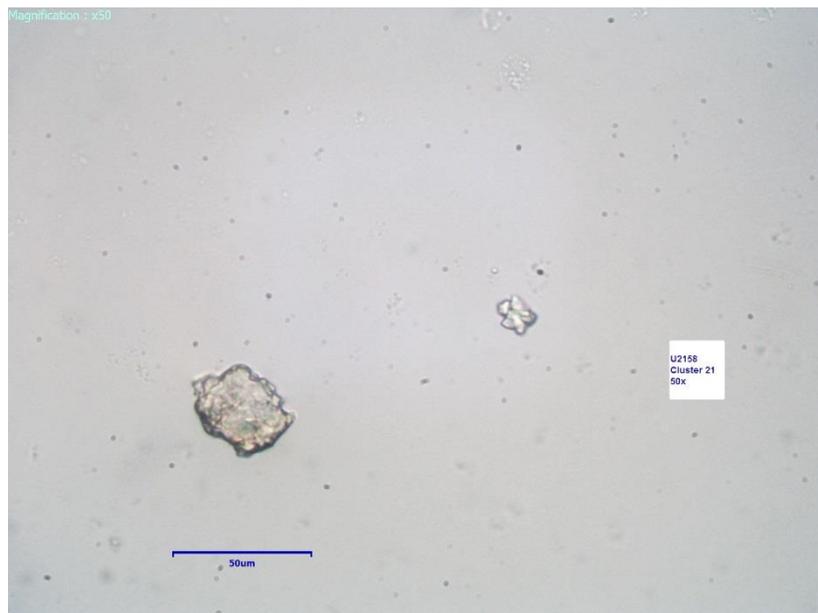


## U2158 B4



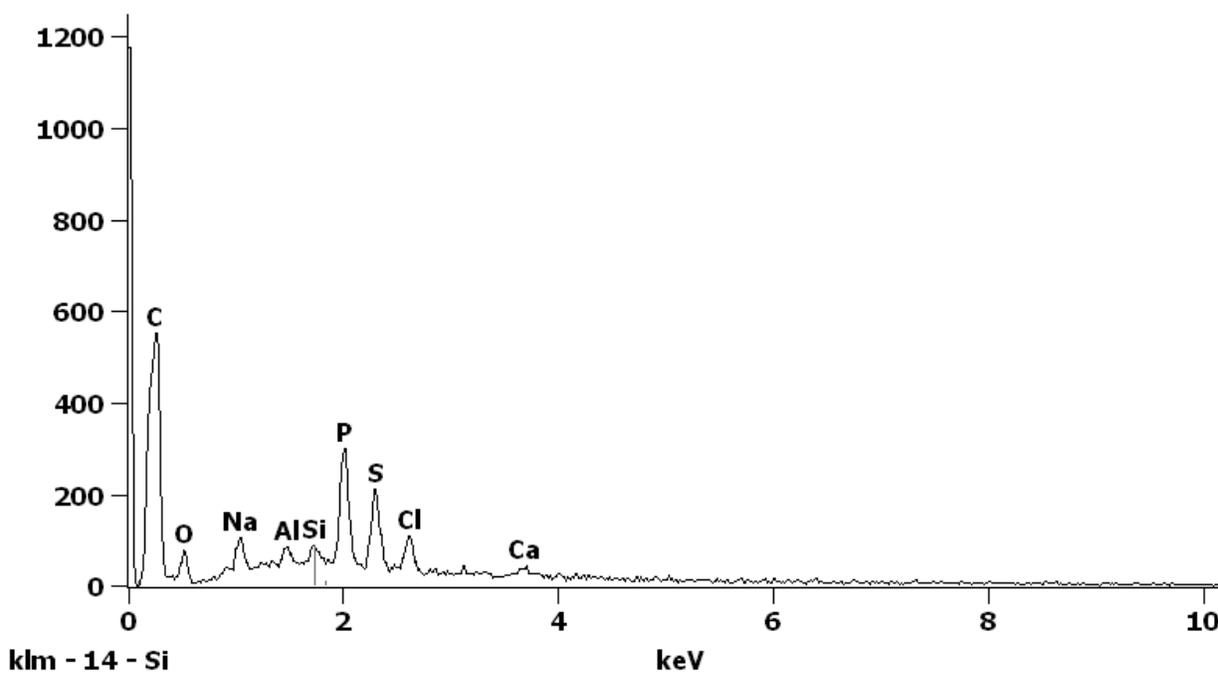
**Particle Size:** 15 µm  
**Shape:** Equidimensional  
**Transparency:** Transparent  
**Color:** Clear  
**Luster:** Vitreous  
**Particle Type:** Possibly Artificial  
Terrestrial  
Contamination  
**Cluster No.:** 21  
**Comments:**

## Cluster of Origin: U2158 Cluster 21

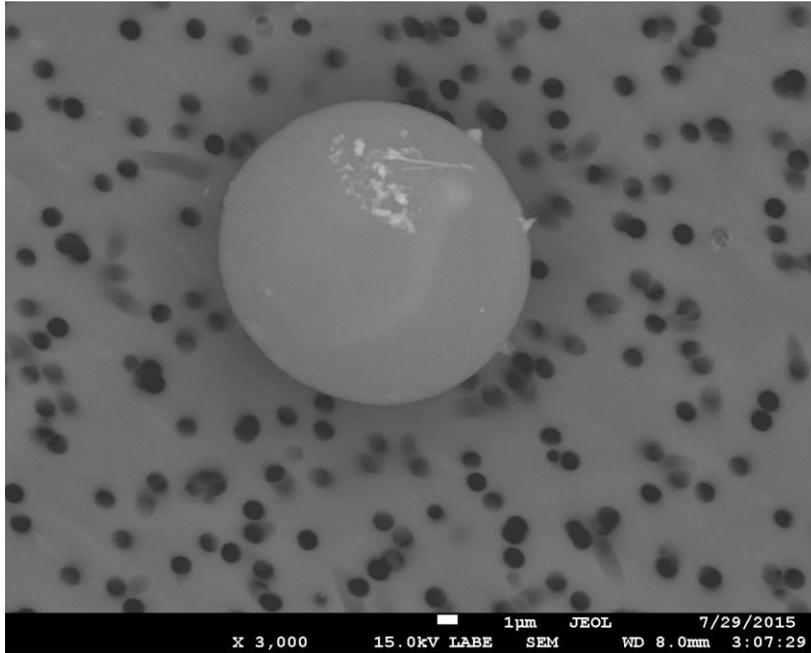


Full scale counts: 1176

U2158B(4)

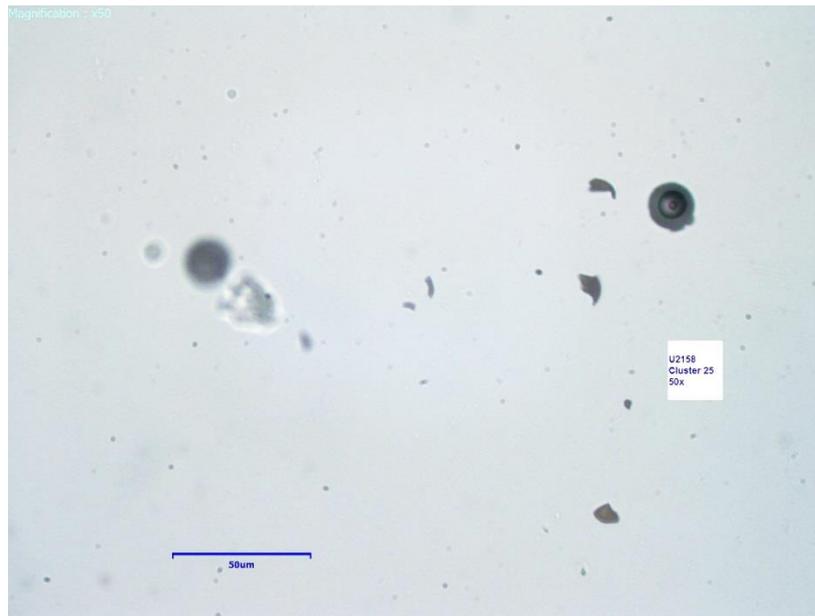


## U2158 B8



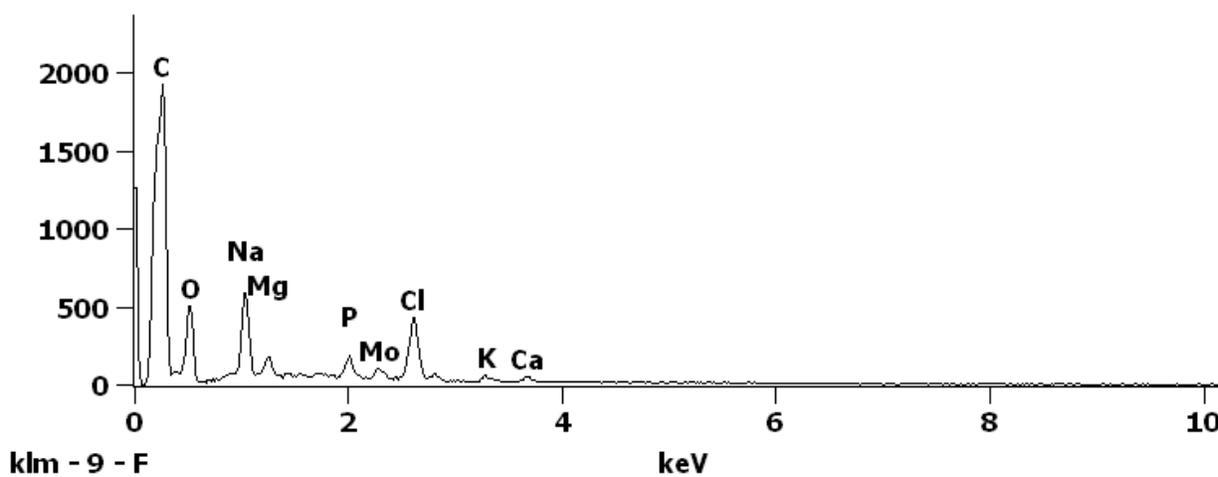
**Particle Size:** 16 µm  
**Shape:** Spherical  
**Transparency:** Opaque  
**Color:** Brown  
**Luster:** Dull  
**Particle Type:** Artificial Terrestrial Contamination  
**Cluster No.:** 25  
**Comments:**

## Cluster of Origin: U2158 Cluster 25

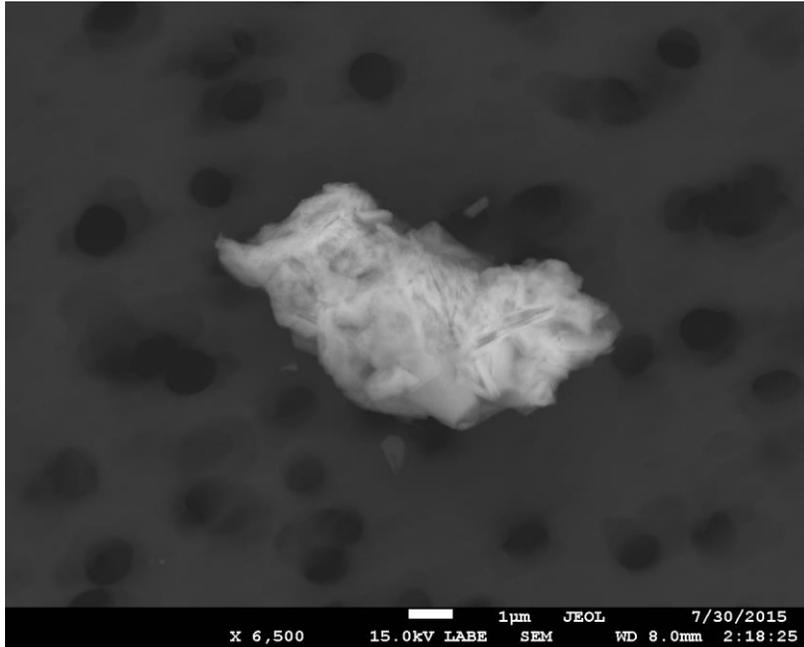


Full scale counts: 1921

U2158B(8a)\_pt1



## U2158 C1



**Particle Size:** 6 µm

**Shape:** Irregular

**Transparency:** Transparent to Translucent

**Color:** Clear, Green, Black, Red

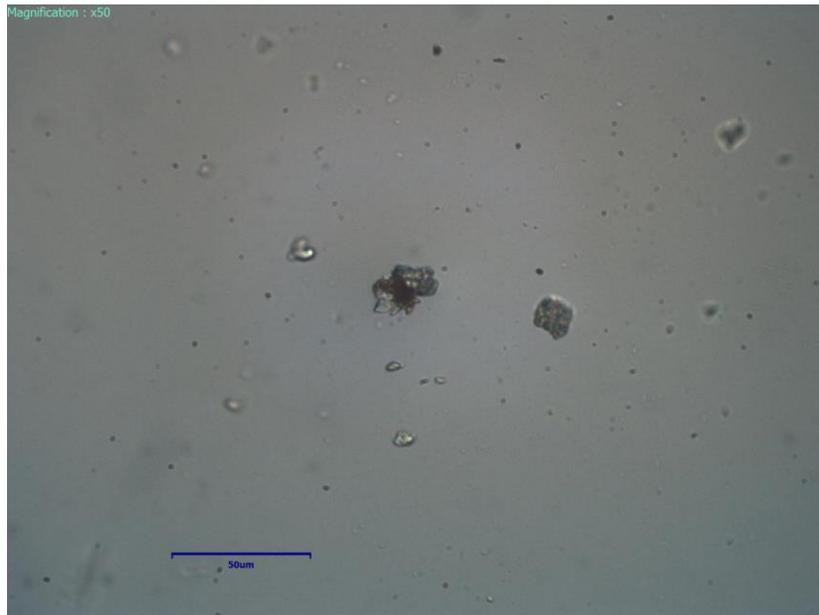
**Luster:** Subvitreous to Vitreous

**Particle Type:** Artificial Terrestrial Contamination

**Cluster No.:** 34

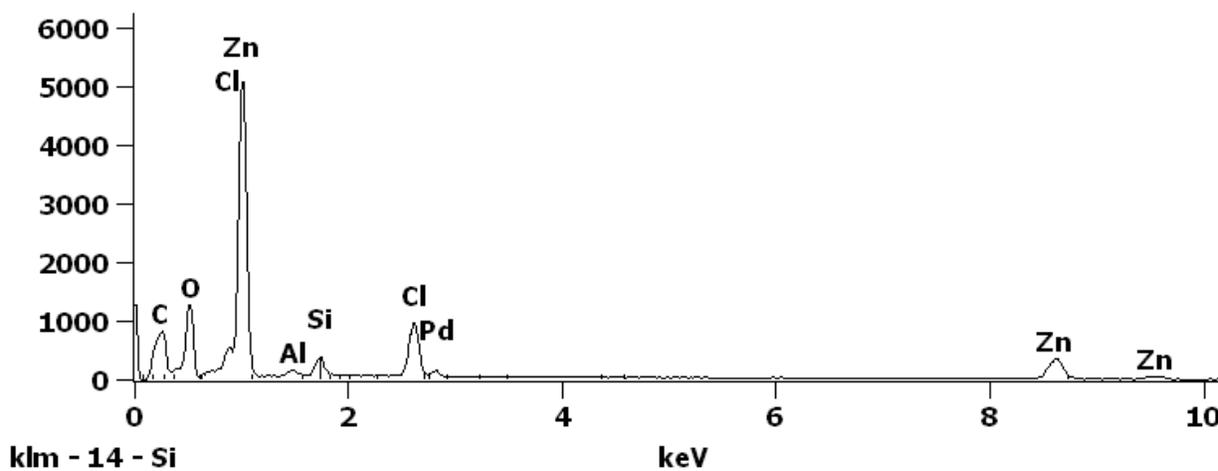
**Comments:**

## Cluster of Origin: U2158 Cluster 34

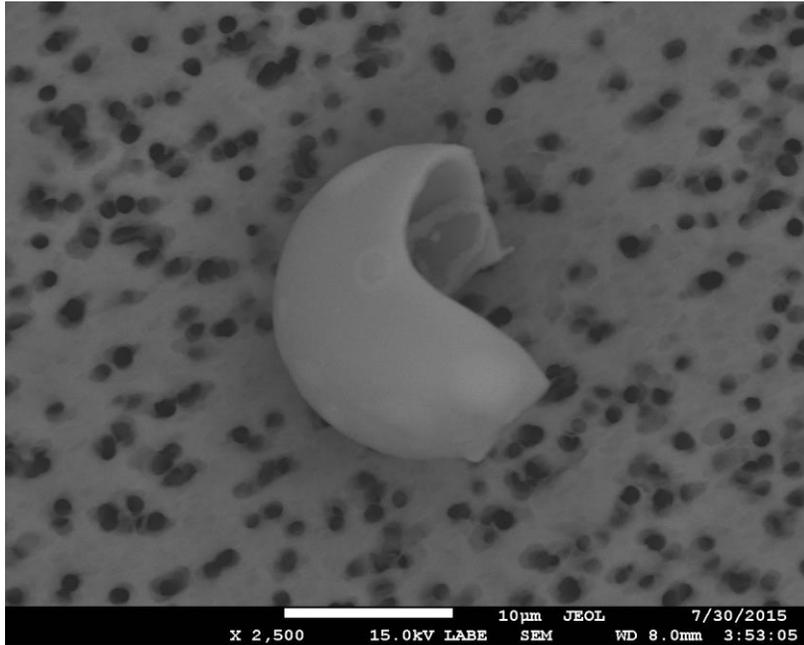


Full scale counts: 5068

U2158C(1)\_pt1

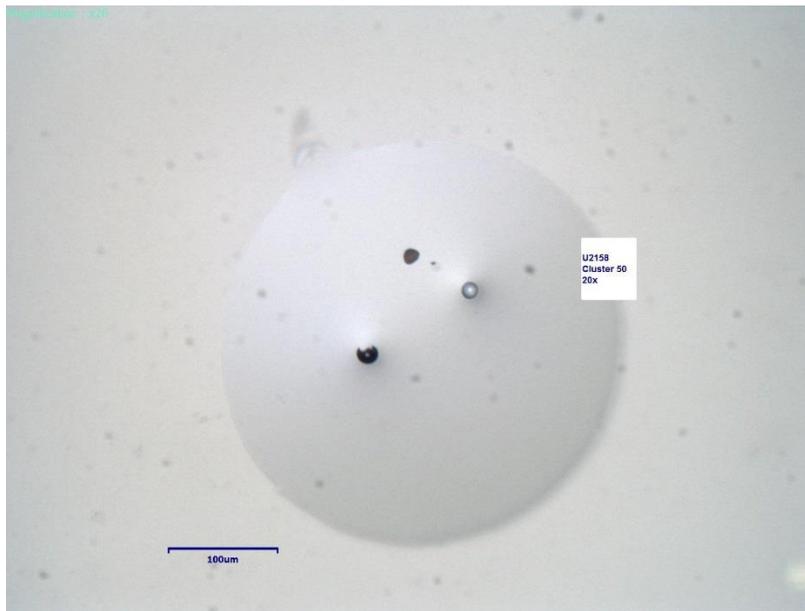


## U2158 C15



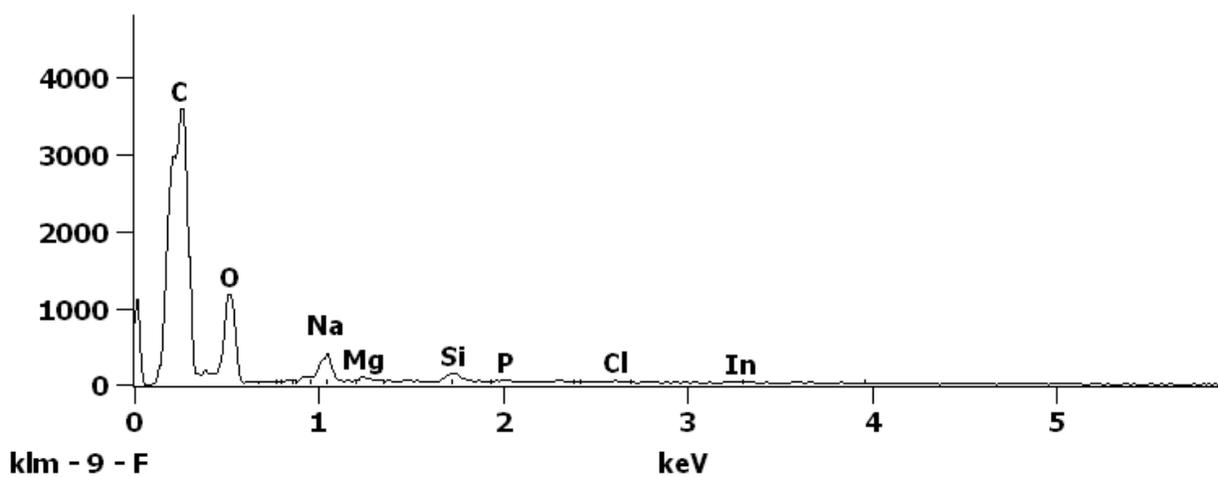
**Particle Size:** 22 μm  
**Shape:** Spherical  
**Transparency:** Opaque  
**Color:** Black  
**Luster:** Pearly  
**Particle Type:** Artificial Terrestrial Contamination  
**Cluster No.:** 50  
**Comments:**

## Cluster of Origin: U2158 Cluster 50

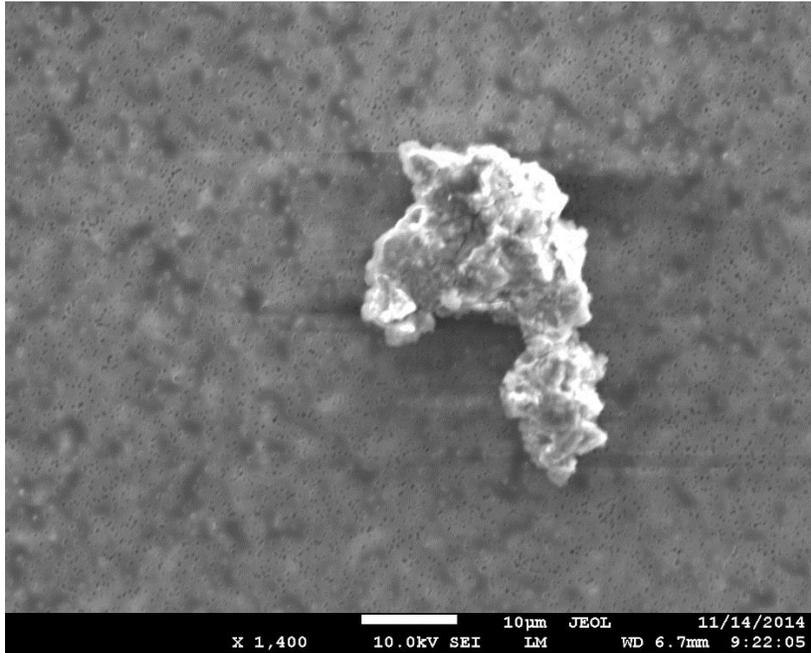


Full scale counts: 3901

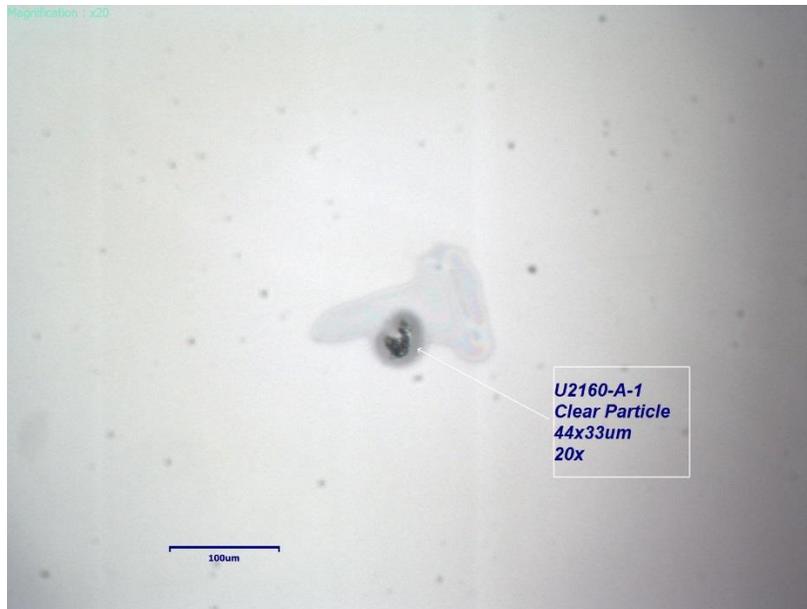
U2158C(15)\_pt1

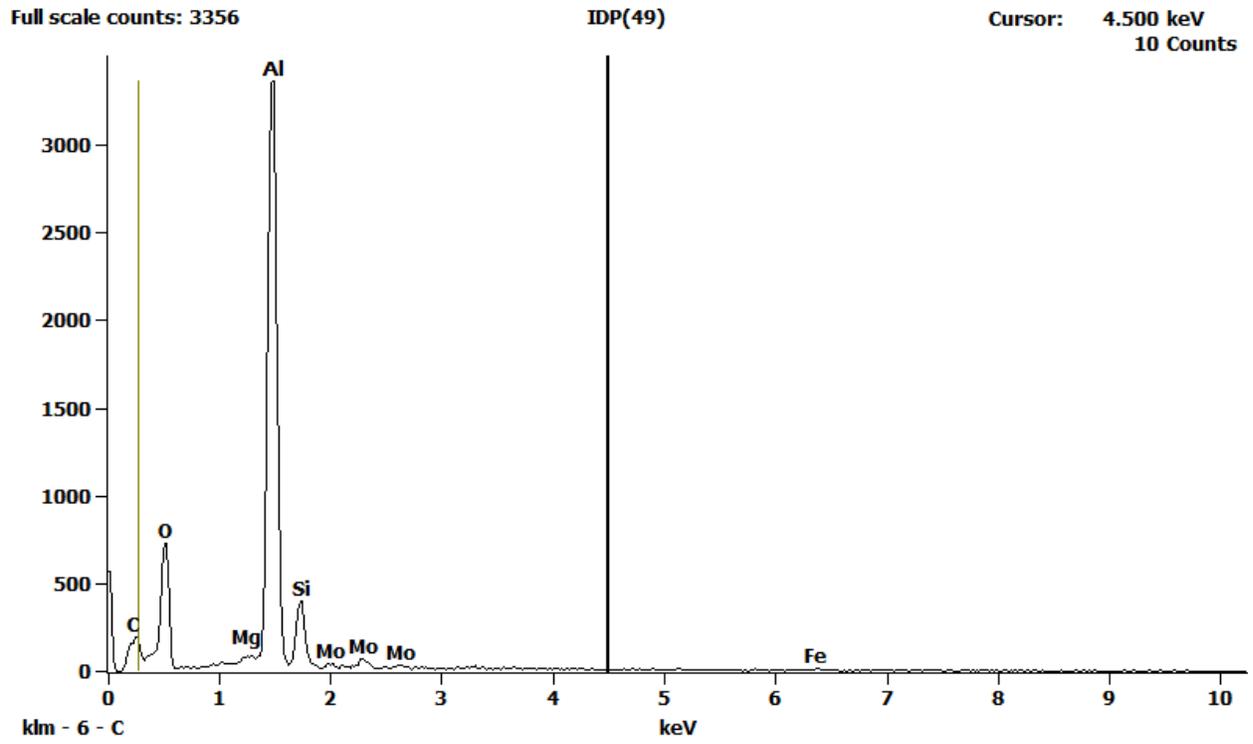


## U2160 A1

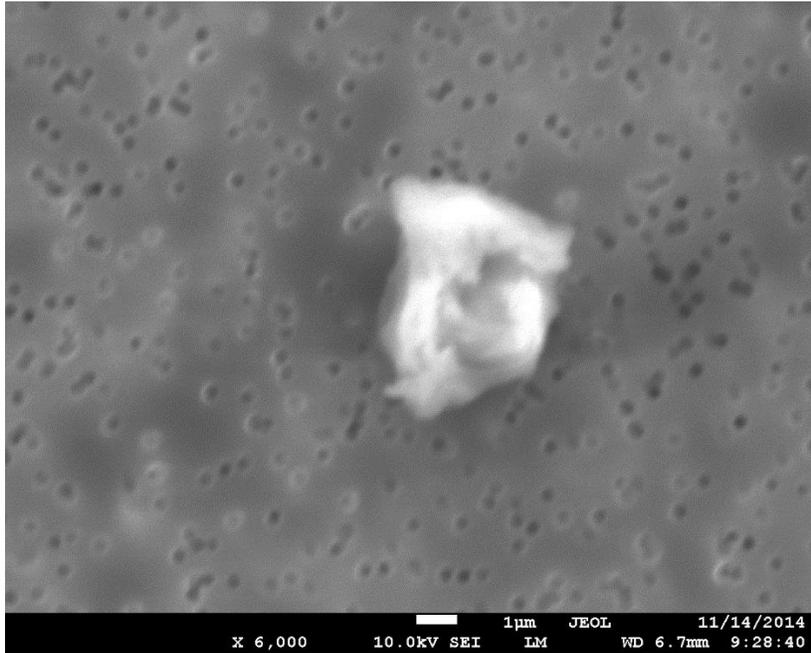


**Particle Size:** 25x40 μm  
**Shape:** Irregular  
**Transparency:** Translucent to Opaque  
**Color:** Gray  
**Luster:** Pearly to Vitreous  
**Particle Type:** Possibly Artificial Terrestrial Contamination  
**Cluster No.:**  
**Comments:**

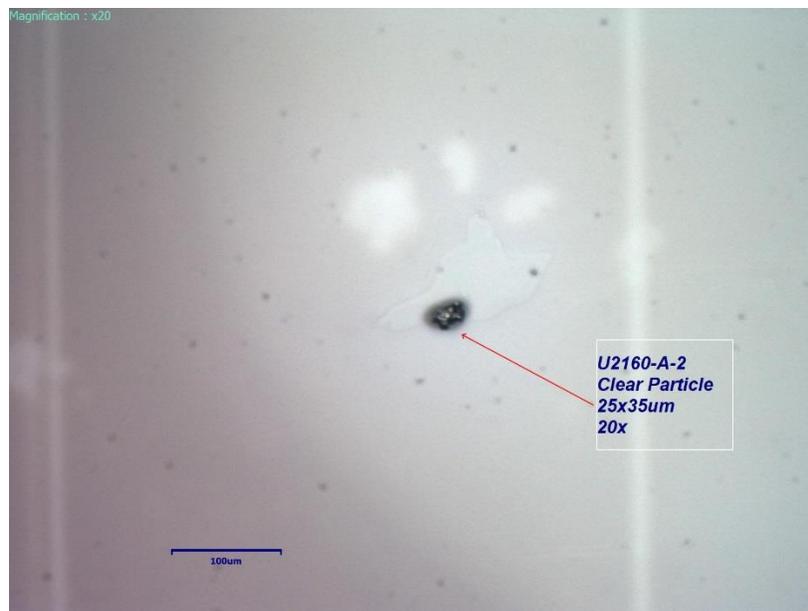


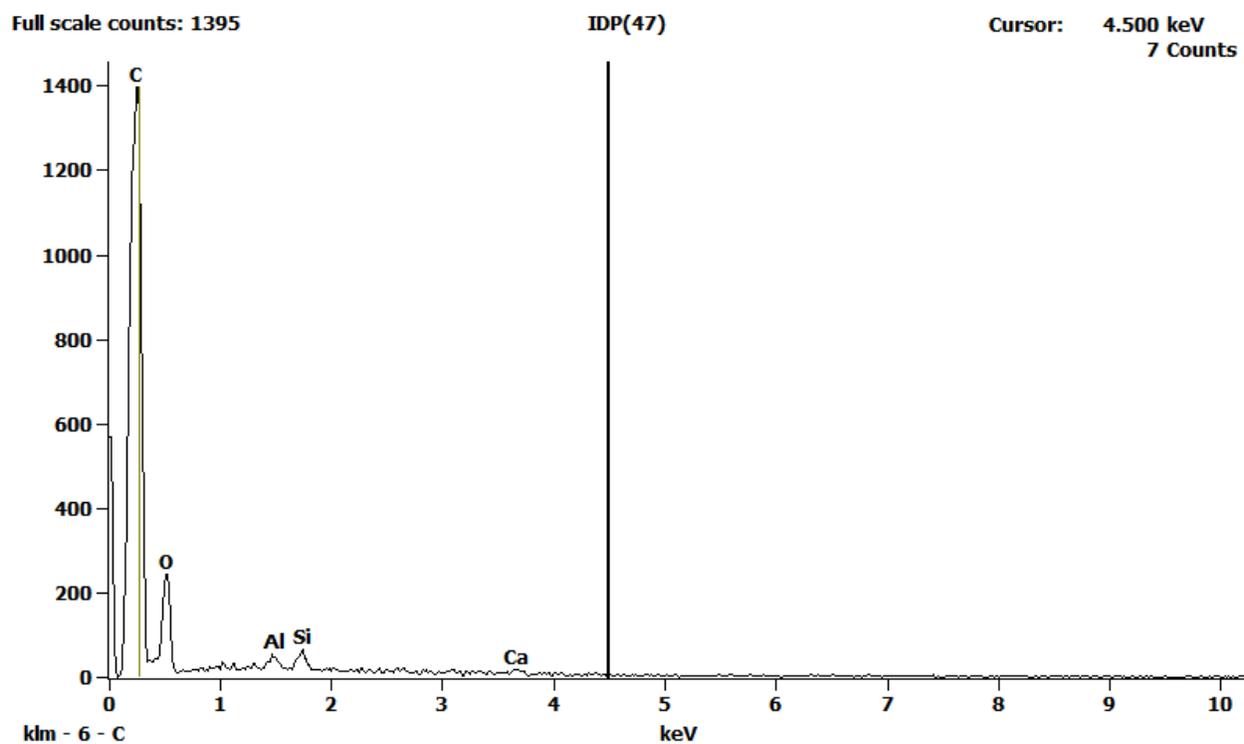


## U2160 A2

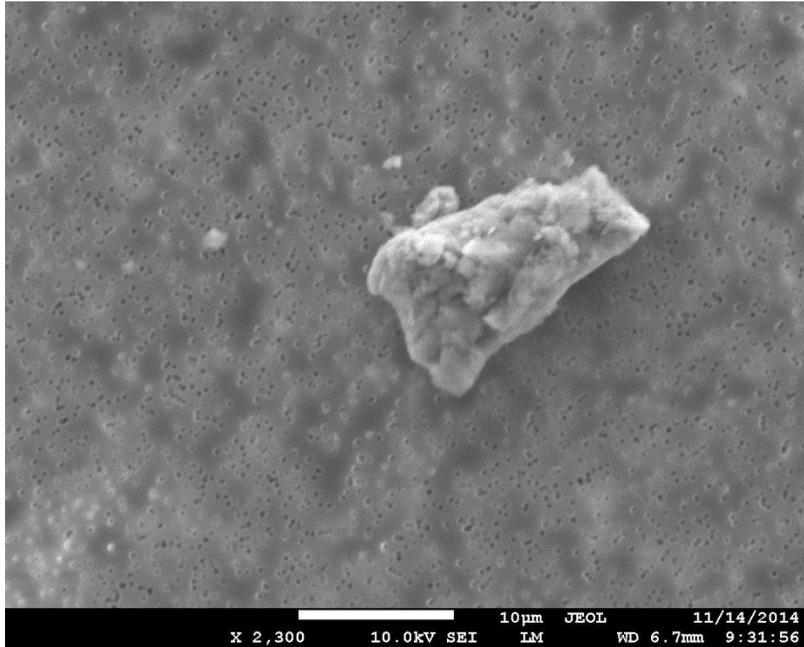


**Particle Size:** 10 µm  
**Shape:** Equidimensional  
**Transparency:** Translucent to Opaque  
**Color:** Gray  
**Luster:** Pearly to Vitreous  
**Particle Type:** Possibly Artificial Terrestrial Contamination  
**Cluster No.:**  
**Comments:**

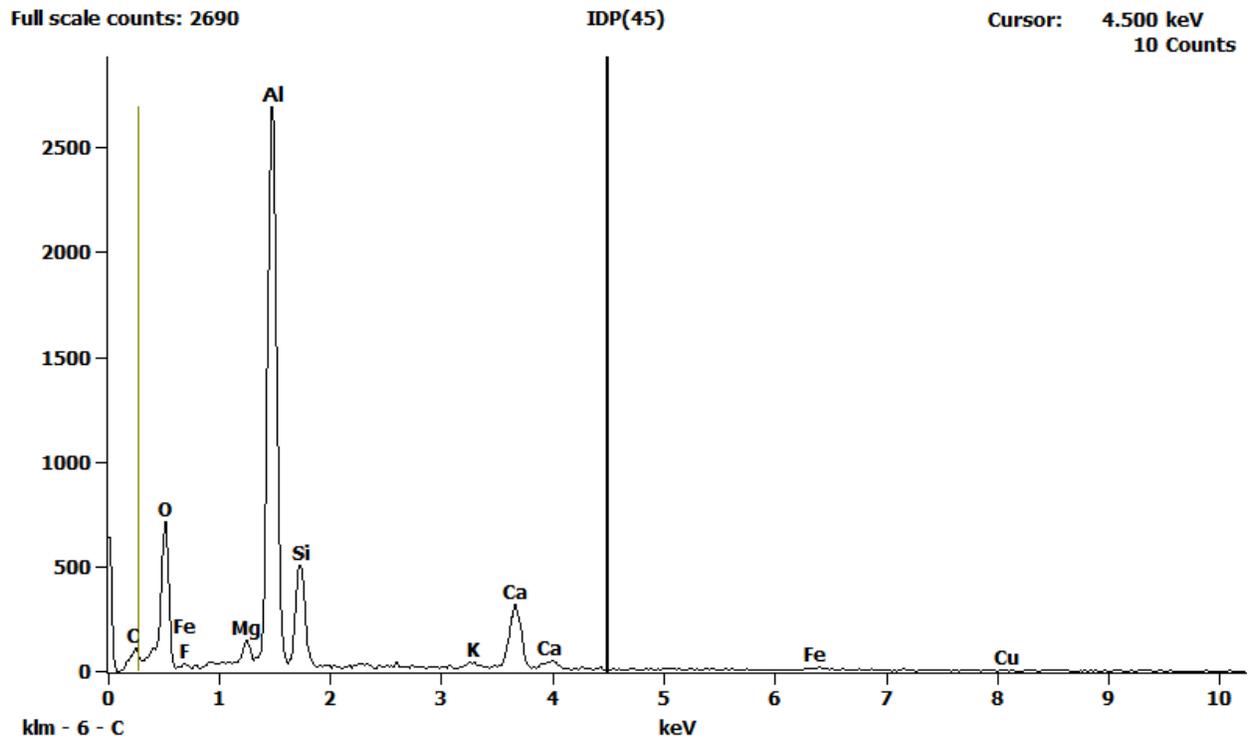




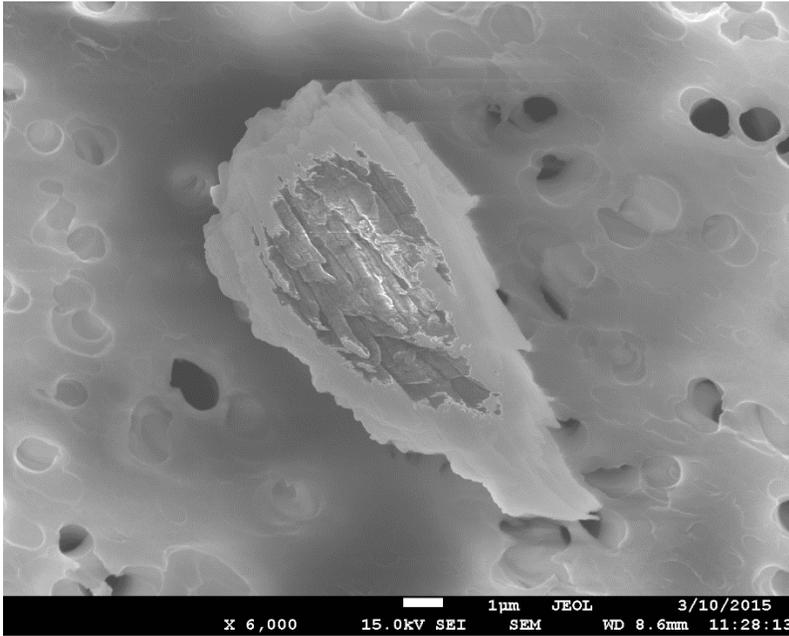
## U2160 A4



**Particle Size:** 10x20 µm  
**Shape:** Equidimensional  
**Transparency:** Opaque  
**Color:** Brown  
**Luster:**  
**Particle Type:** Artificial Terrestrial Contamination  
**Cluster No.:**  
**Comments:**



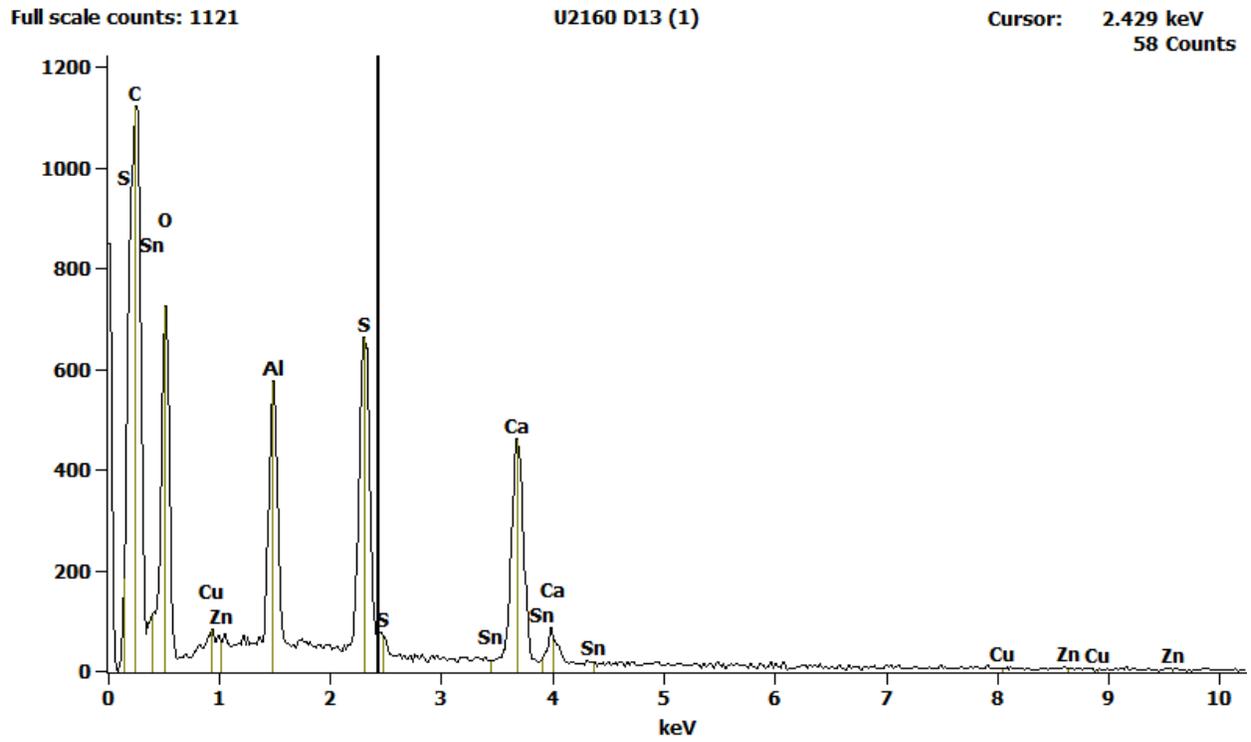
## U2160 D1



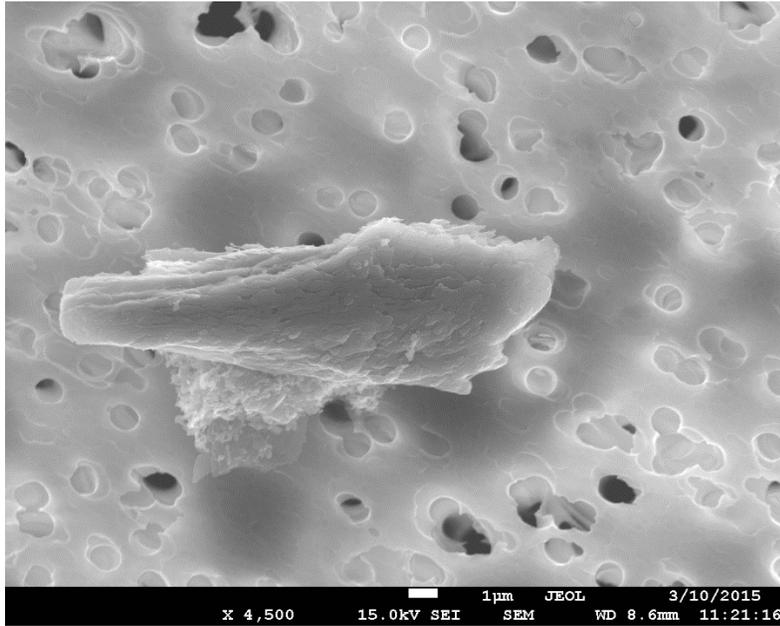
**Particle Size:** 3 µm  
**Shape:** Irregular to Equidimensional  
**Transparency:** Translucent to Opaque  
**Color:** Green, Clear, Gray  
**Luster:** Pearly to Vitreous  
**Particle Type:** Artificial Terrestrial Contamination  
**Cluster No.:** 1  
**Comments:**

## Cluster of Origin: U2160 Cluster 1





## U2160 D2



**Particle Size:** 4 µm  
**Shape:** Equidimensional to Spherical  
**Transparency:** Translucent to Opaque  
**Color:** Clear, Gray  
**Luster:** Pearly to Vitreous  
**Particle Type:** Artificial Terrestrial Contamination  
**Cluster No.:** 1  
**Comments:**

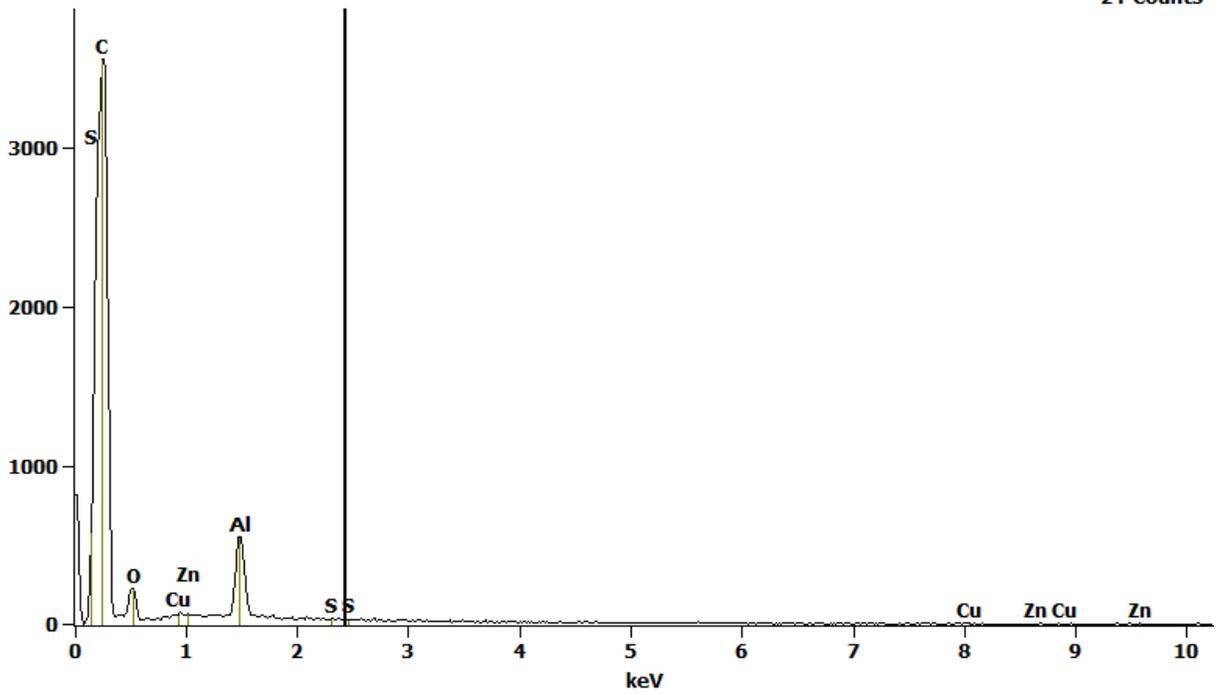
## Cluster of Origin: U2160 Cluster 1



Full scale counts: 3558

U2160 D8 maybe (1)

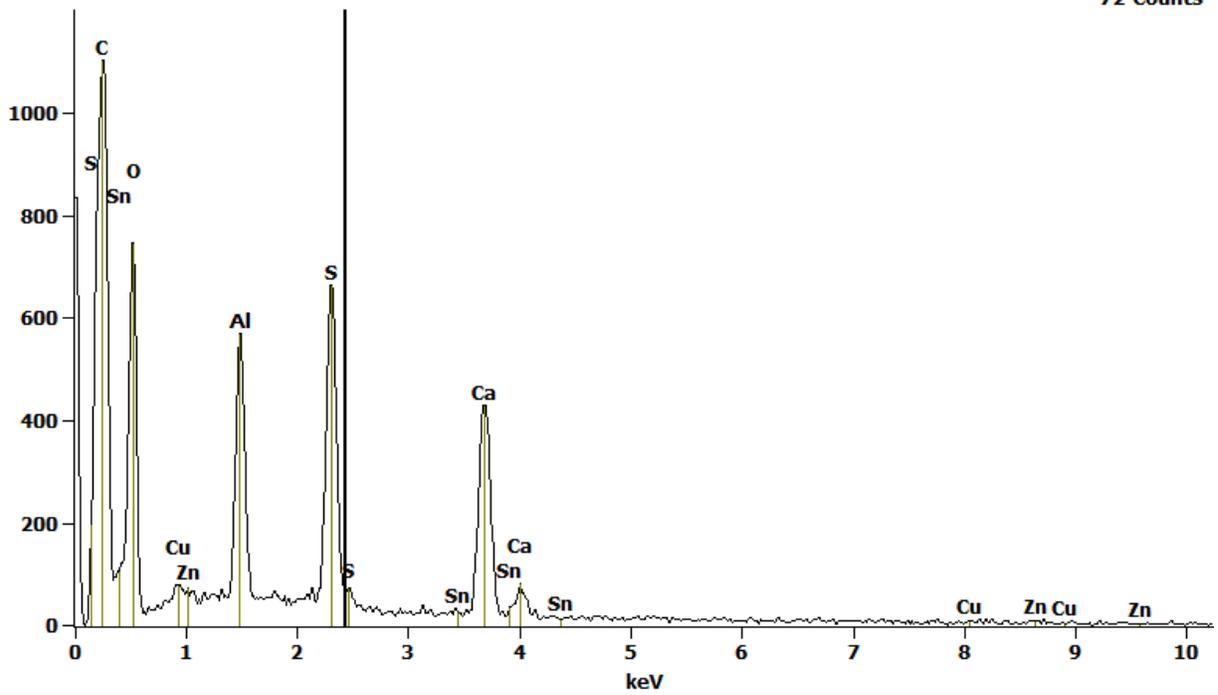
Cursor: 2.429 keV  
24 Counts



Full scale counts: 1103

U2160 D8 maybe (2)

Cursor: 2.429 keV  
72 Counts

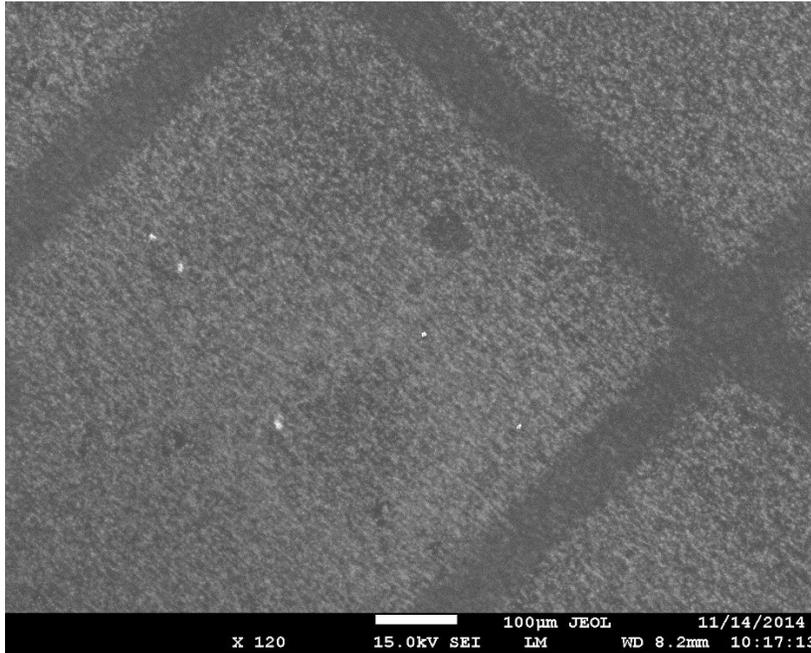


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**Natural Terrestrial Contamination (TCN Type)**



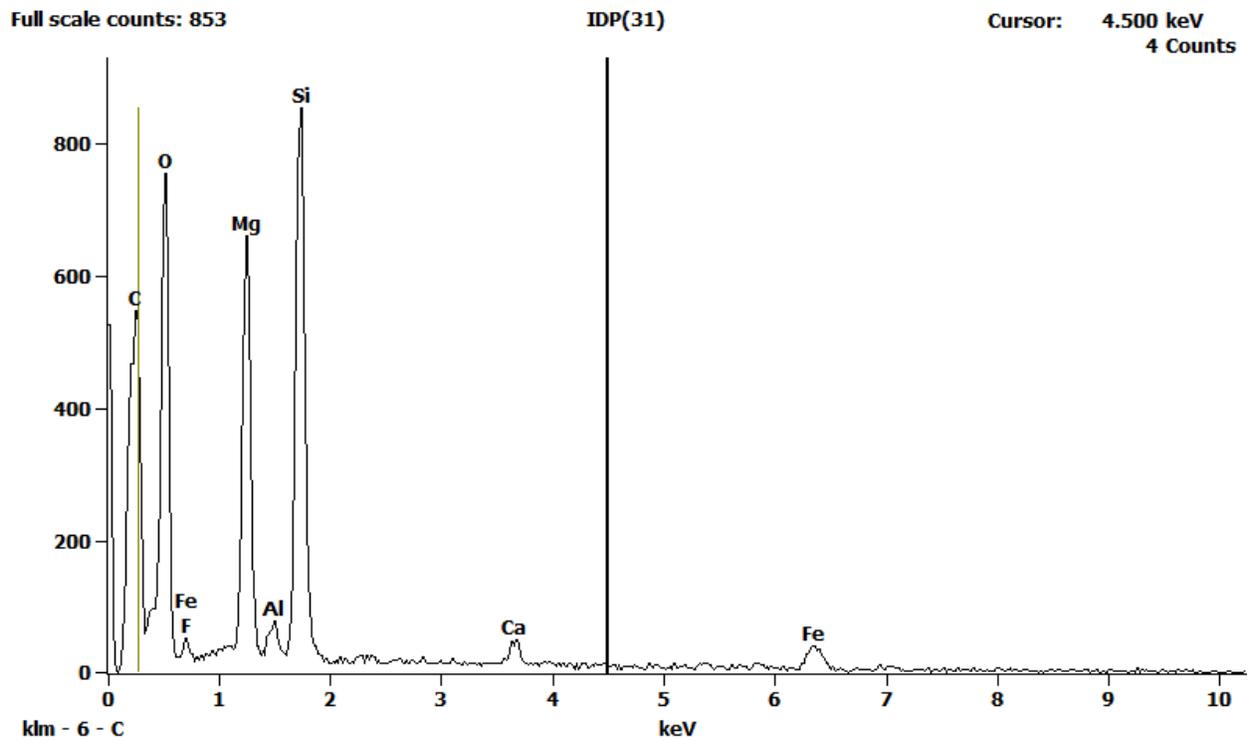
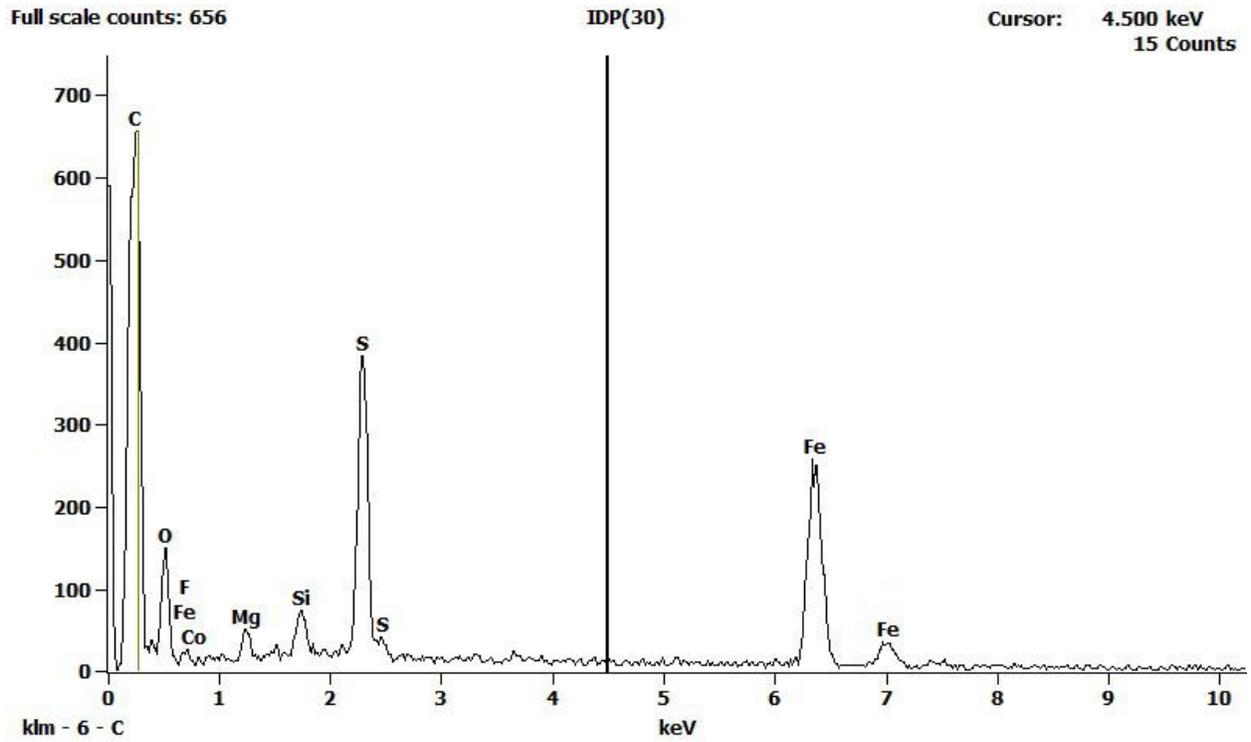
## U2153 A18



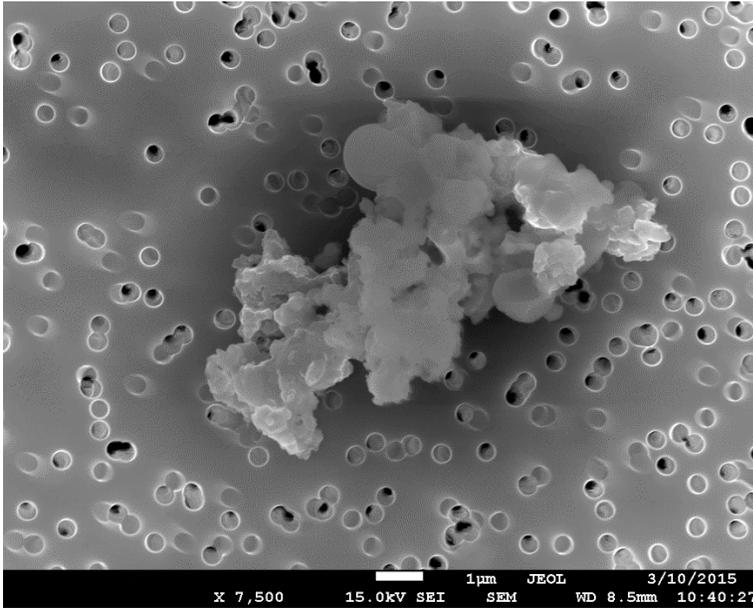
**Particle Size:** 6x5 µm  
**Shape:** Equidimensional  
**Transparency:** Opaque to Subvitreous  
**Color:** Gray  
**Luster:** Pearly to Subvitreous  
**Particle Type:** Possibly Natural Terrestrial Contamination  
**Cluster No.:** 3  
**Comments:** Cu-sulfide+Fe metal

## Cluster of Origin: U2153 Cluster 3



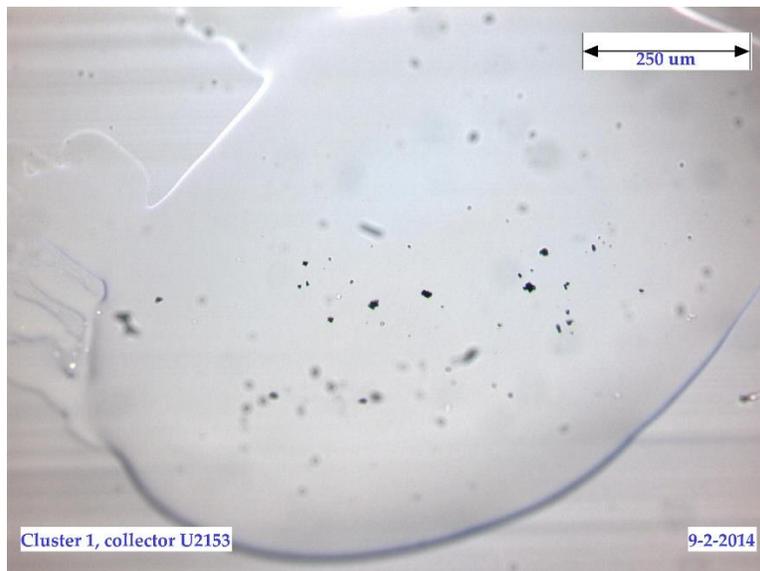


## U2153 B1



**Particle Size:** 9x4 µm  
**Shape:** Equidimensional to Irregular  
**Transparency:** Opaque  
**Color:** Black  
**Luster:** Pearly to Dull  
**Particle Type:** Possibly Natural Terrestrial Contamination  
**Cluster No.:** 1  
**Comments:**

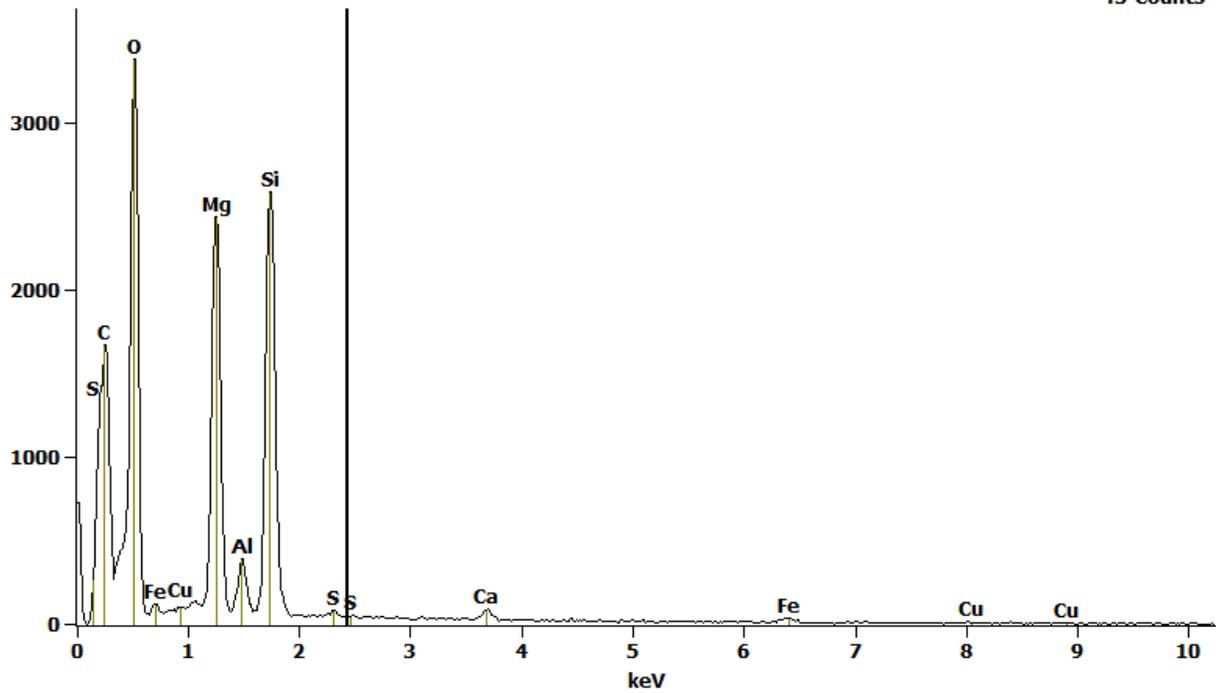
## Cluster of Origin: U2153 Cluster 1



Full scale counts: 3374

U2153 B1

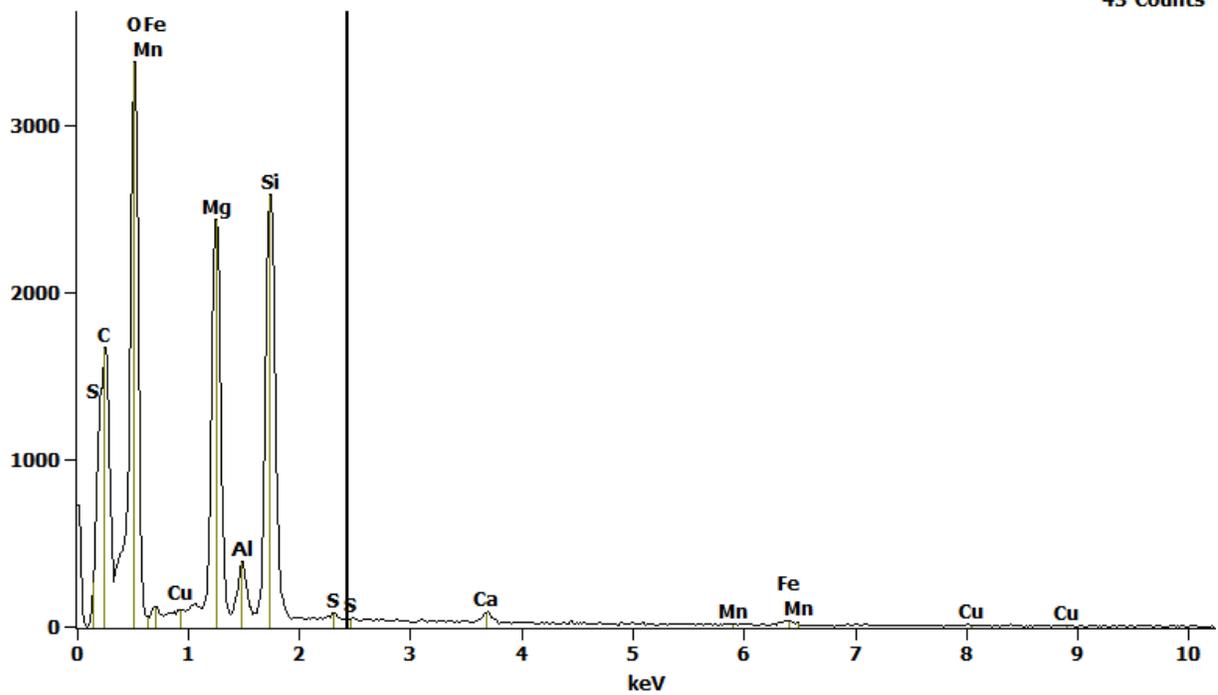
Cursor: 2.429 keV  
43 Counts



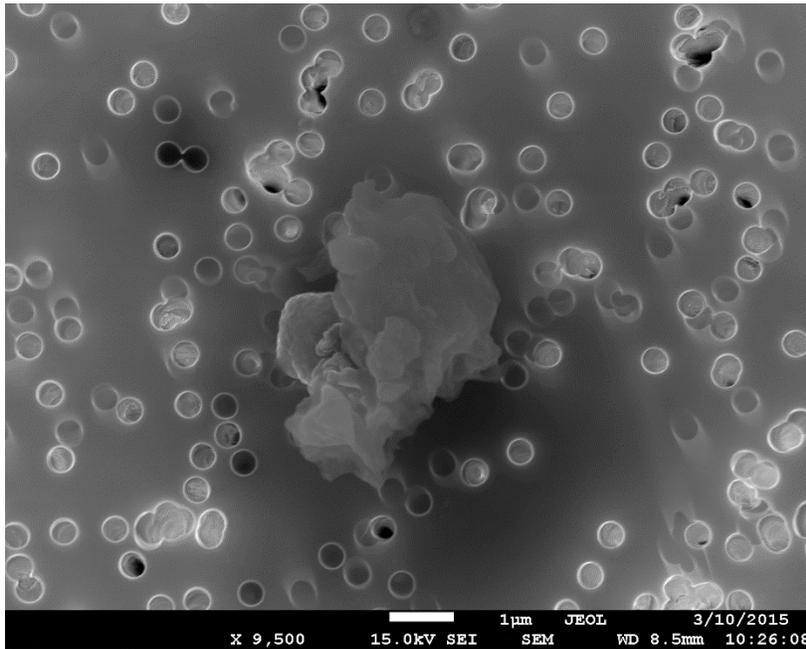
Full scale counts: 3374

U2153 b 1 maybe(1)

Cursor: 2.429 keV  
43 Counts



## U2153 C3



**Particle Size:** 3 µm

**Shape:** Equidimensional to Spherical

**Transparency:** Opaque to Subvitreous

**Color:** Black

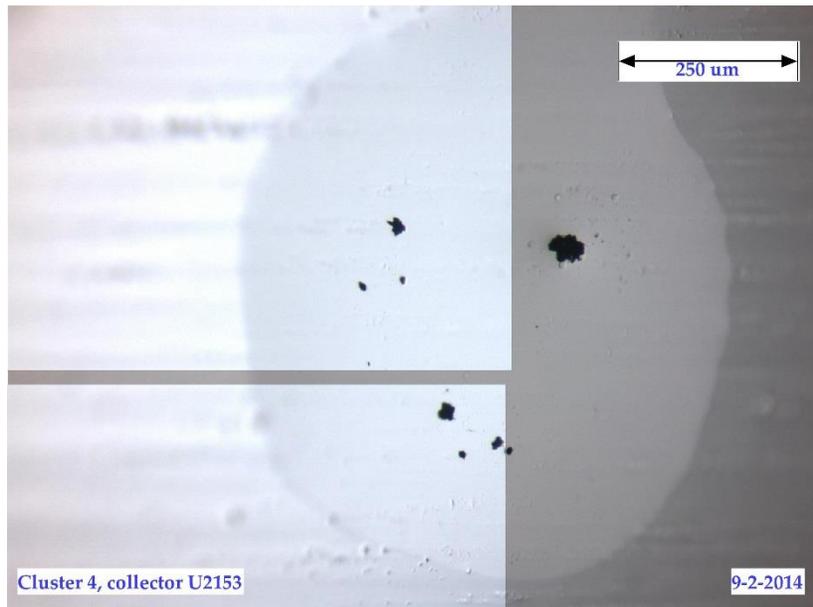
**Luster:** Pearly to Subvitreous

**Particle Type:** Possibly Natural Terrestrial Contamination

**Cluster No.:** 4

**Comments:**

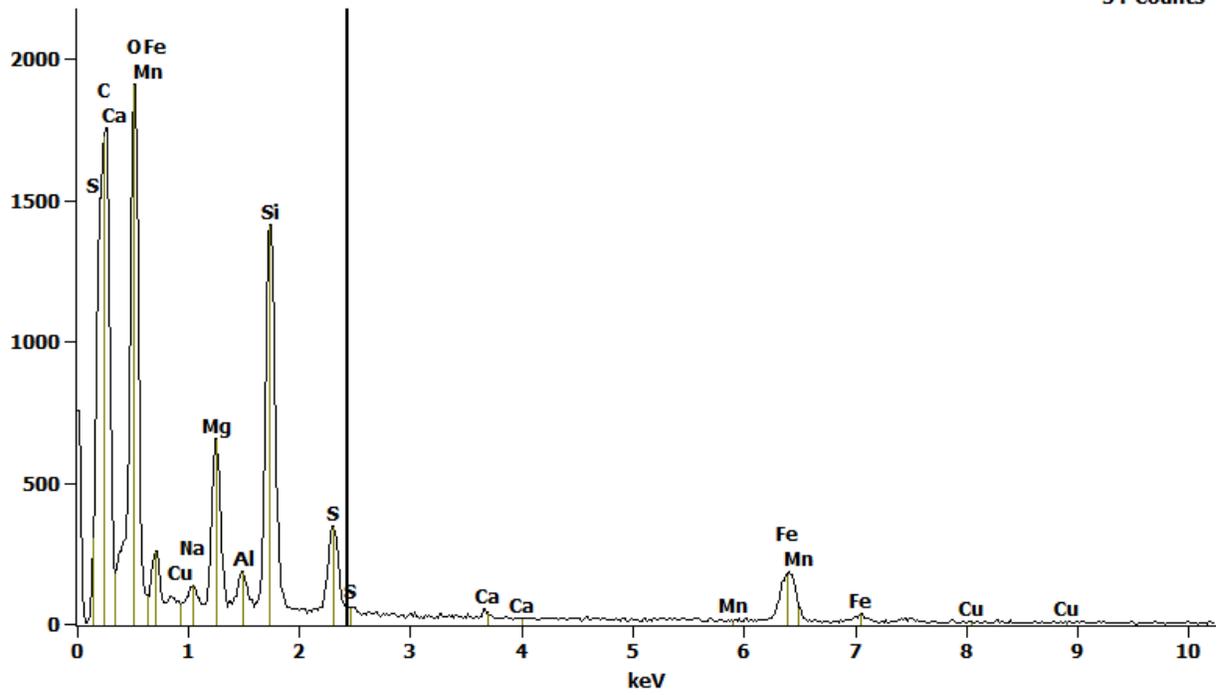
## Cluster of Origin: Cluster 4



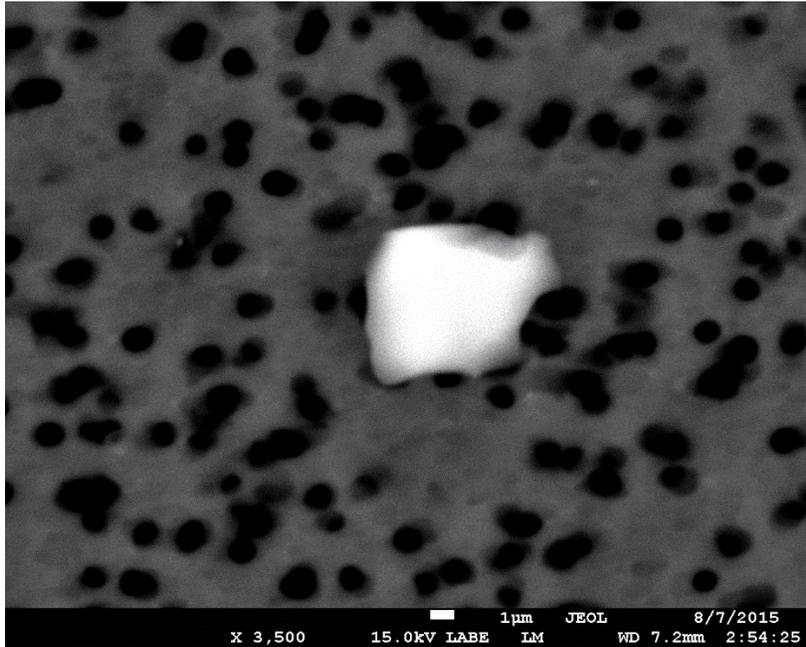
Full scale counts: 1910

2153C 7 maybe(1)

Cursor: 2.429 keV  
54 Counts

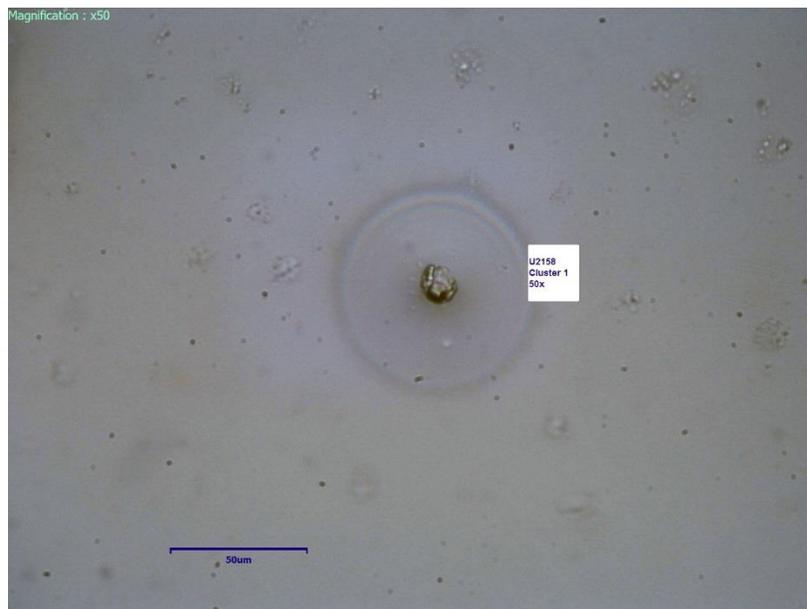


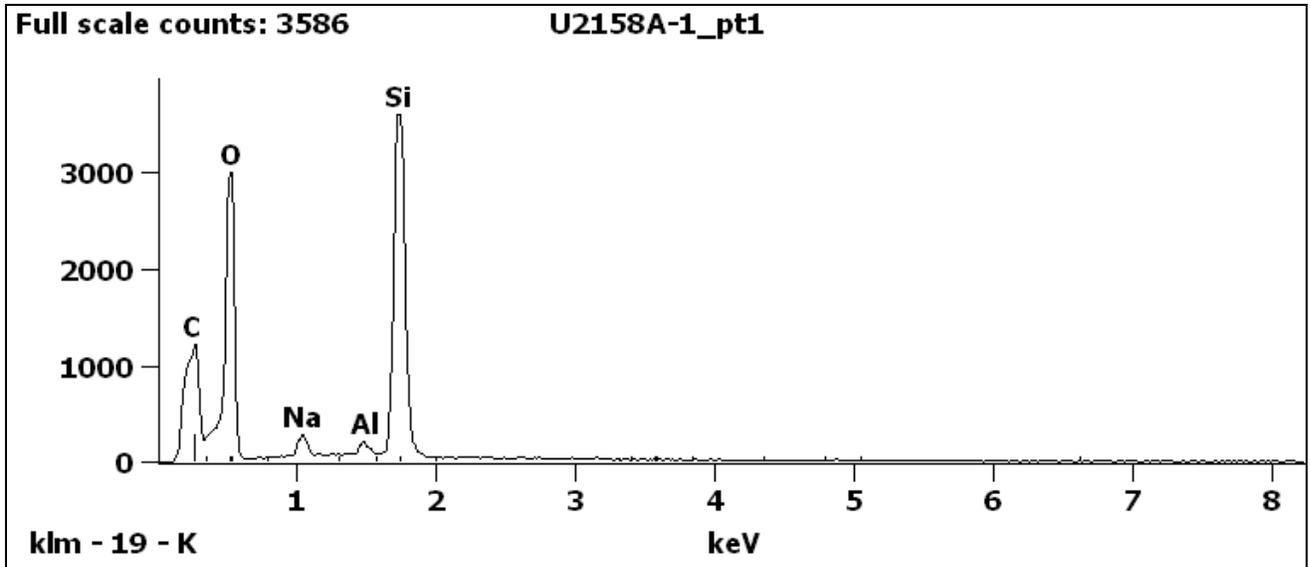
## U2158 A1



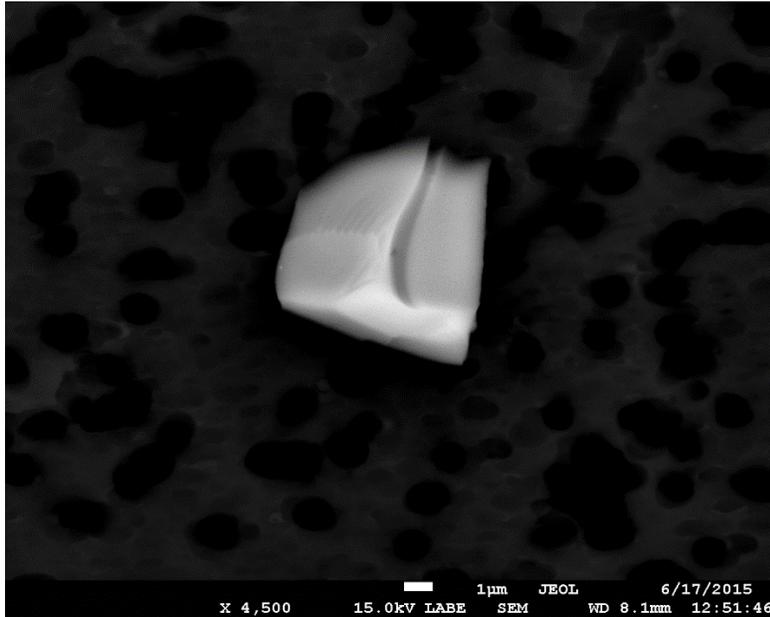
**Particle Size:** 8x10 µm  
**Shape:** Irregular  
**Transparency:** Opaque  
**Color:** Black  
**Luster:** Dull  
**Particle Type:** Possibly Natural  
Terrestrial  
Contamination  
**Cluster No.:** 1  
**Comments:**

## Cluster of Origin: U2158 Cluster 1





## U2158 A2



**Particle Size:** 8.5 µm

**Shape:** Equidimensional

**Transparency:** Opaque

**Color:** Black

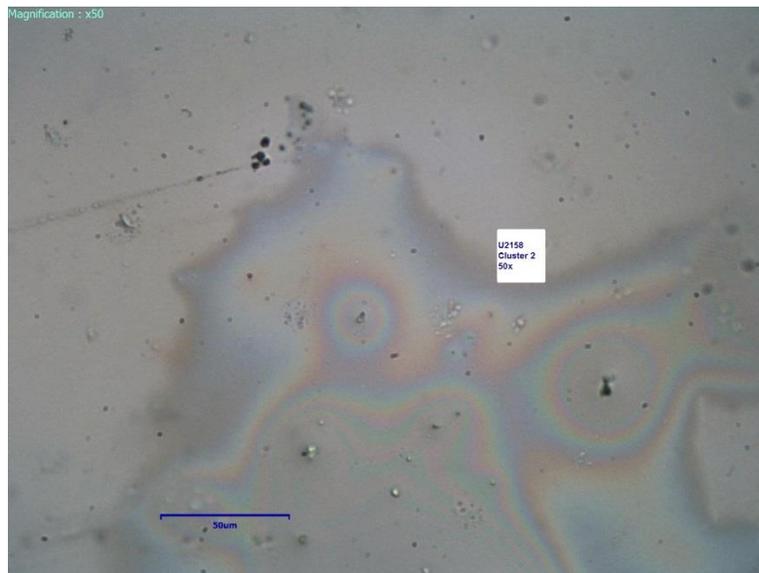
**Luster:** Pearly to Dull

**Particle Type:** Natural Terrestrial Contamination

**Cluster No.:** 2

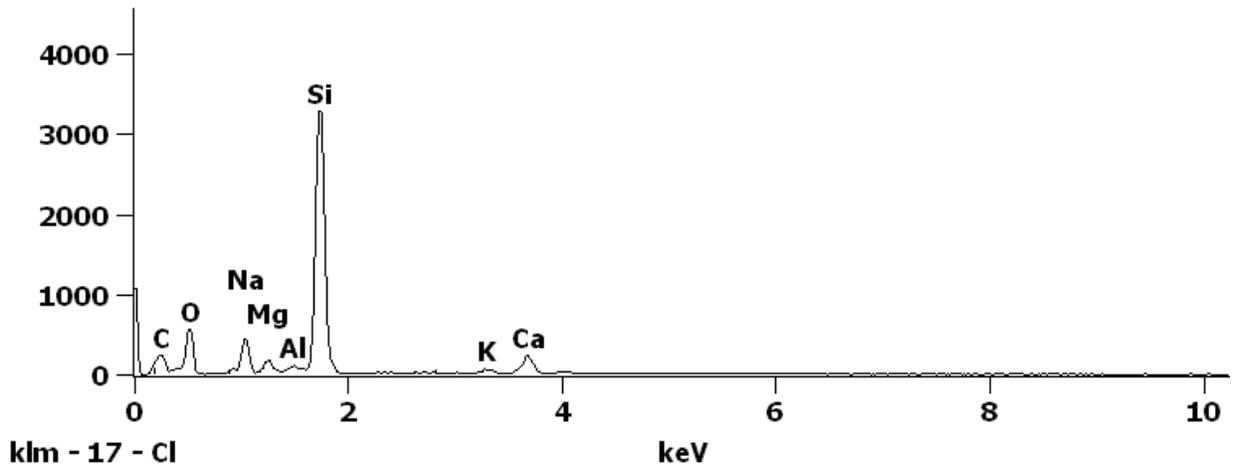
**Comments:**

## Cluster of Origin: U2158 Cluster 2

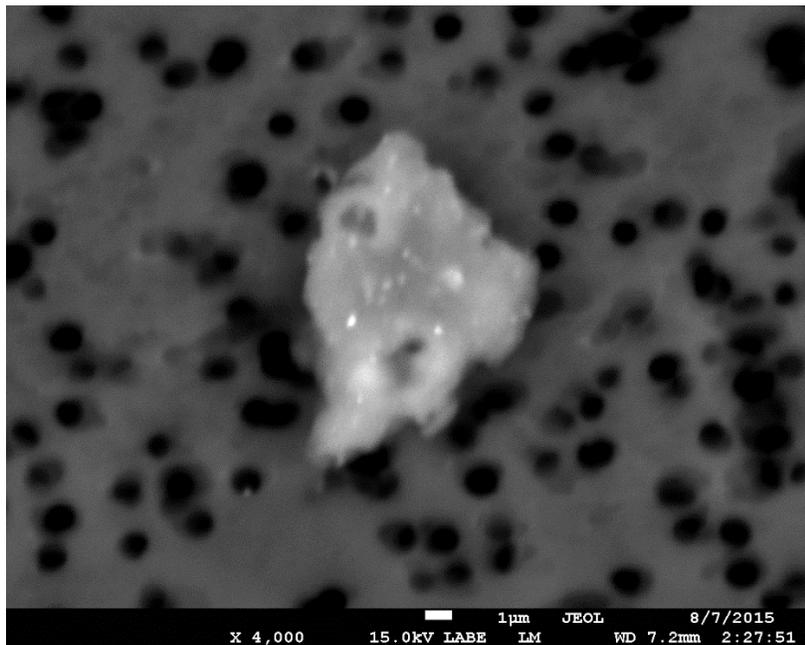


Full scale counts: 3274

A2(1)\_pt1



## U2158 A3



**Particle Size:** 15x20 µm

**Shape:** Irregular to Equidimensional

**Transparency:** Opaque

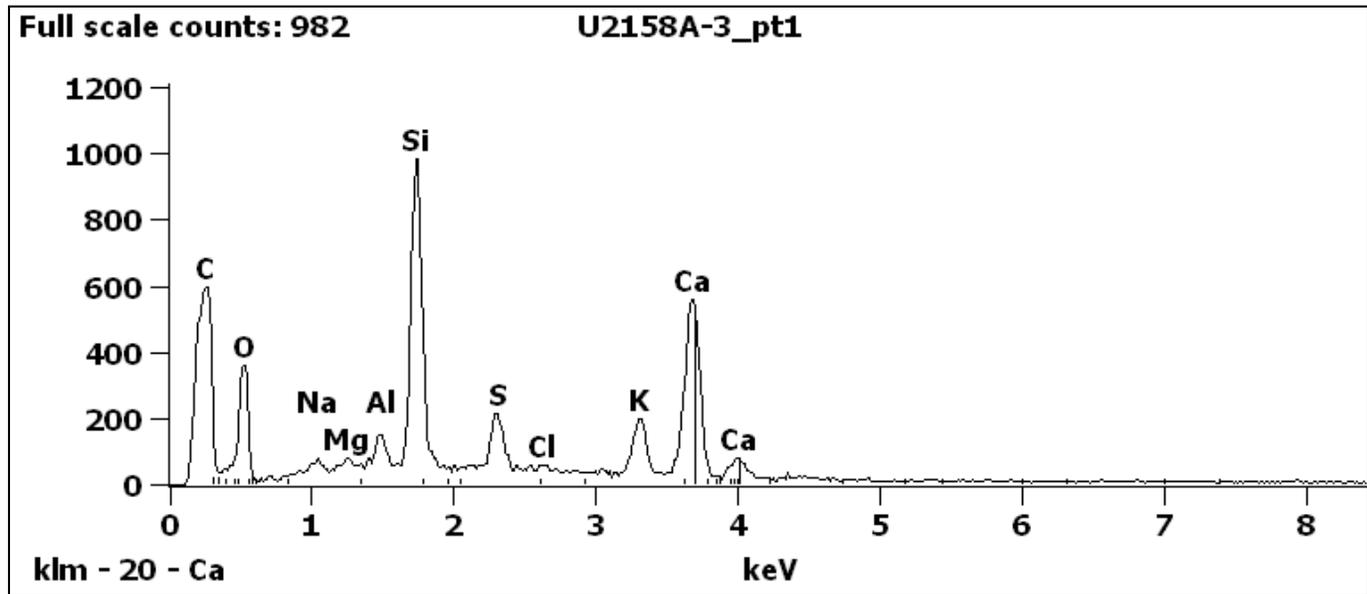
**Color:** Black, Green

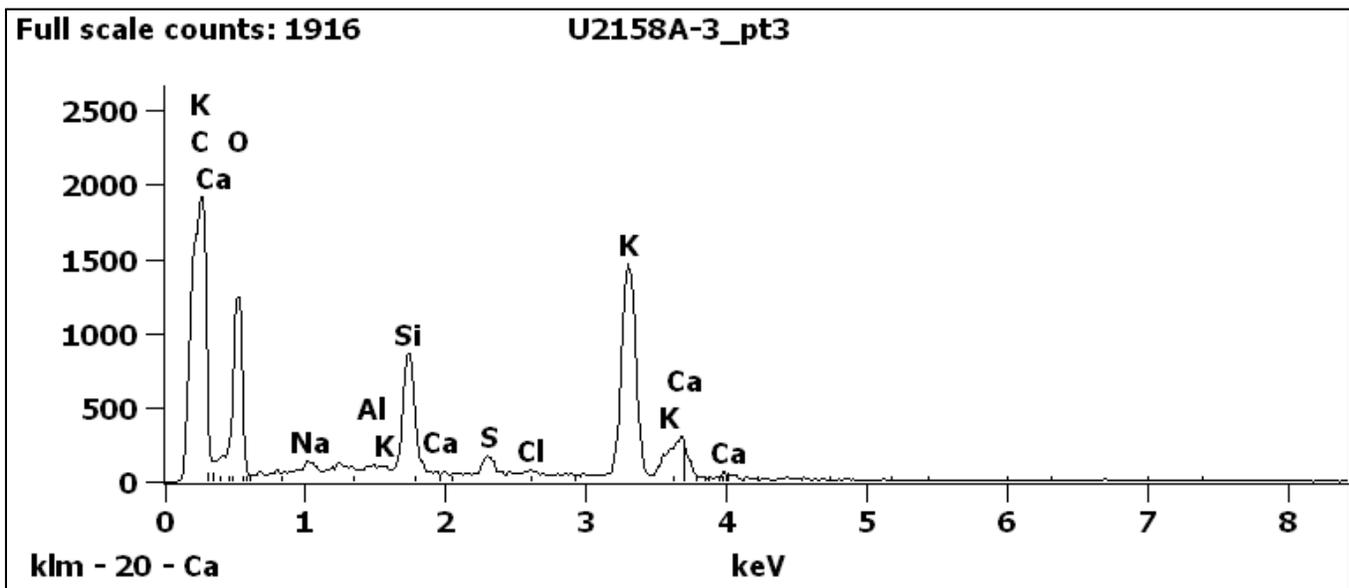
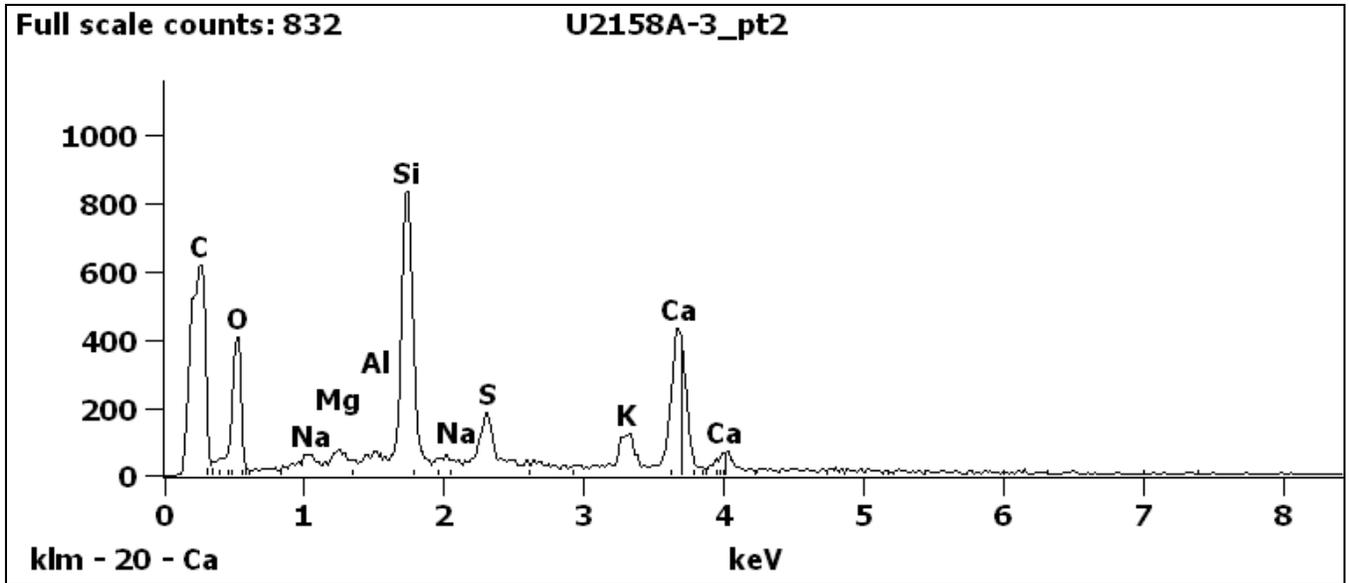
**Luster:** Vitreous

**Particle Type:** Natural Terrestrial Contamination

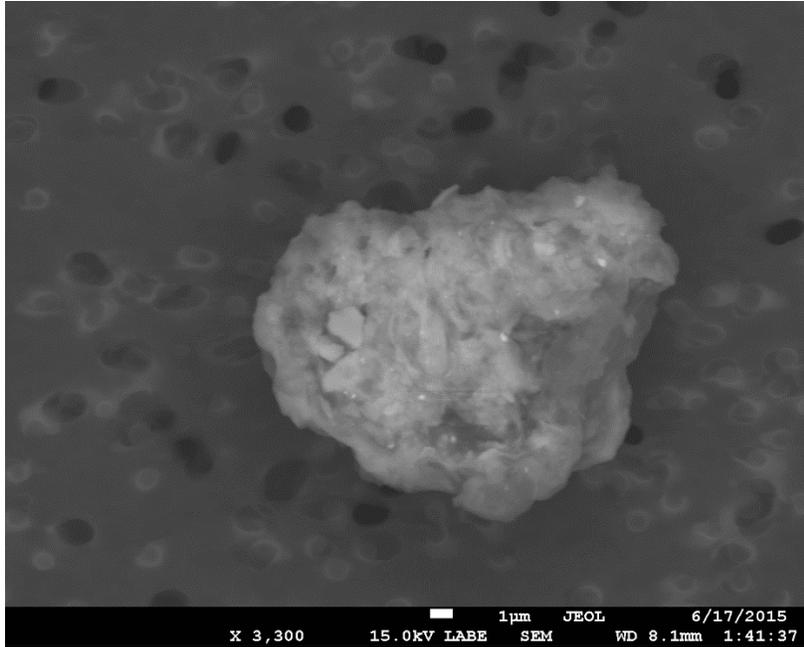
**Cluster No.:** 3

**Comments:**



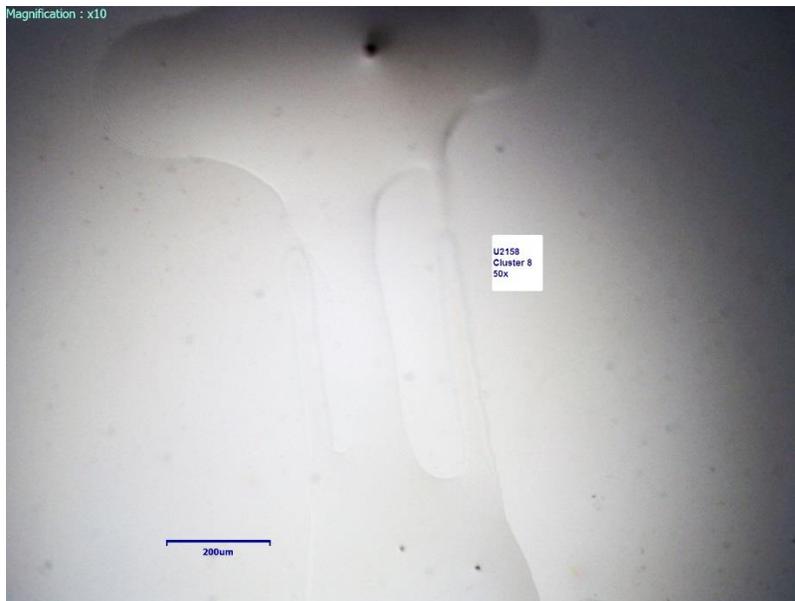


## U2158 A8



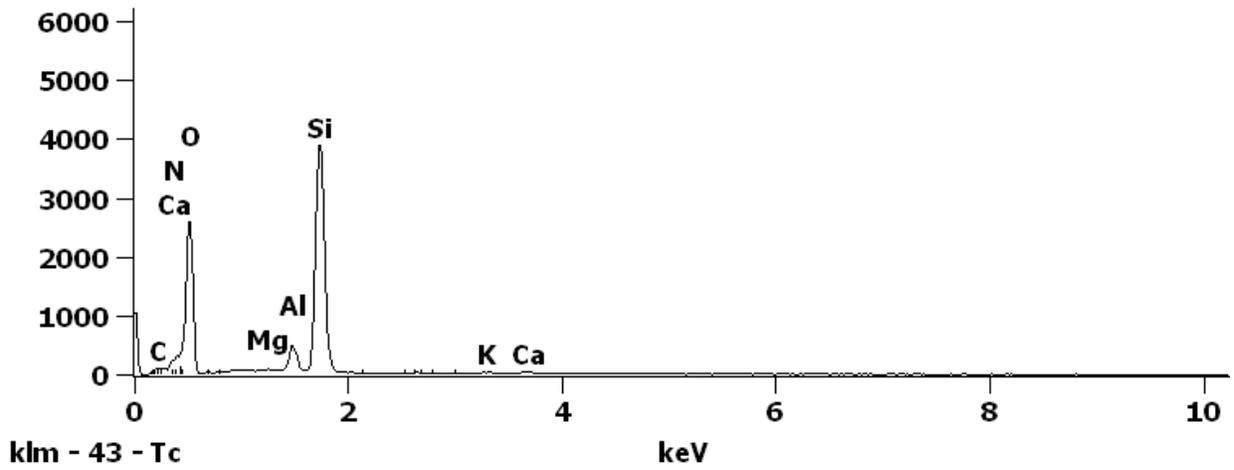
**Particle Size:** 20 µm  
**Shape:** Equidimensional to Irregular  
**Transparency:** Translucent to Opaque  
**Color:** Brown, Red  
**Luster:** Pearly to Dull  
**Particle Type:** Possibly Natural Terrestrial Contamination  
**Cluster No.:** 8  
**Comments:**

## Cluster of Origin: U2158 Cluster 8



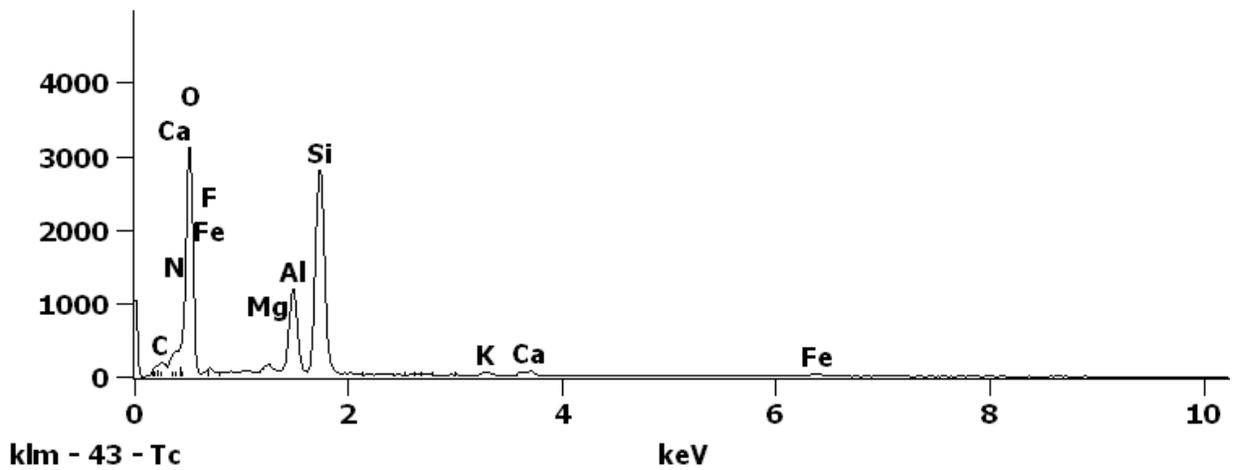
Full scale counts: 3887

A8(1)\_pt1

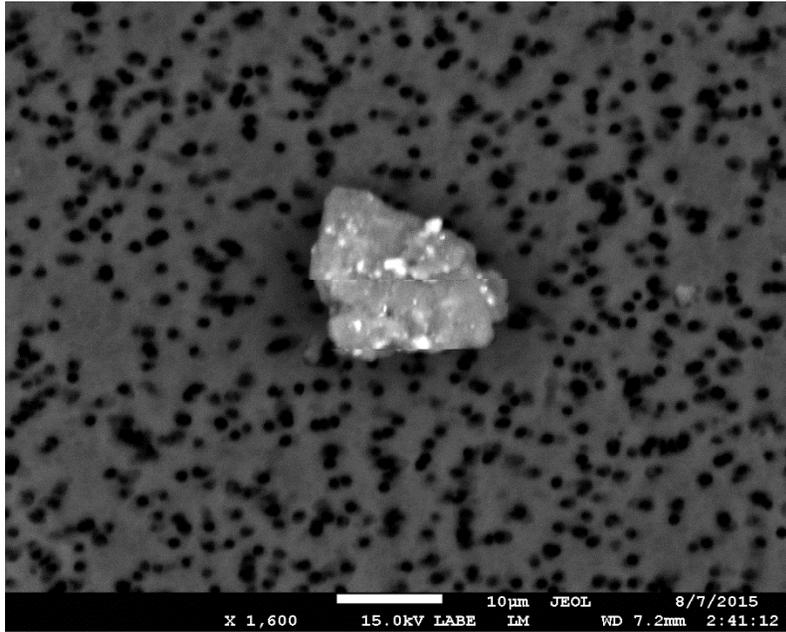


Full scale counts: 3116

A8(1)\_pt2



## U2158 A9



**Particle Size:** 15x20 µm

**Shape:** Irregular

**Transparency:** Transparent to Translucent

**Color:** Clear

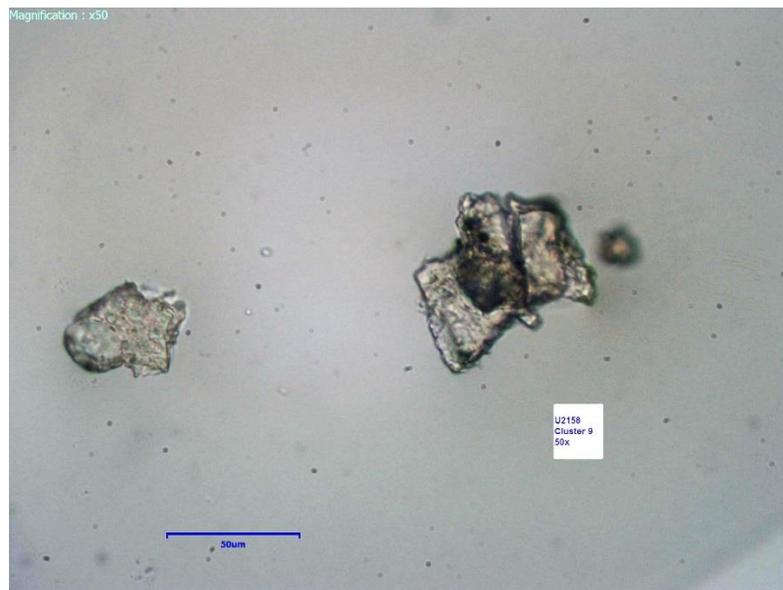
**Luster:** Vitreous

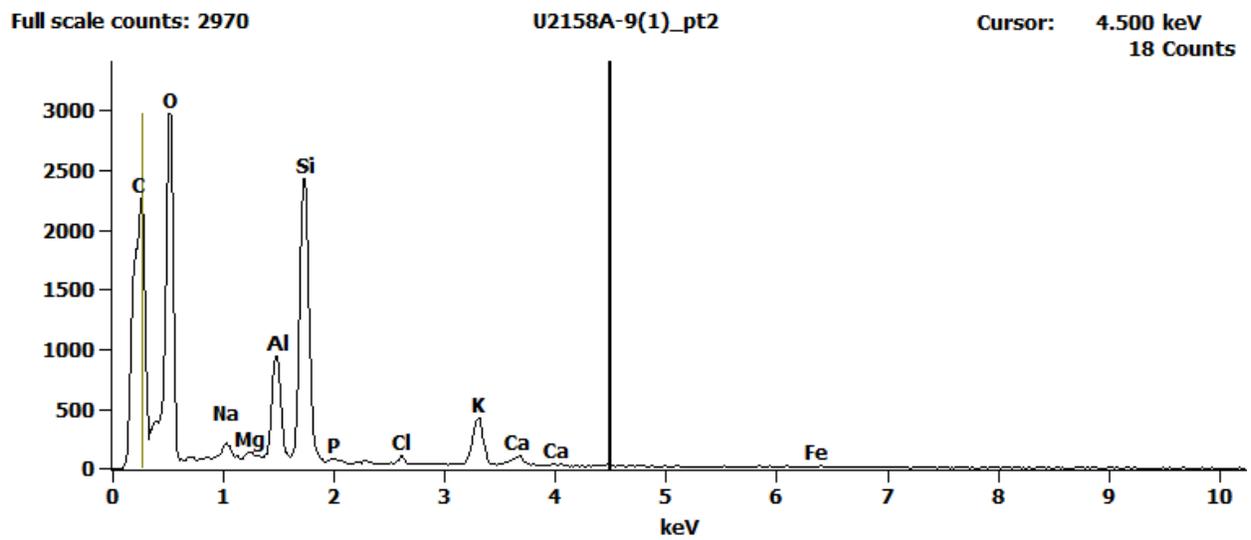
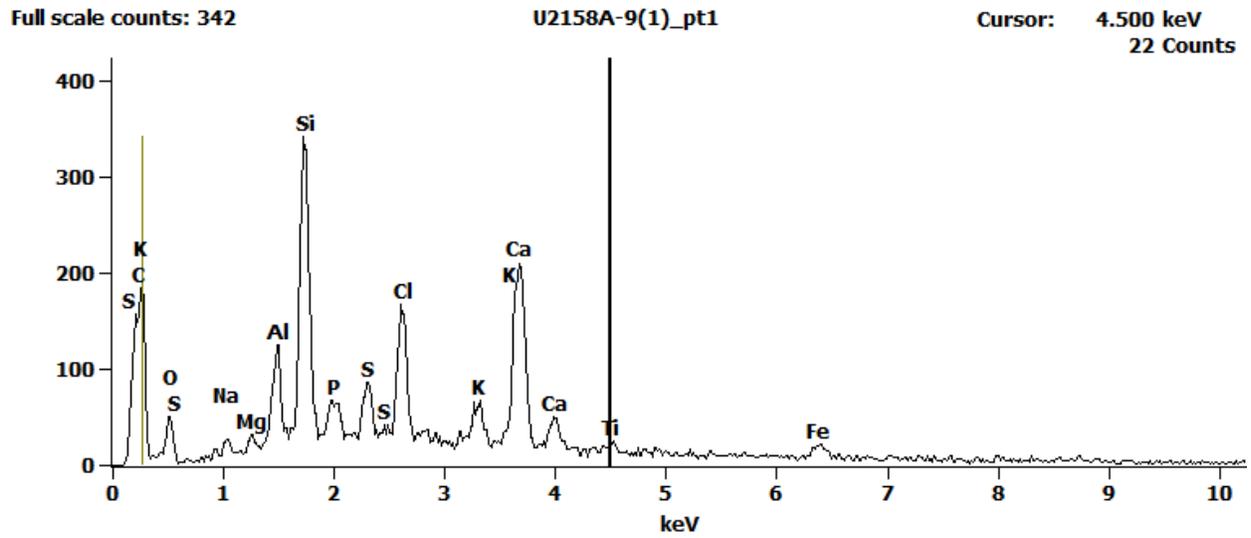
**Particle Type:** Possibly Natural Terrestrial Contamination

**Cluster No.:** 9

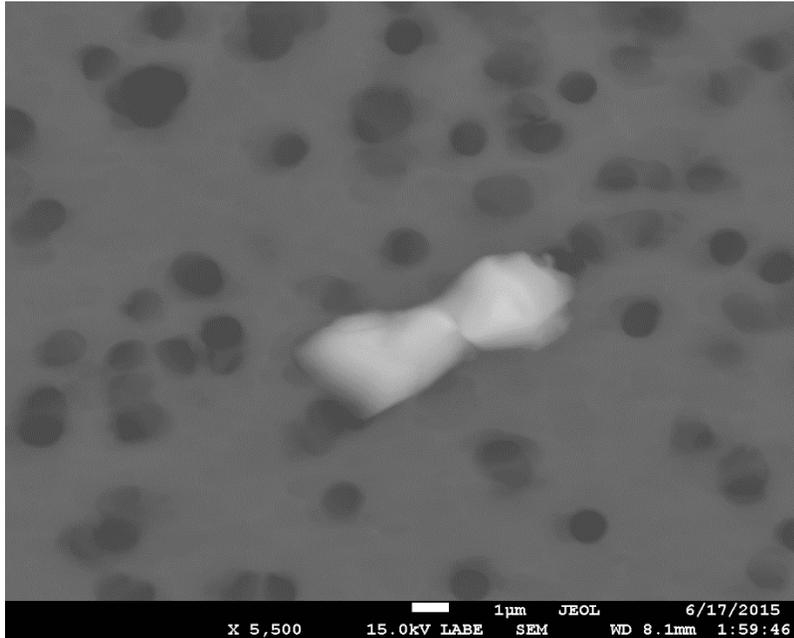
**Comments:**

## Cluster of Origin: U2158 Cluster 9



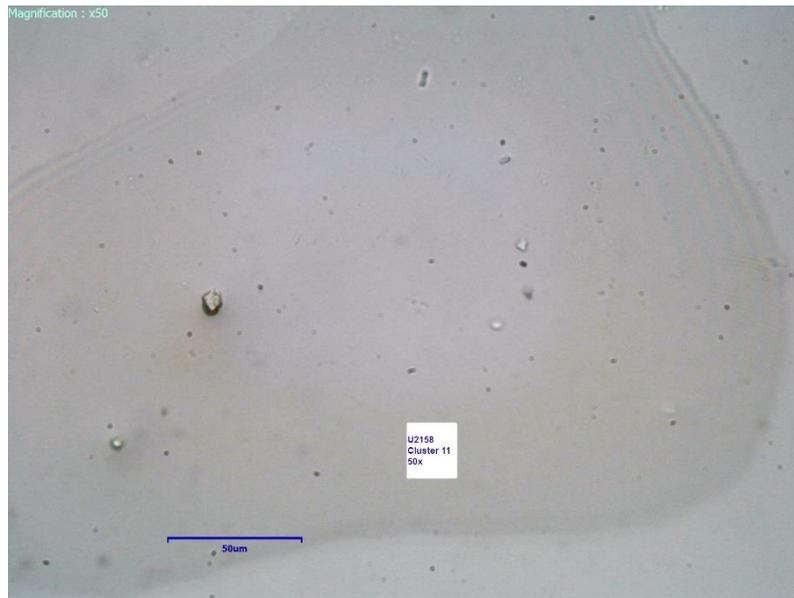


## U2158 A11



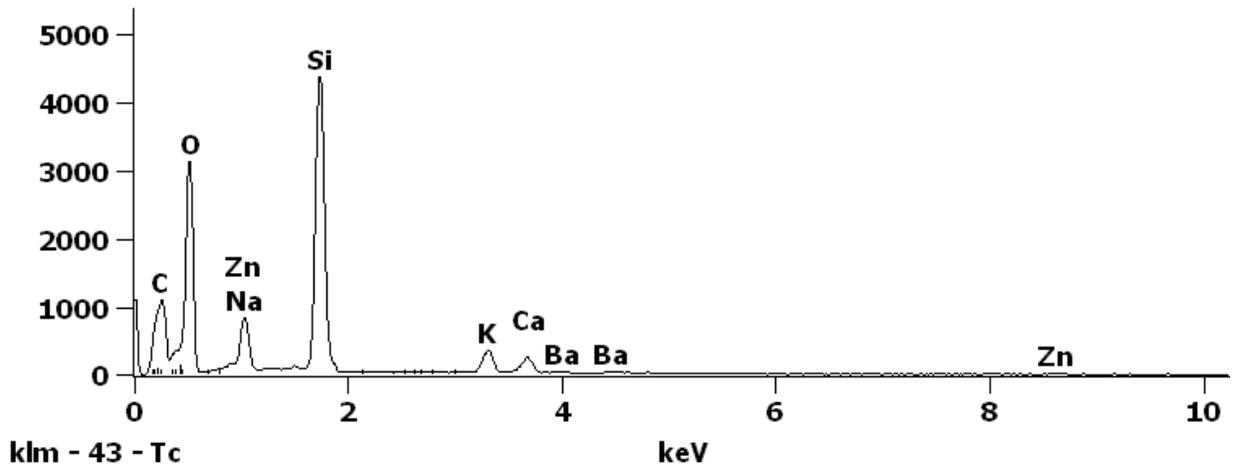
**Particle Size:** 3x6 µm  
**Shape:** Equidimensional to Irregular  
**Transparency:** Translucent to Transparent  
**Color:** Clear  
**Luster:** Pearly to Vitreous  
**Particle Type:** Natural Terrestrial Contamination  
**Cluster No.:** 11  
**Comments:**

## Cluster of Origin: U2158 A11



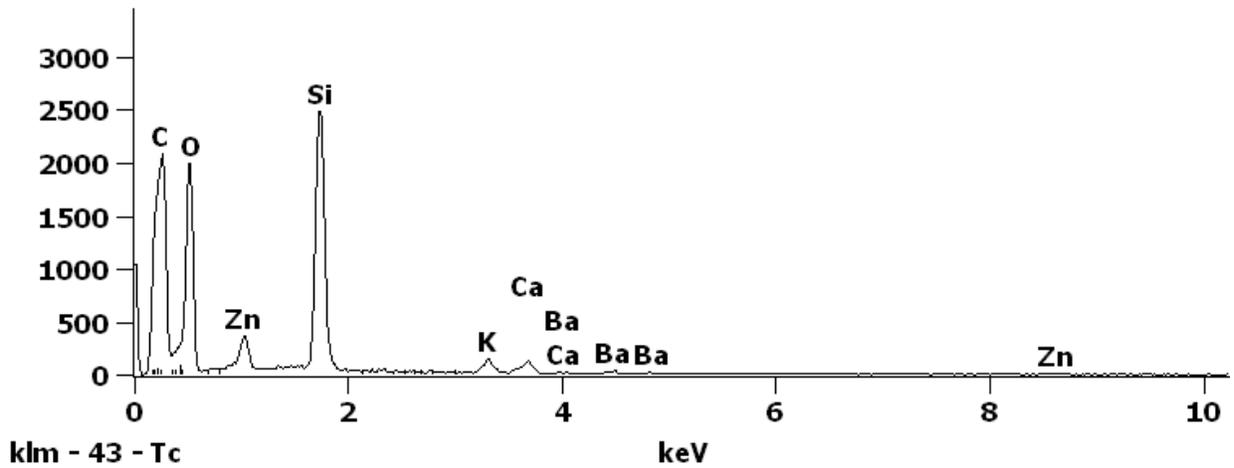
Full scale counts: 4366

A11(1)\_pt1

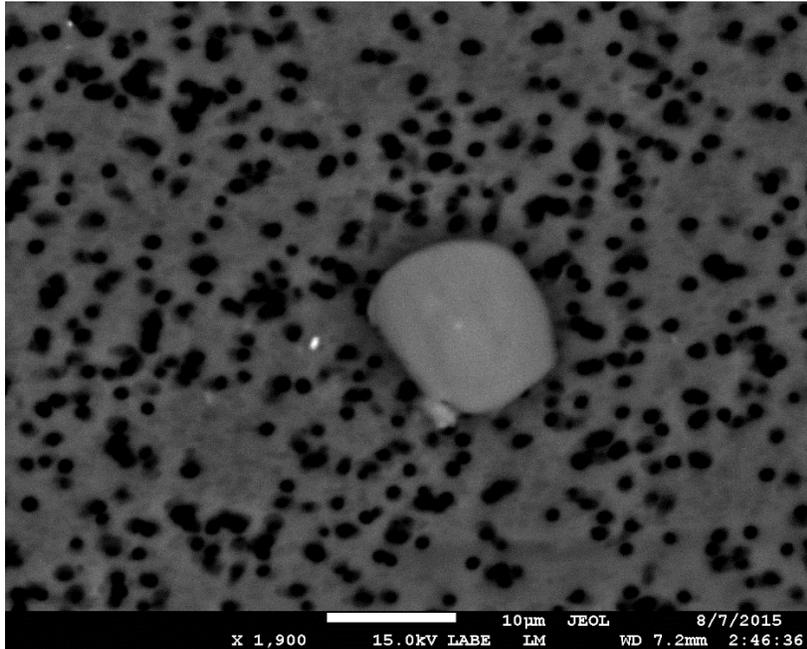


Full scale counts: 2480

A11(1)\_pt2

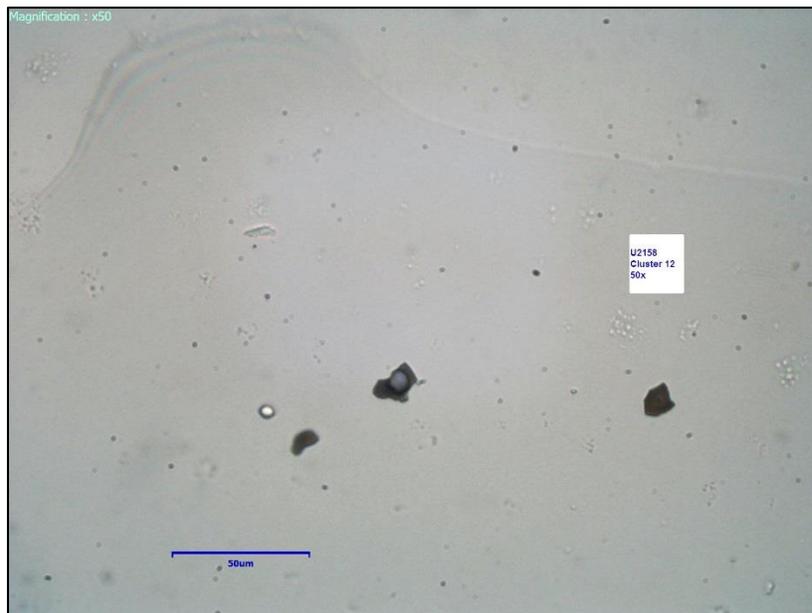


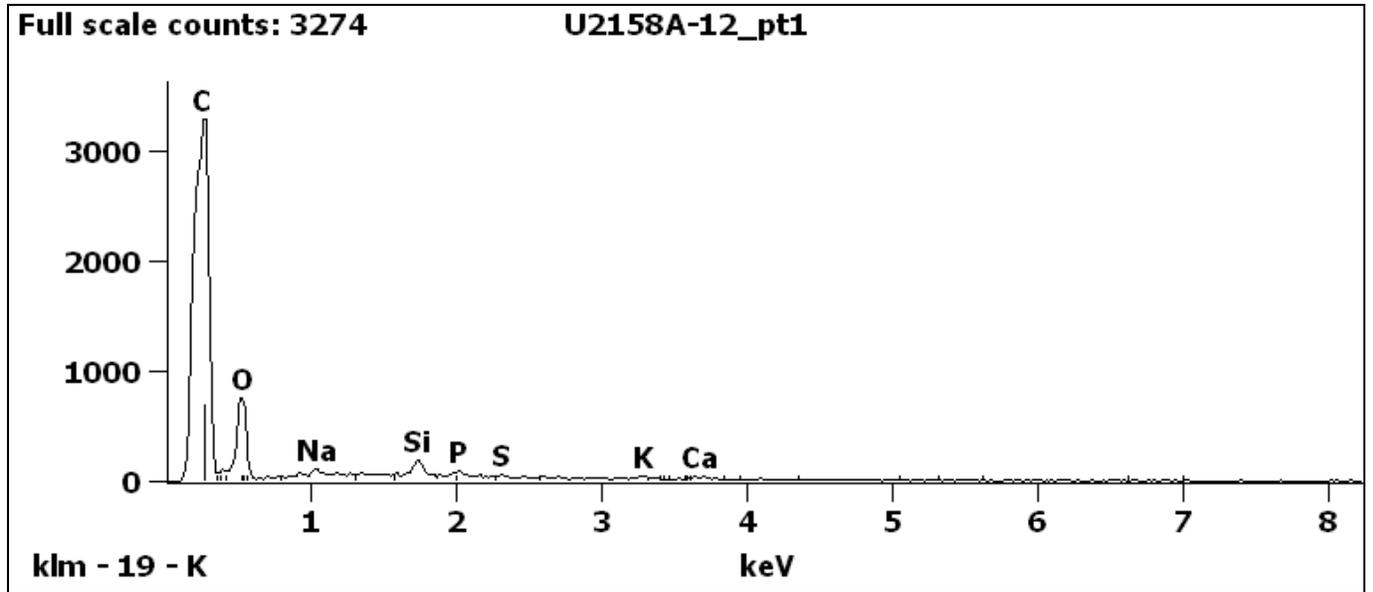
## U2158 A12



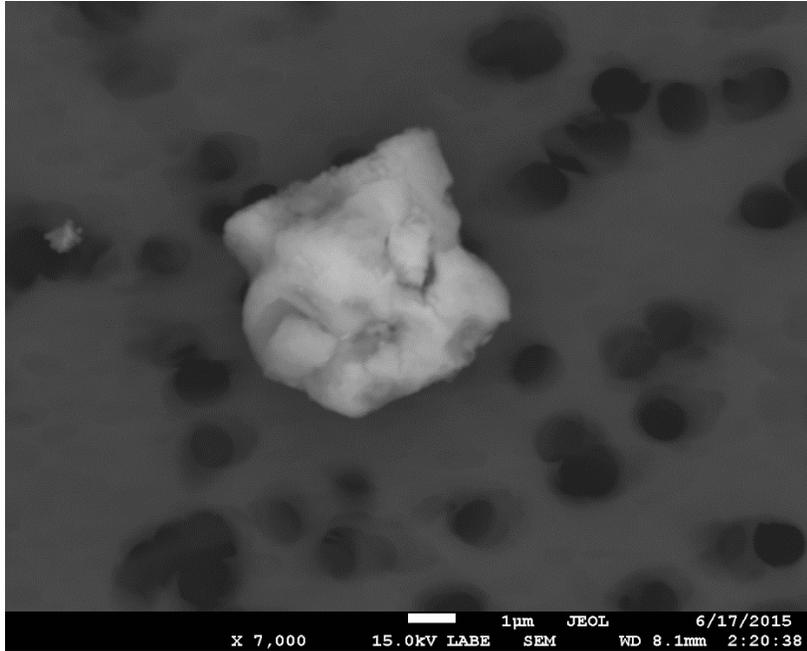
**Particle Size:** 12 µm  
**Shape:** Spherical to Equidimensional  
**Transparency:** Opaque  
**Color:** Brown  
**Luster:** Dull  
**Particle Type:** Possibly Natural Terrestrial Contamination  
**Cluster No.:** 12  
**Comments:**

## Cluster of Origin: U2158 Cluster 12





## U2158 A13



**Particle Size:** 5 µm

**Shape:** Equidimensional

**Transparency:** Translucent to Transparent

**Color:** Clear, Green

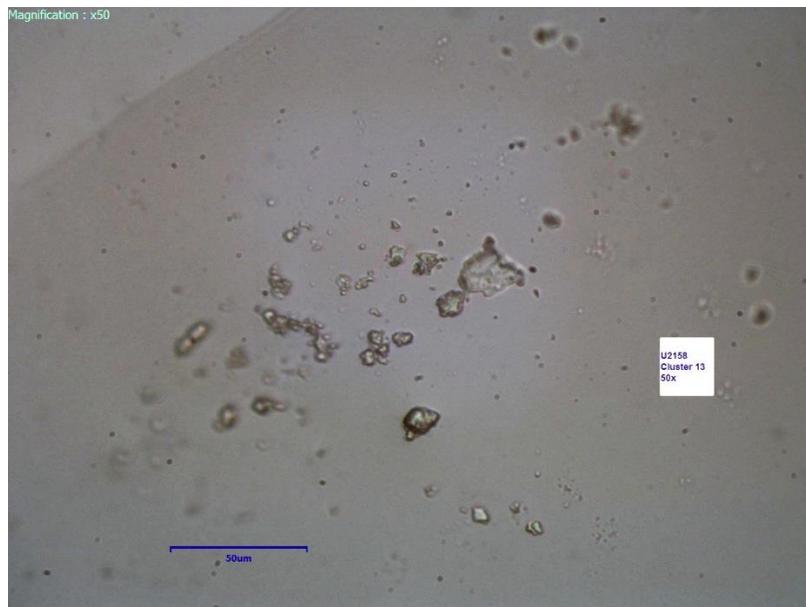
**Luster:** Pearly to Vitreous

**Particle Type:** Possibly Natural Terrestrial Contamination

**Cluster No.:** 13

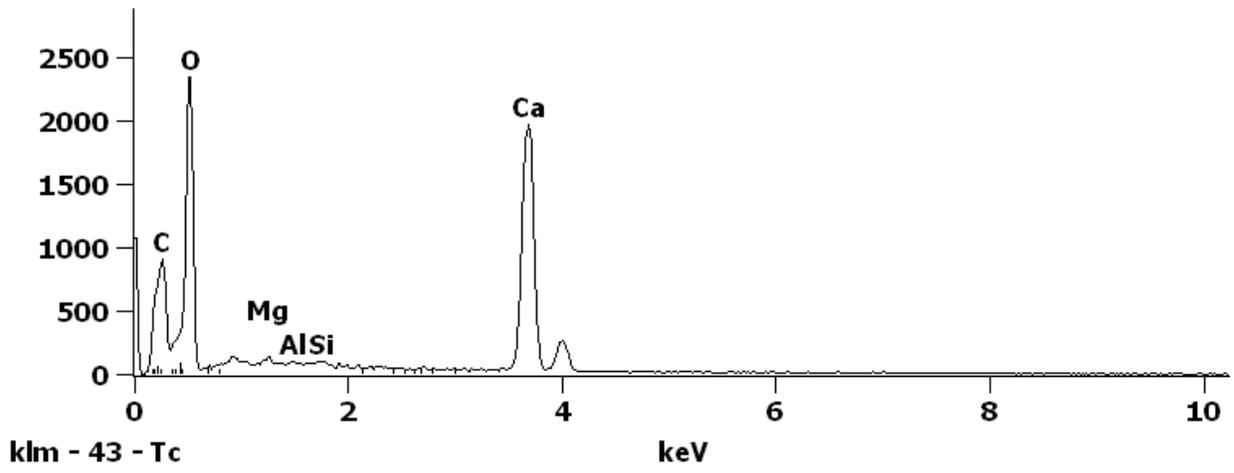
**Comments:**

## Cluster of Origin: U2158 Cluster 13

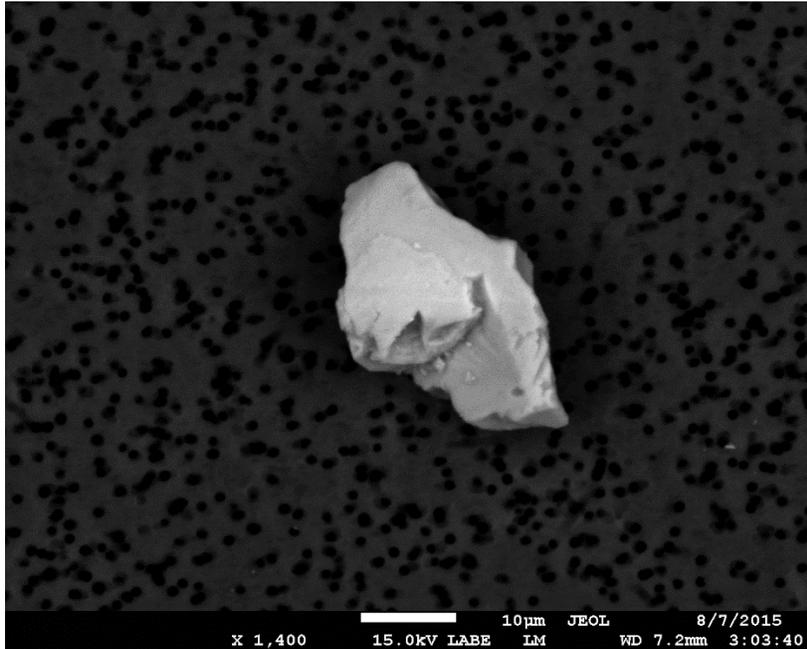


Full scale counts: 2343

A13(1)\_pt1



## U2158 A14



**Particle Size:** 20x40 µm

**Shape:** Irregular to Equidimensional

**Transparency:** Transparent to Translucent

**Color:** Clear

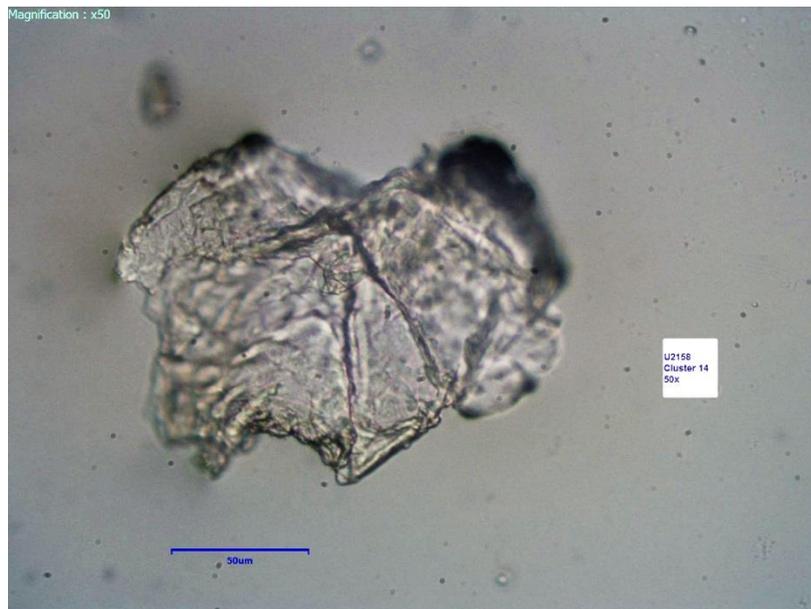
**Luster:** Vitreous

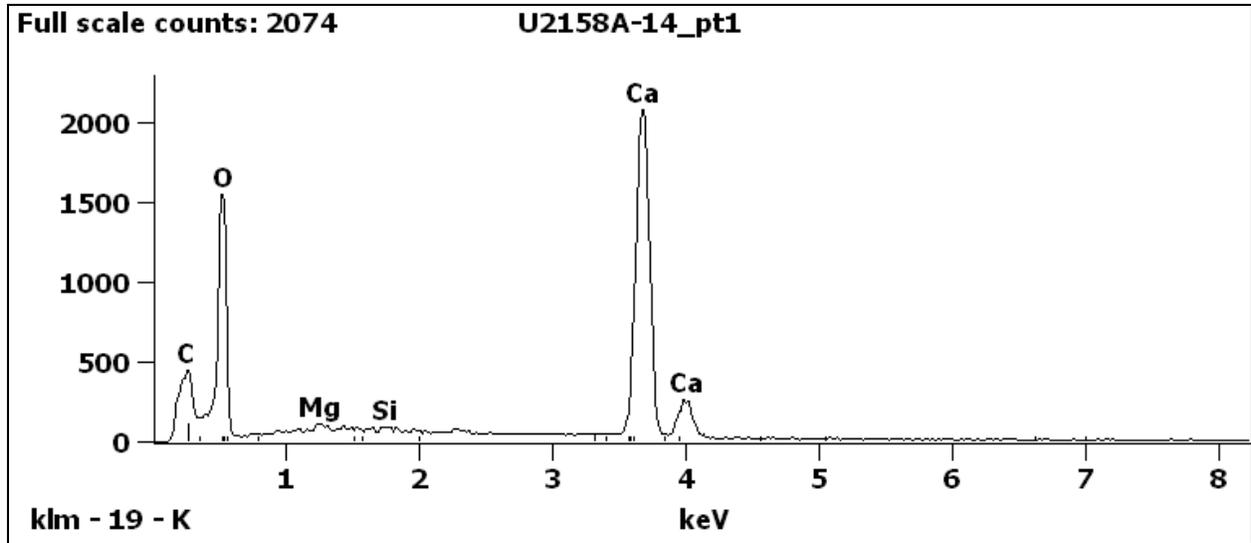
**Particle Type:** Natural Terrestrial Contamination

**Cluster No.:** 14

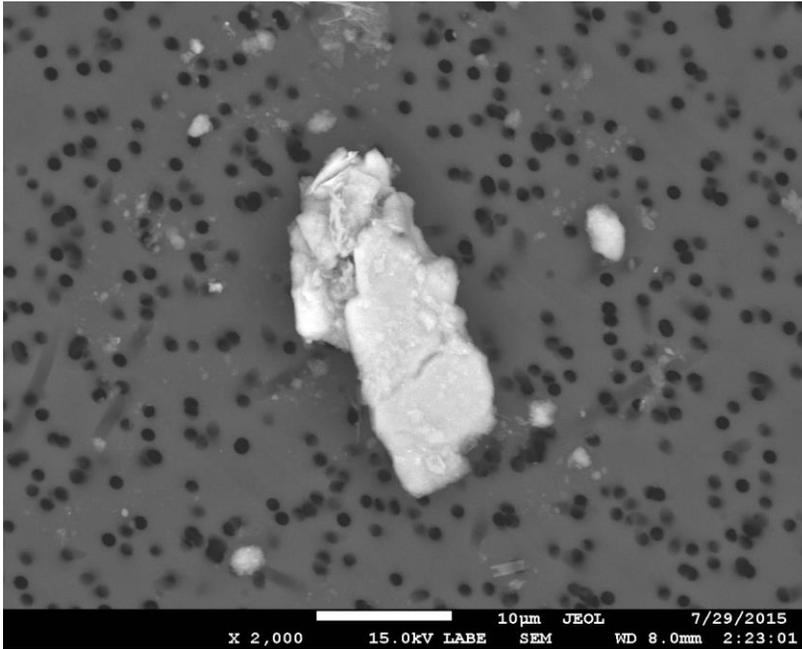
**Comments:**

## Cluster of Origin: U2158 Cluster 14



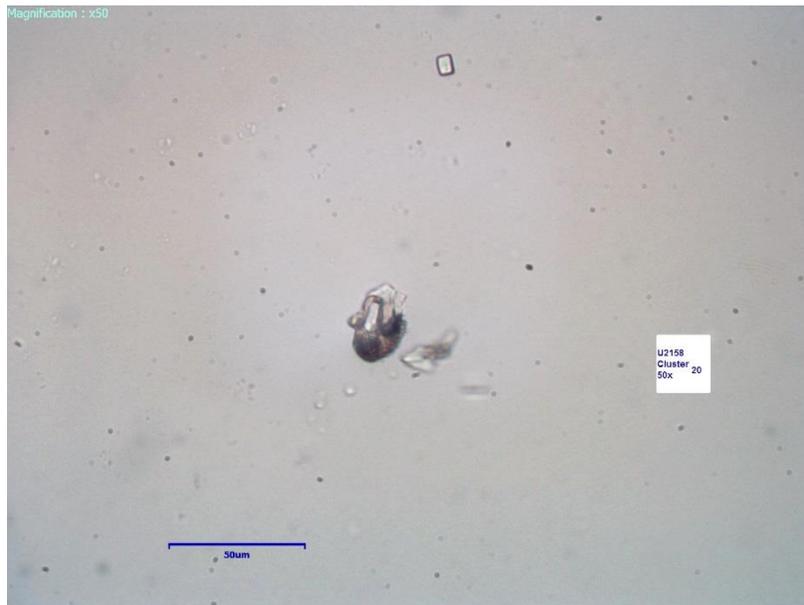


## U2158 B3



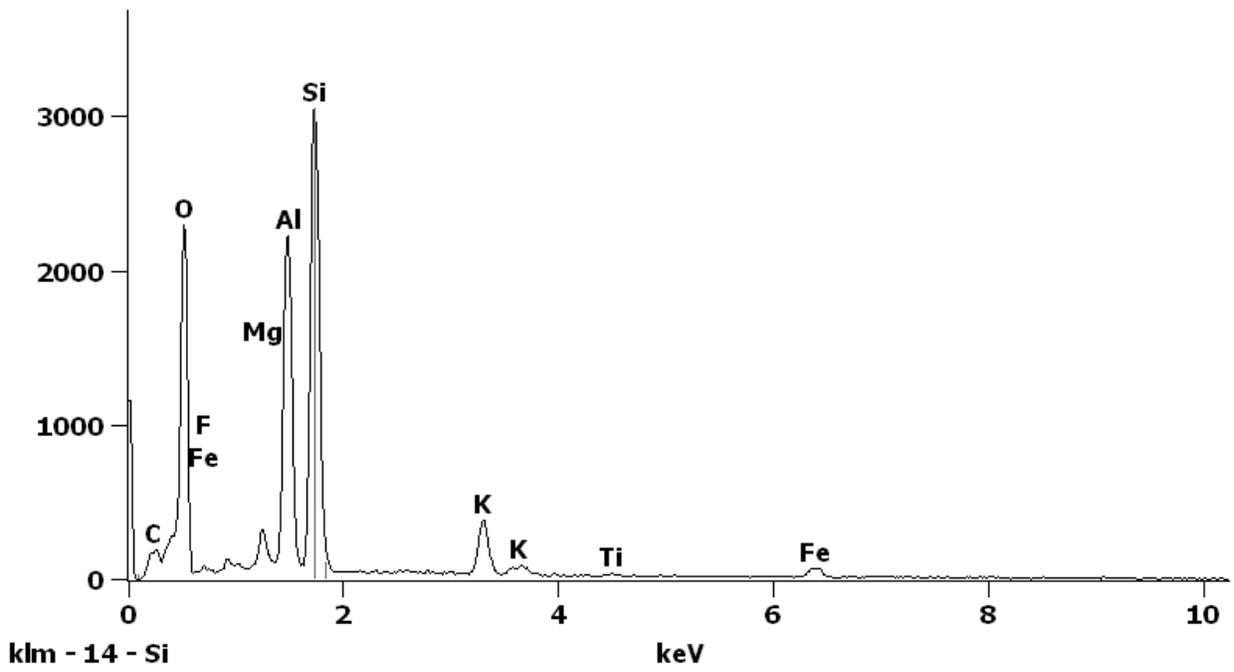
**Particle Size:** 28 μm  
**Shape:** Equidimensional  
**Transparency:** Transparent to Translucent  
**Color:** Black  
**Luster:** Subvitreous  
**Particle Type:** Possibly Natural Terrestrial Contamination  
**Cluster No.:** 20  
**Comments:**

## Cluster of Origin: U2158 Cluster 20

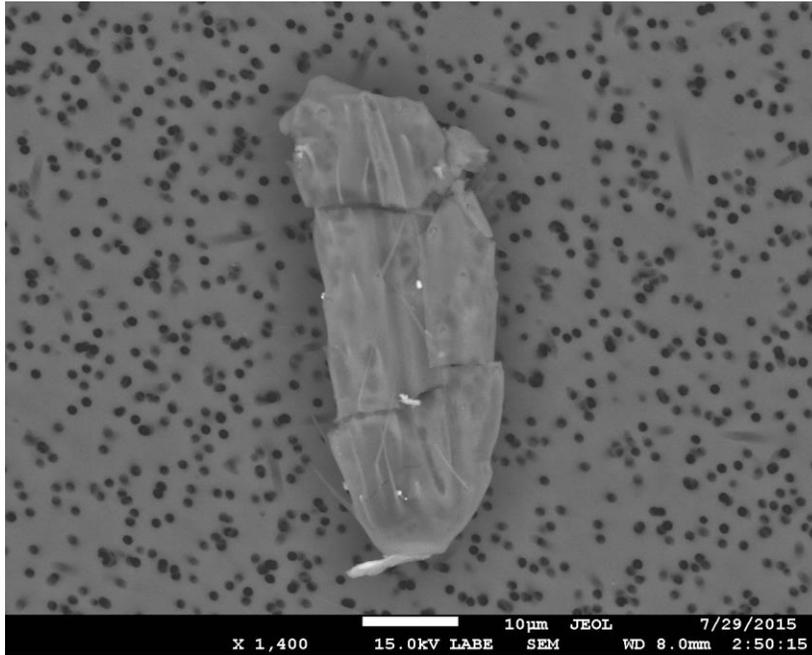


Full scale counts: 3046

U2158B(3)



## U2158 B6



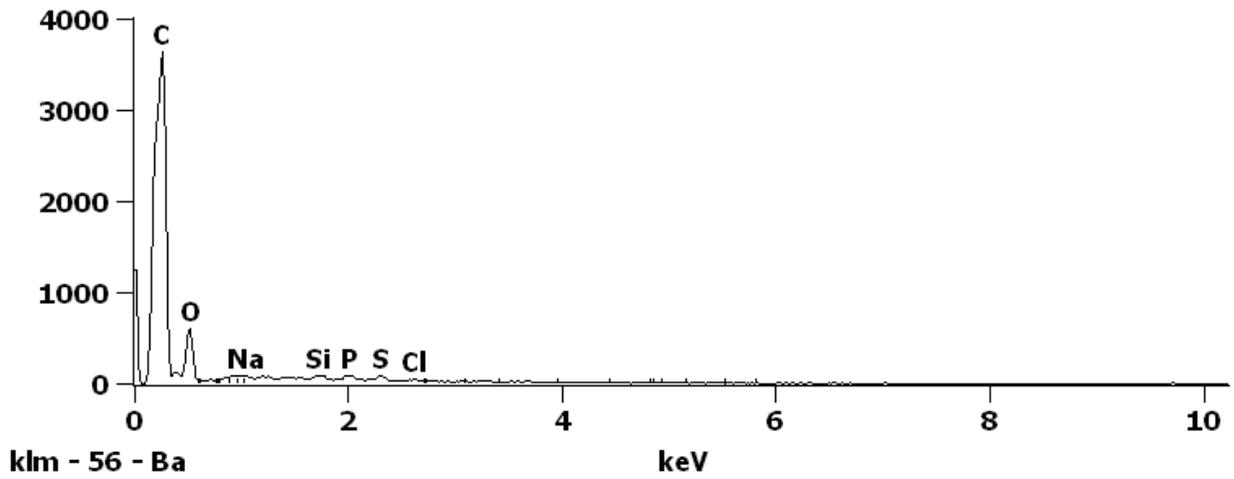
**Particle Size:** 52x14 µm  
**Shape:** Equidimensional to Irregular  
**Transparency:** Translucent  
**Color:** Brown, Clear  
**Luster:** Subvitreous  
**Particle Type:** Possibly Natural Terrestrial Contamination  
**Cluster No.:** 23  
**Comments:**

## Cluster of Origin: U2158 Cluster 23



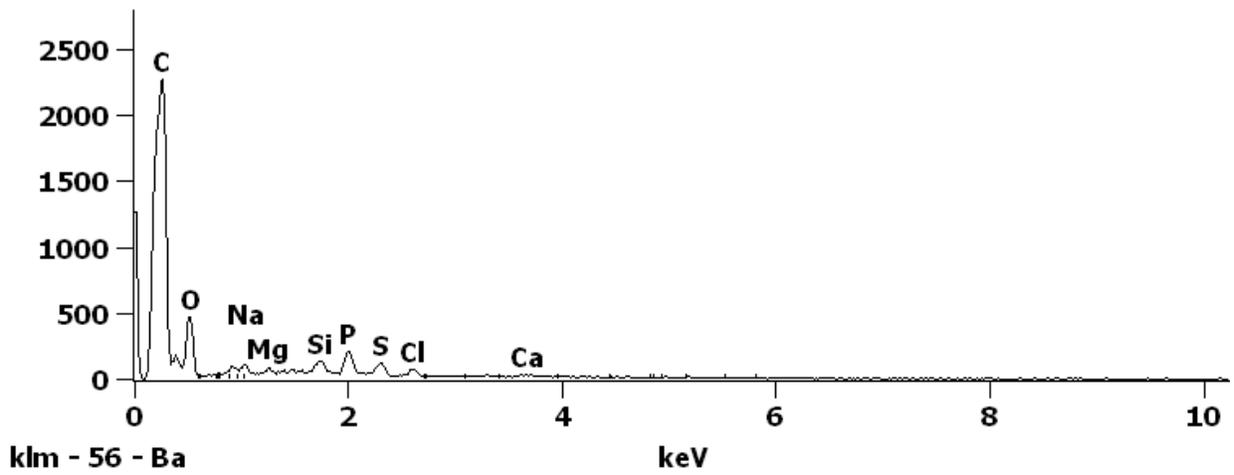
Full scale counts: 3633

U2158B(6)\_pt1

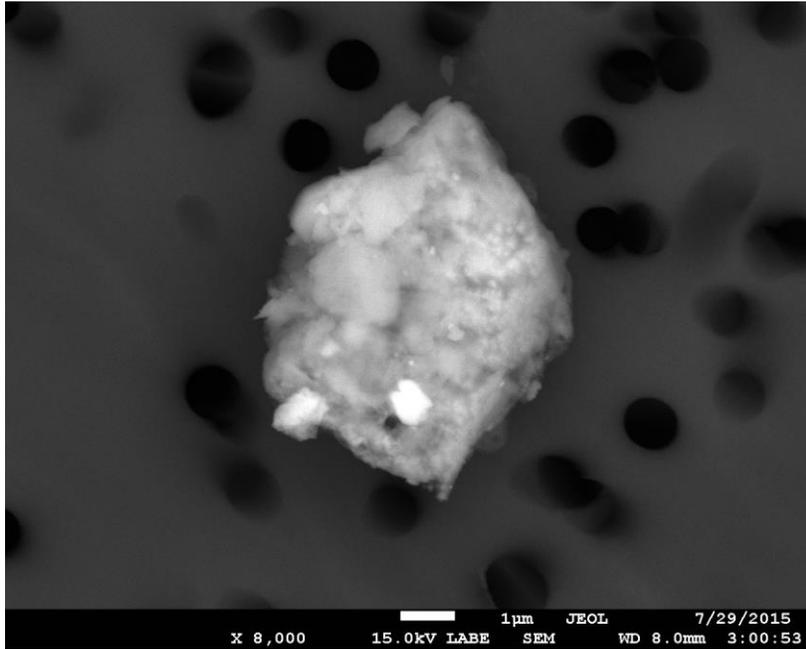


Full scale counts: 2269

U2158B(6)\_pt2

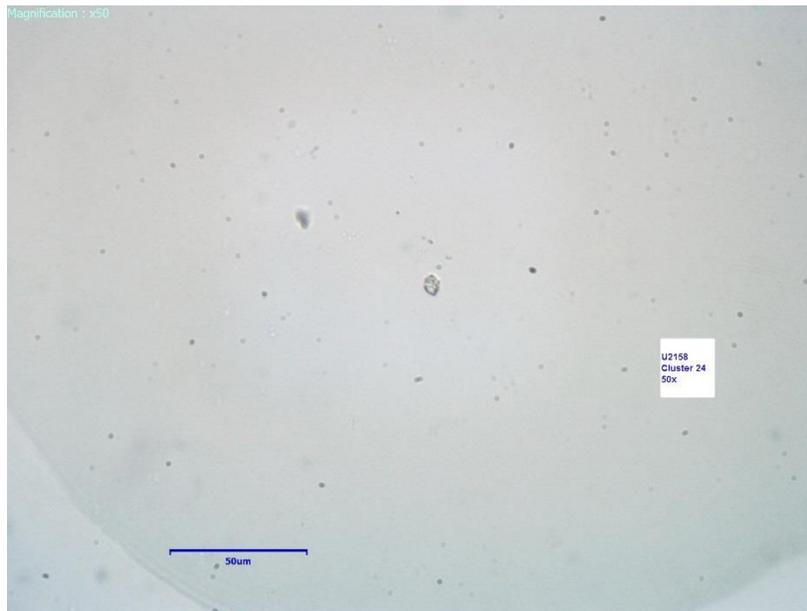


## U2158 B7



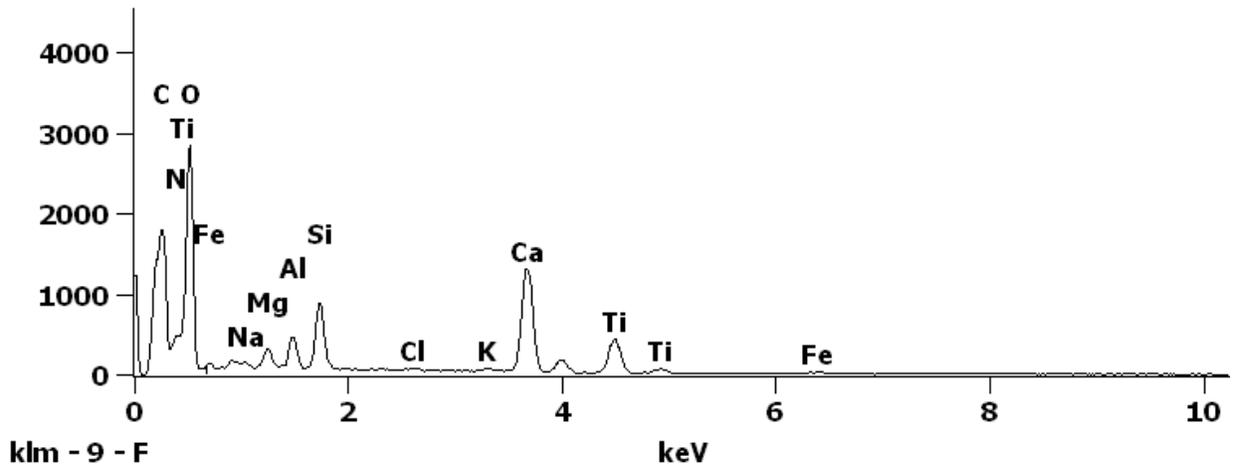
**Particle Size:** 7 µm  
**Shape:** Equidimensional  
**Transparency:** Translucent  
**Color:** Clear  
**Luster:** Vitreous to Pearly  
**Particle Type:** Possibly Natural  
Terrestrial  
Contamination  
**Cluster No.:** 24  
**Comments:**

## Cluster of Origin: U2158 Cluster 24



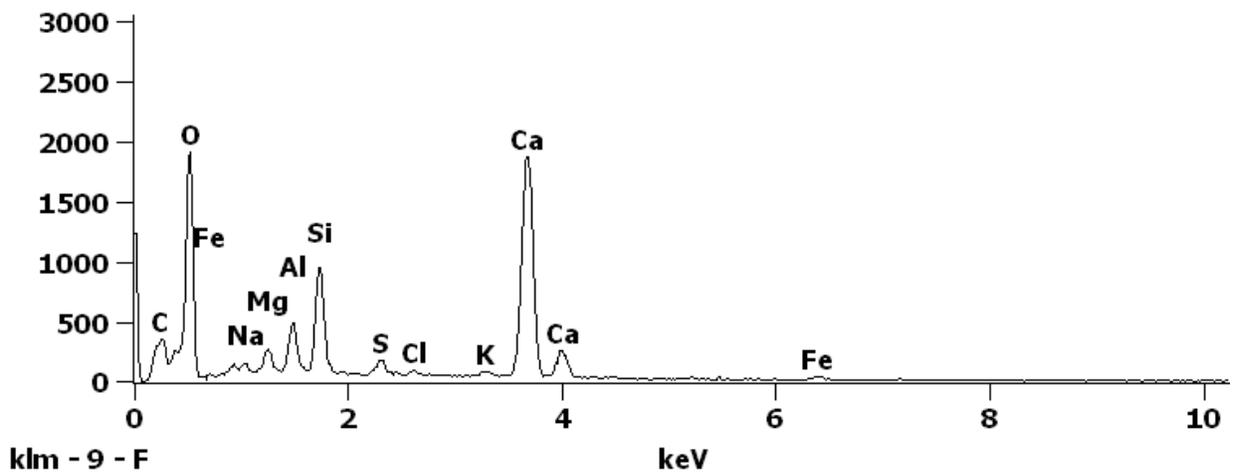
Full scale counts: 2843

U2158B(7)\_pt1



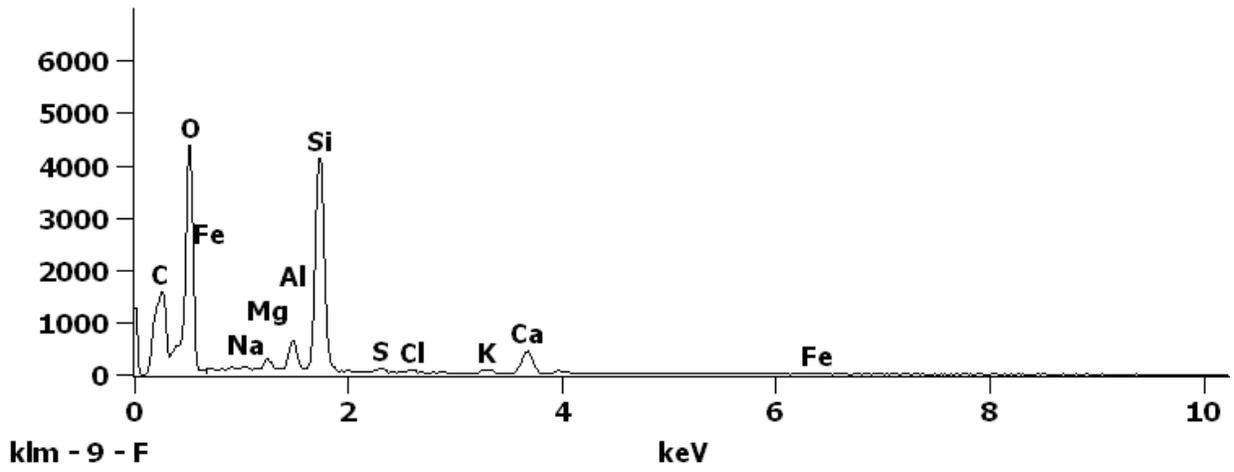
Full scale counts: 1907

U2158B(7)\_pt2

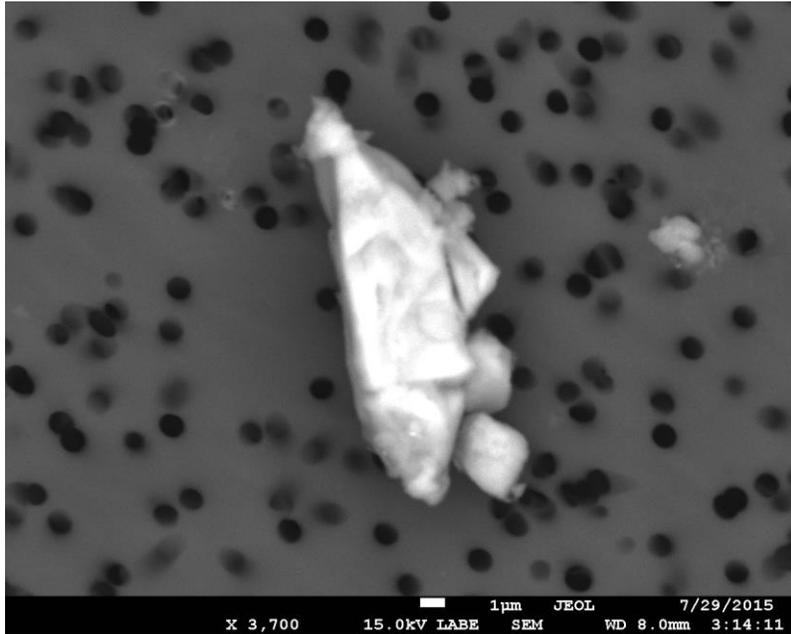


Full scale counts: 4378

U2158B(7)\_pt3

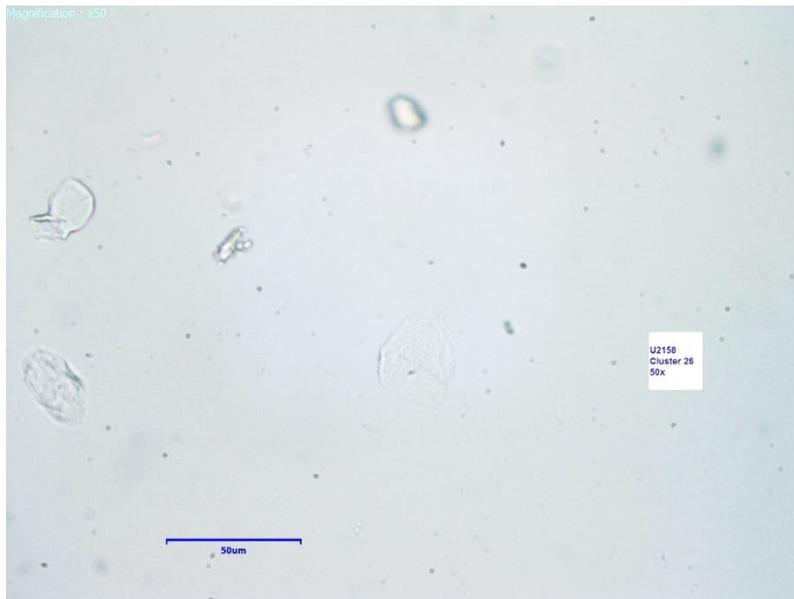


## U2158 B9



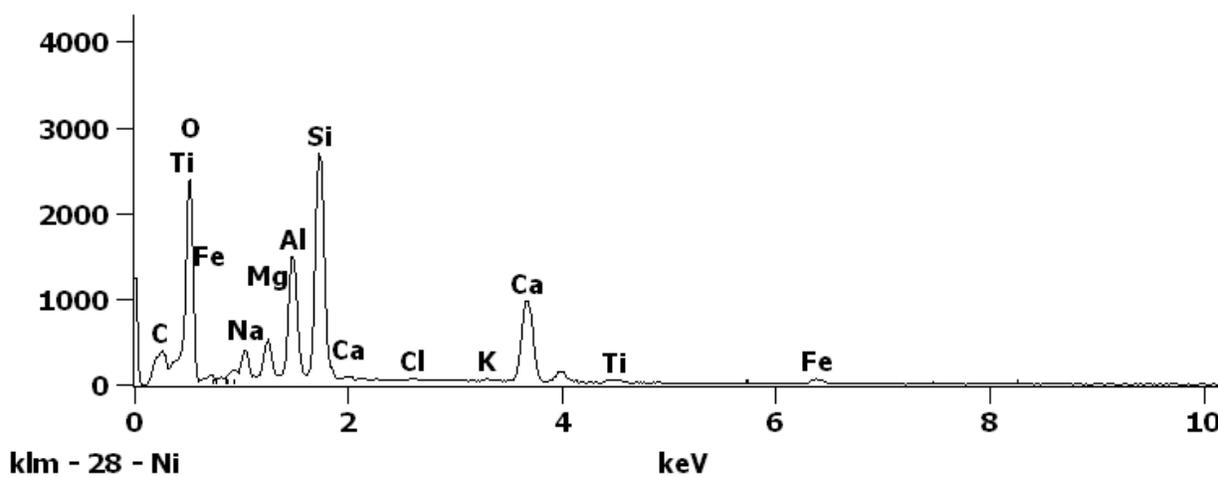
**Particle Size:** 10x5 µm  
**Shape:** Irregular  
**Transparency:** Transparent  
**Color:** Clear  
**Luster:** Vitreous  
**Particle Type:** Natural Terrestrial Contamination  
**Cluster No.:** 26  
**Comments:**

## Cluster of Origin: U2158 Cluster 26

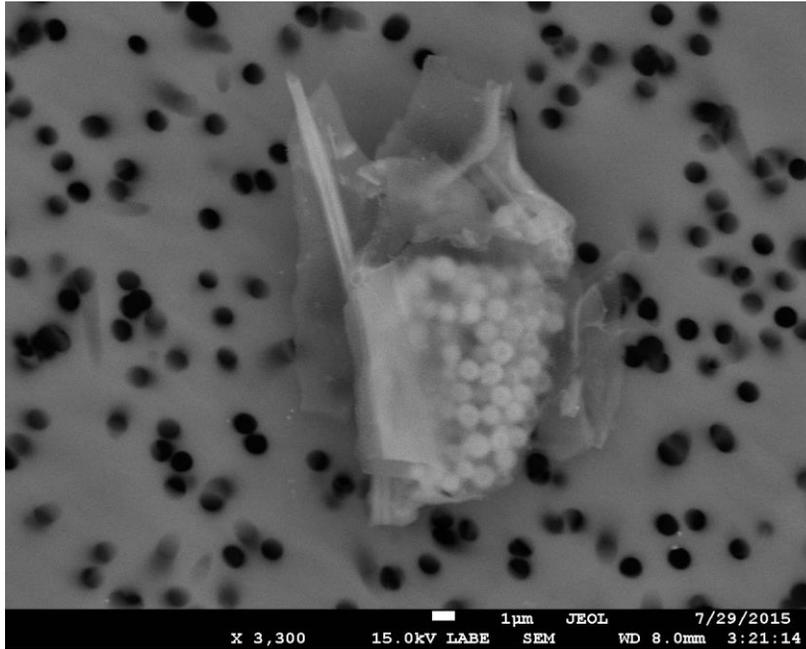


Full scale counts: 2699

U2158B(9)\_pt1

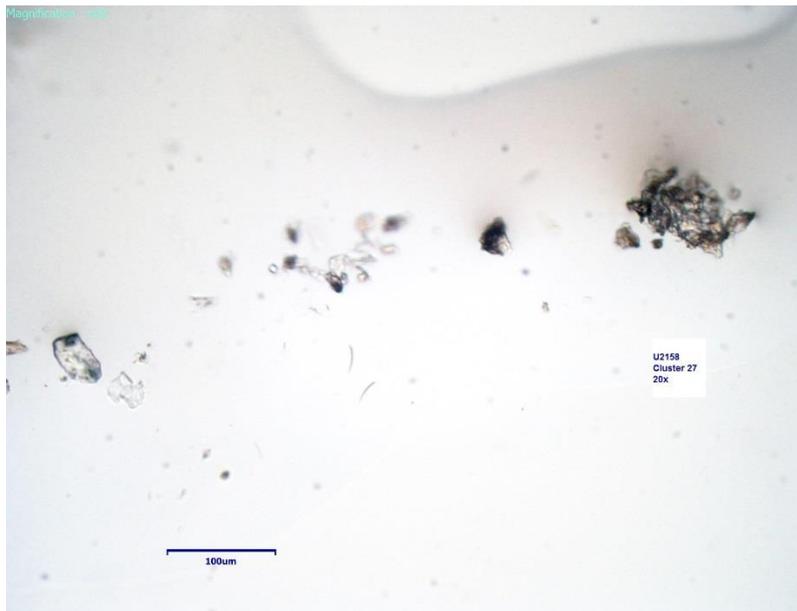


## U2158 B10



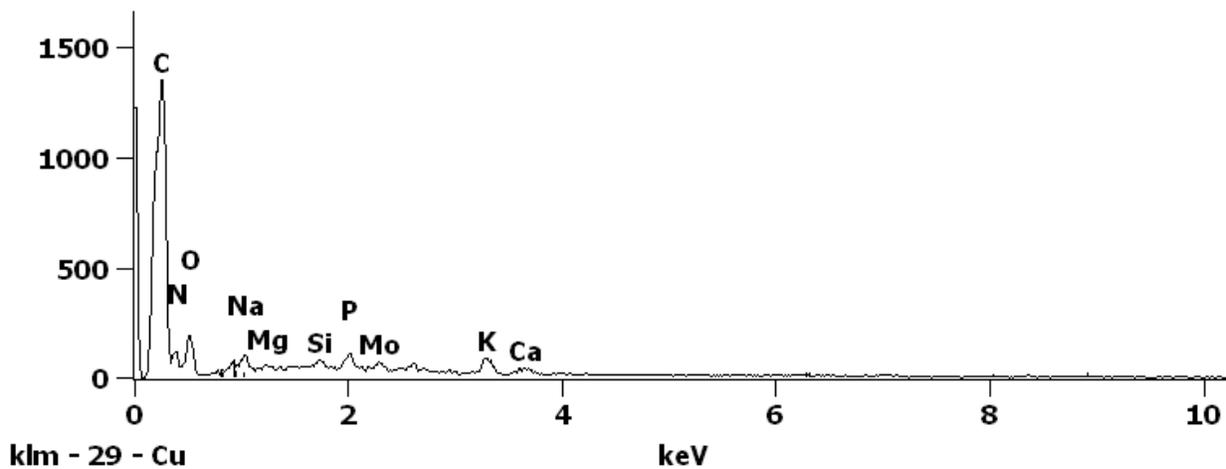
**Particle Size:** 15 µm  
**Shape:** Irregular  
**Transparency:** Transparent to Opaque  
**Color:** Clear, Black, Brown  
**Luster:** Vitreous  
**Particle Type:** Natural Terrestrial Contamination  
**Cluster No.:** 27  
**Comments:**

## Cluster of Origin: U2158 Cluster 27



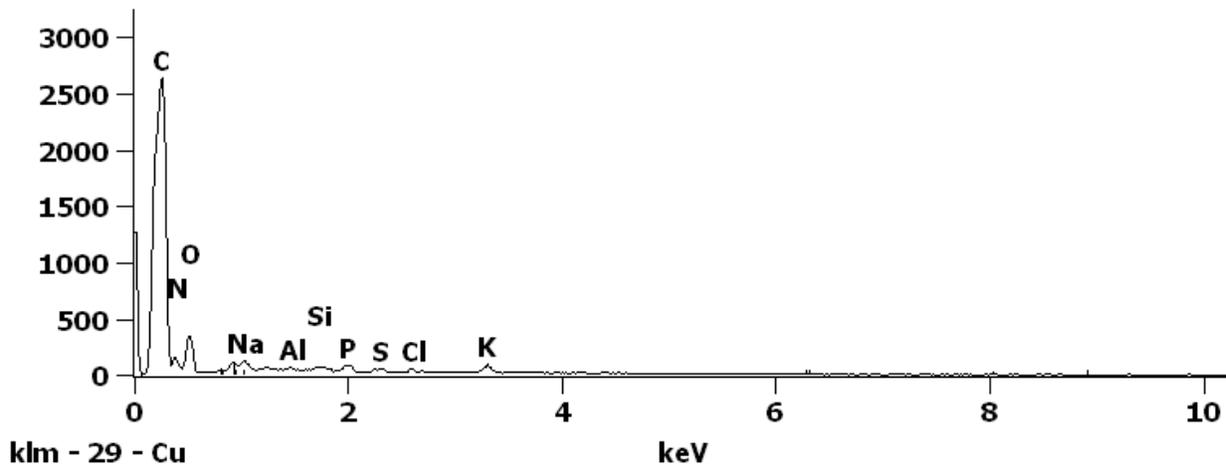
Full scale counts: 1349

U2158B(10)\_pt1

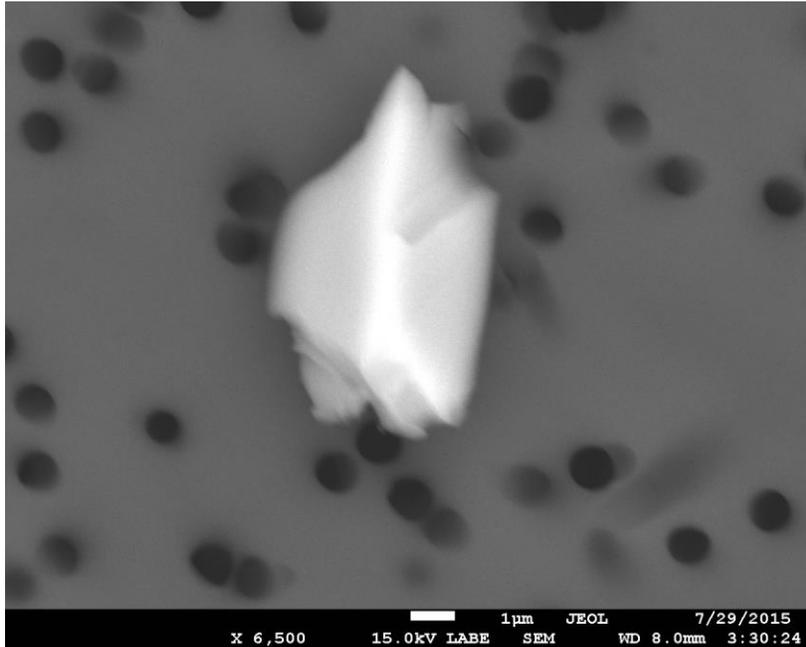


Full scale counts: 2636

U2158B(10)\_pt2



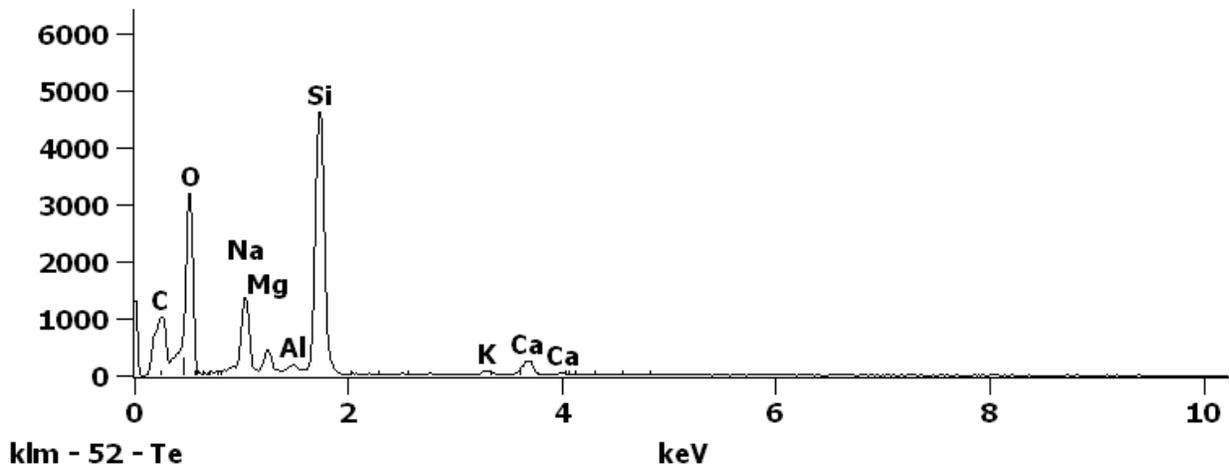
## U2158 B11



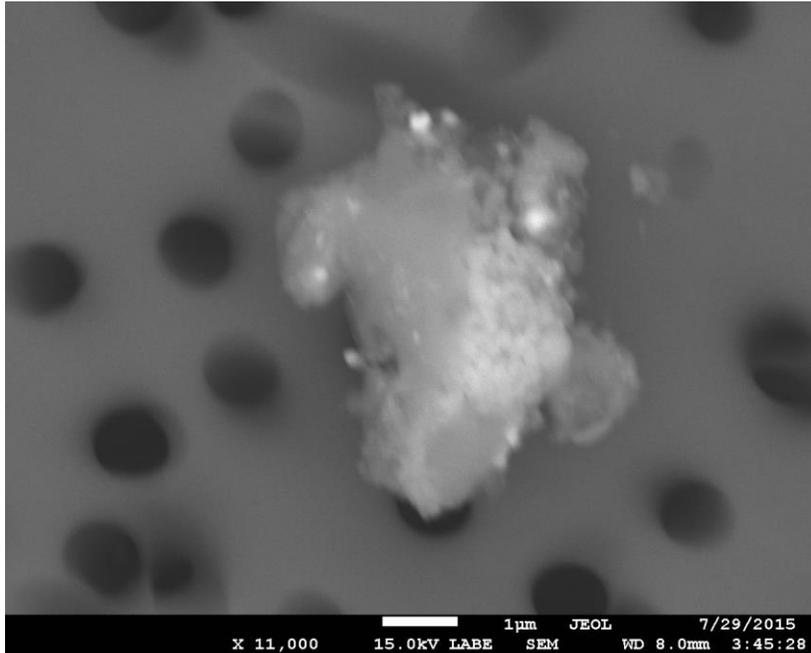
**Particle Size:** 4x6 µm  
**Shape:** Equidimensional  
**Transparency:** Opaque  
**Color:** White, Gray, Black, Brown  
**Luster:** Resinous to Dull  
**Particle Type:** Possibly Natural Terrestrial Contamination  
**Cluster No.:** 28  
**Comments:**

Full scale counts: 4618

U2158B(11)\_pt1



## U2158 B12



**Particle Size:** 4x7 µm

**Shape:** Irregular to Equidimensional

**Transparency:** Transparent to Opaque

**Color:** Clear, Brown

**Luster:** Subvitreous

**Particle Type:** Possibly Natural Terrestrial Contamination

**Cluster No.:** 29

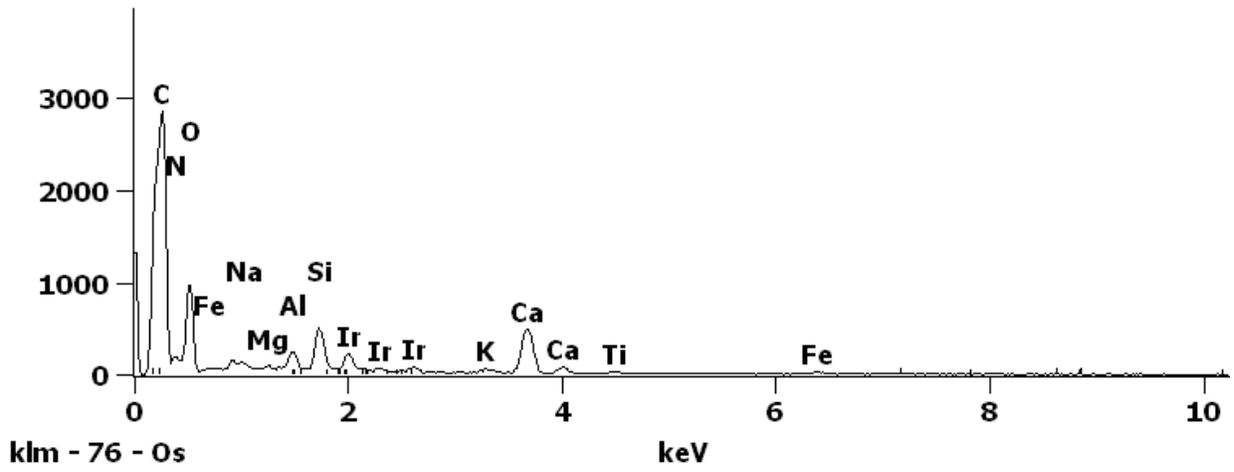
**Comments:** Probably not Ir

## Cluster of Origin: U2158 Cluster 29

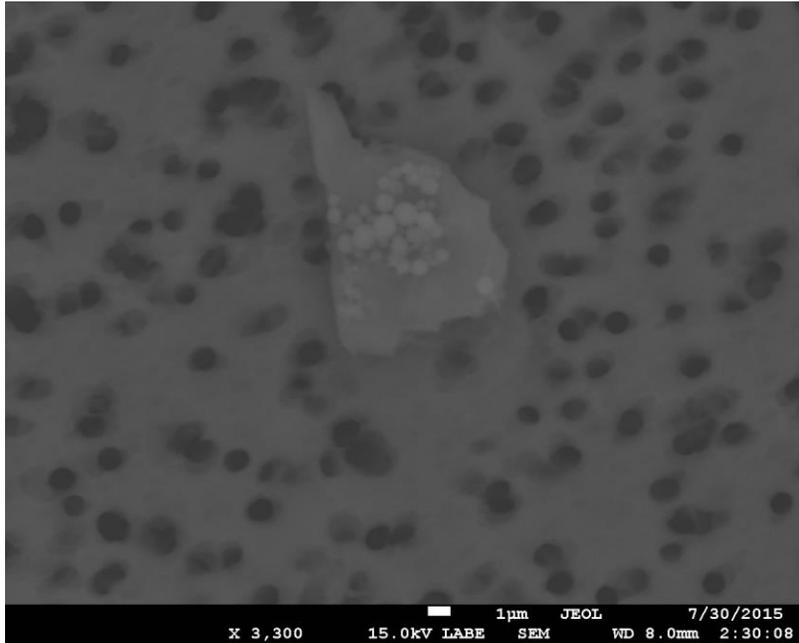


Full scale counts: 2855

U2158B(12)\_pt1

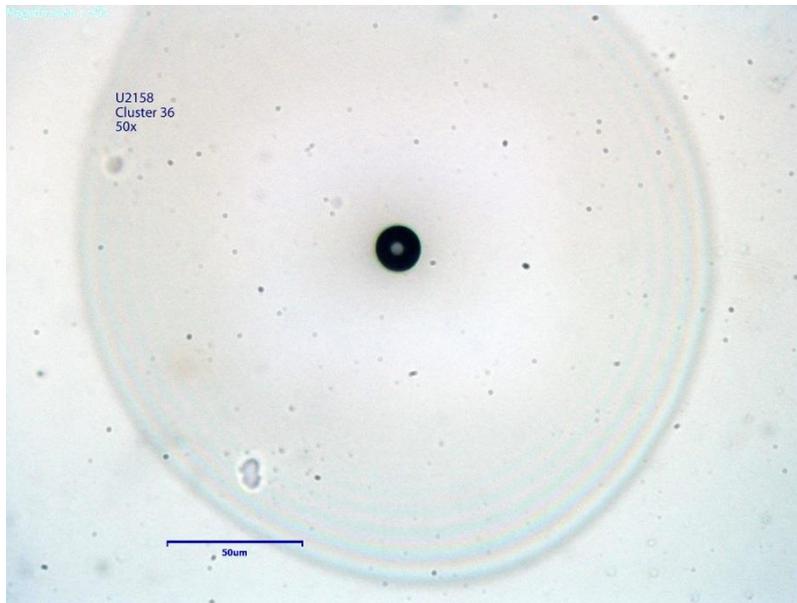


## U2158 C2



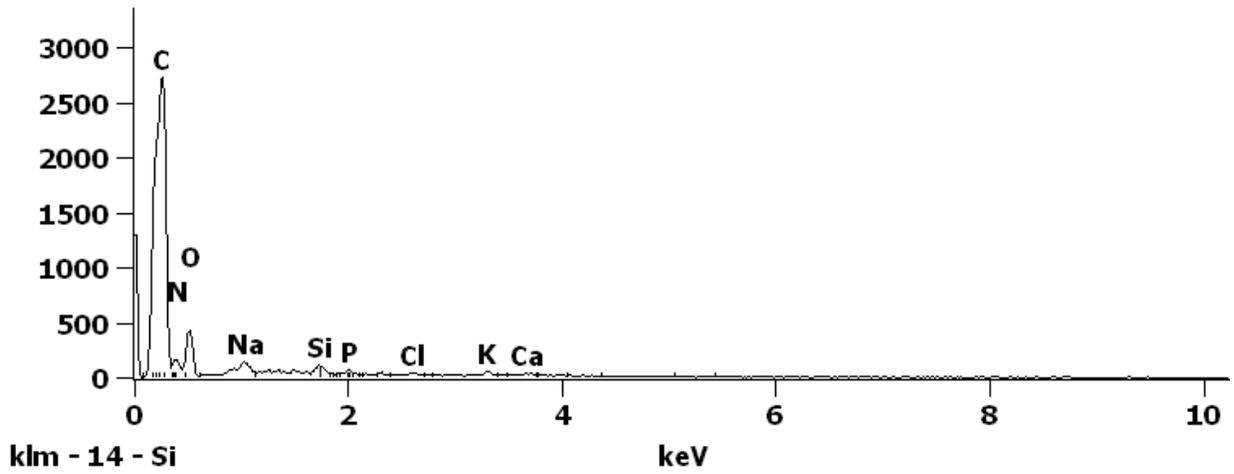
**Particle Size:** 10 µm  
**Shape:** Spherical  
**Transparency:** Opaque  
**Color:** Brown  
**Luster:** Pearly  
**Particle Type:** Natural Terrestrial Contamination  
**Cluster No.:** 36  
**Comments:**

## Cluster of Origin: U2158 Cluster 36



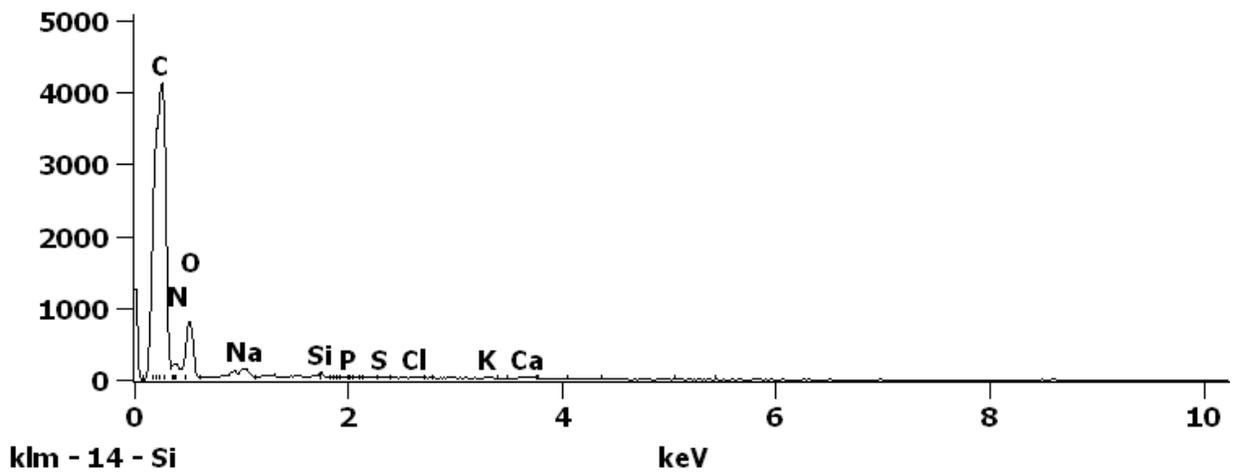
Full scale counts: 2726

U2158C(2)\_pt1

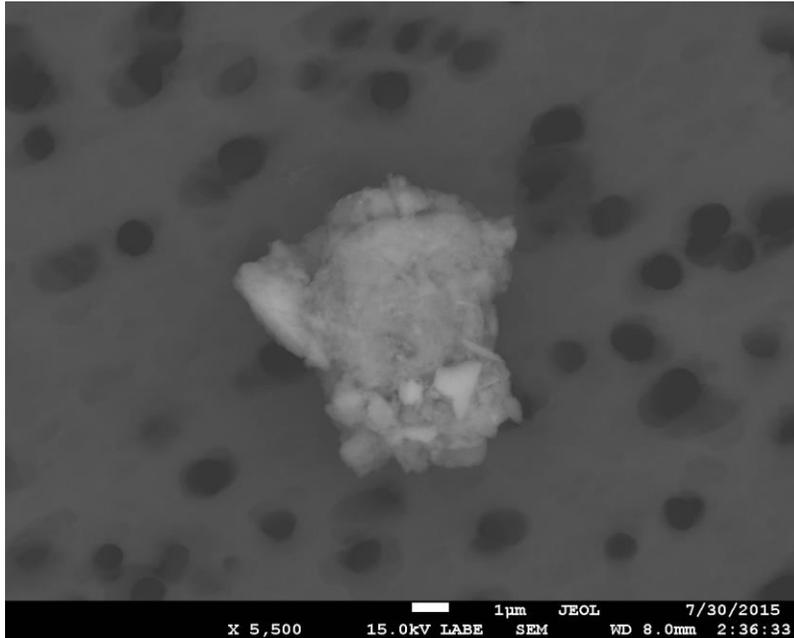


Full scale counts: 4124

U2158C(2)\_pt2



## U2158 C3



**Particle Size:** 10 µm

**Shape:** Spherical to Equidimensional

**Transparency:** Translucent to Opaque

**Color:** Brown, Red

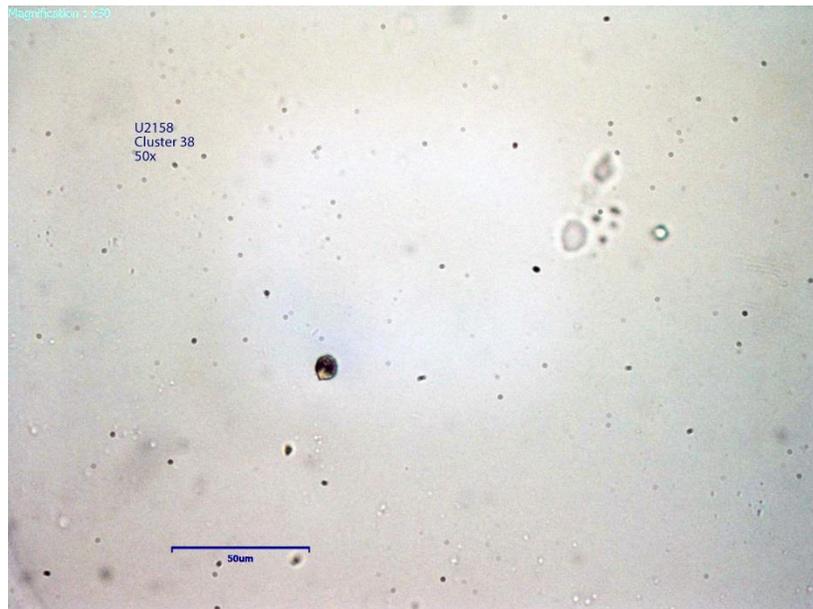
**Luster:** Subvitreous to Vitreous

**Particle Type:** Possibly Natural Terrestrial Contamination

**Cluster No.:** 38

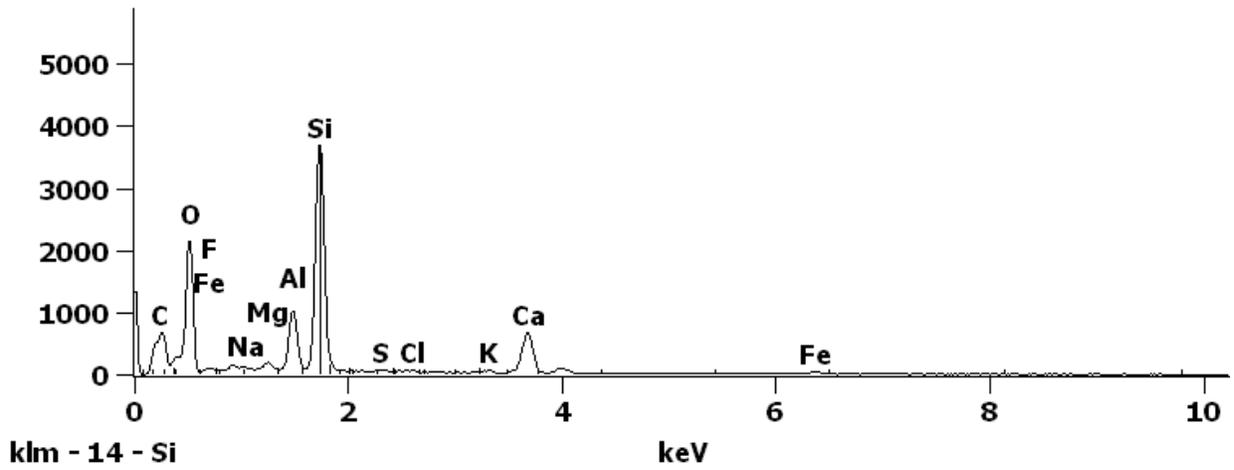
**Comments:**

## Cluster of Origin: U2158 Cluster 38



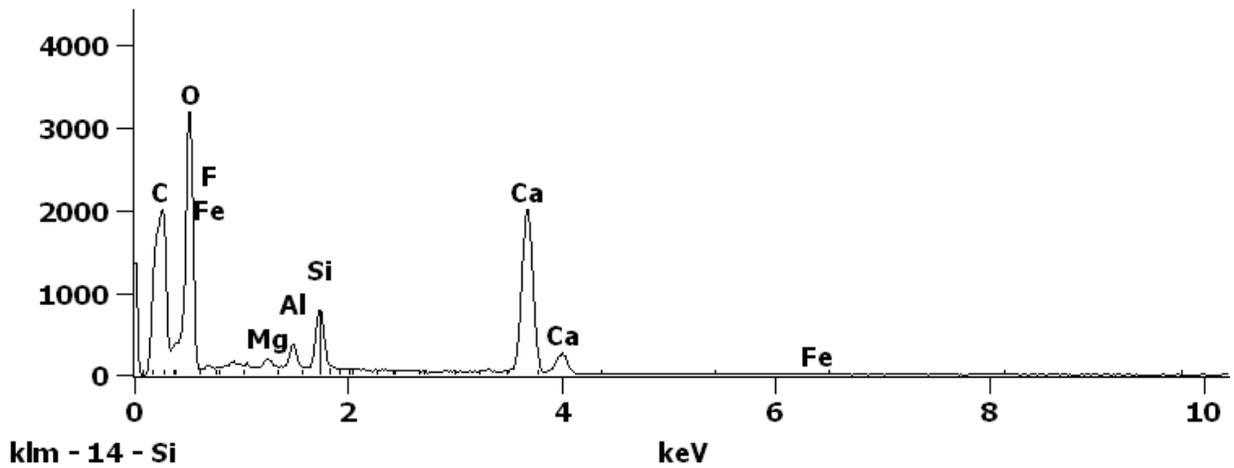
Full scale counts: 3682

U2158C(3)\_pt1

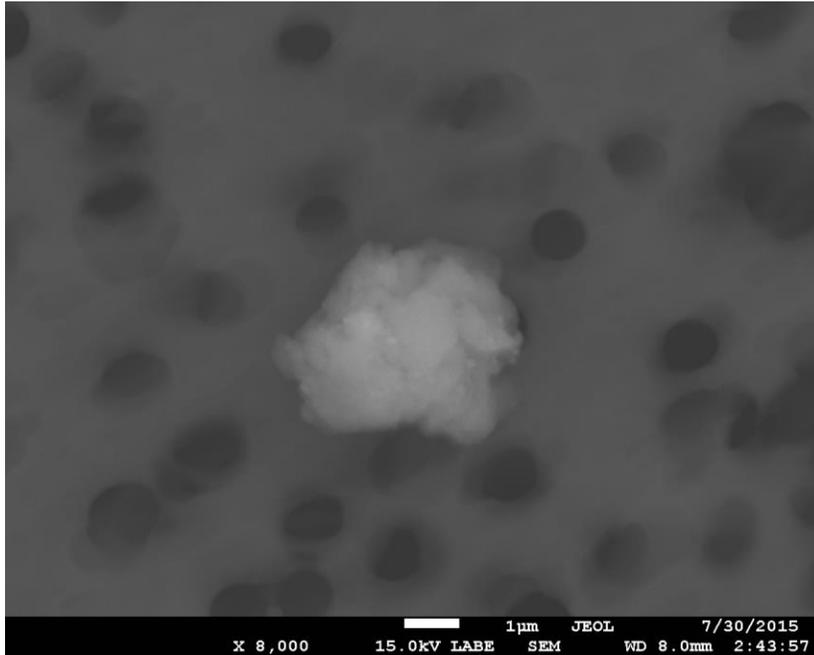


Full scale counts: 3190

U2158C(3)\_pt2

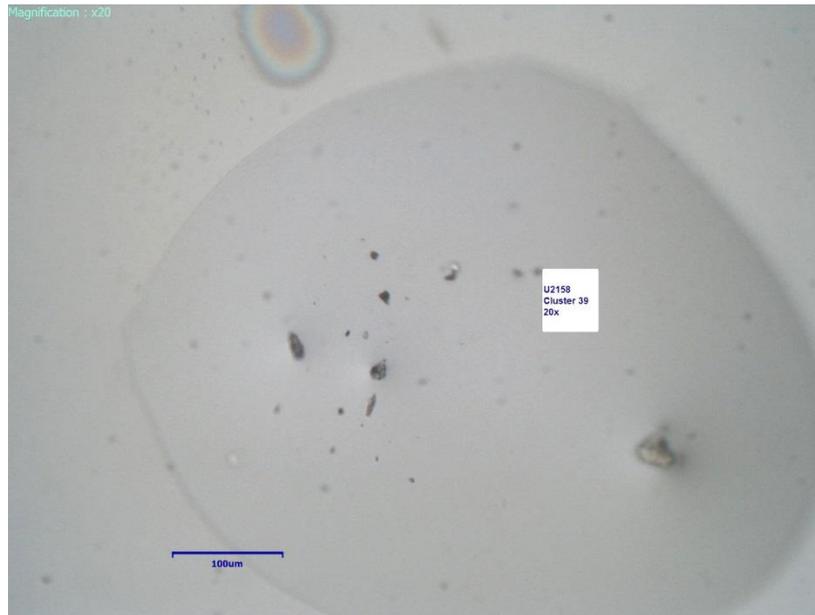


## U2158 C4



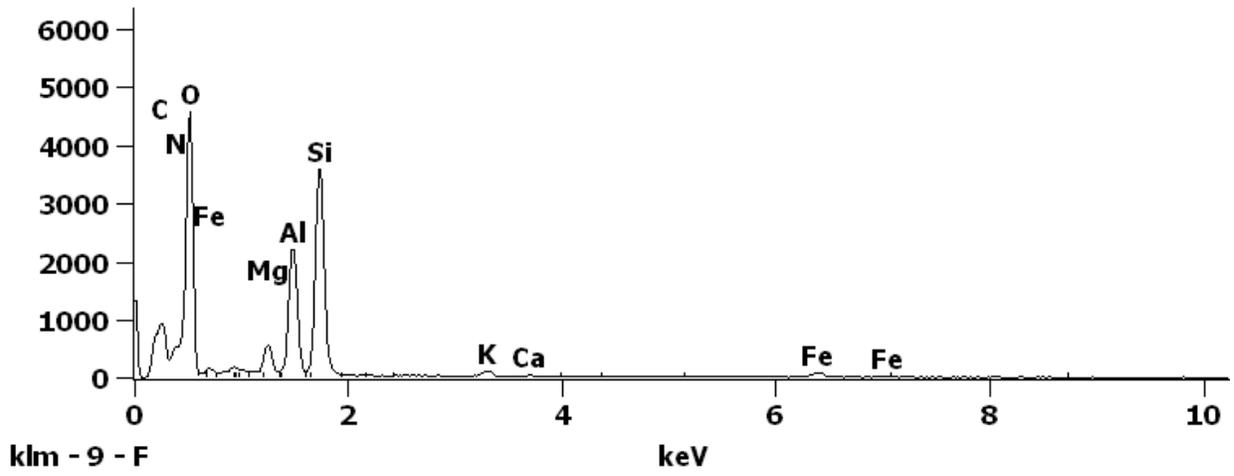
**Particle Size:** 11 µm  
**Shape:** Irregular to Equidimensional  
**Transparency:** Transparent to Translucent  
**Color:** Brown, Clear  
**Luster:** Vitreous  
**Particle Type:** Possibly Natural Terrestrial Contamination  
**Cluster No.:** 39  
**Comments:**

## Cluster of Origin: U2158 Cluster 39

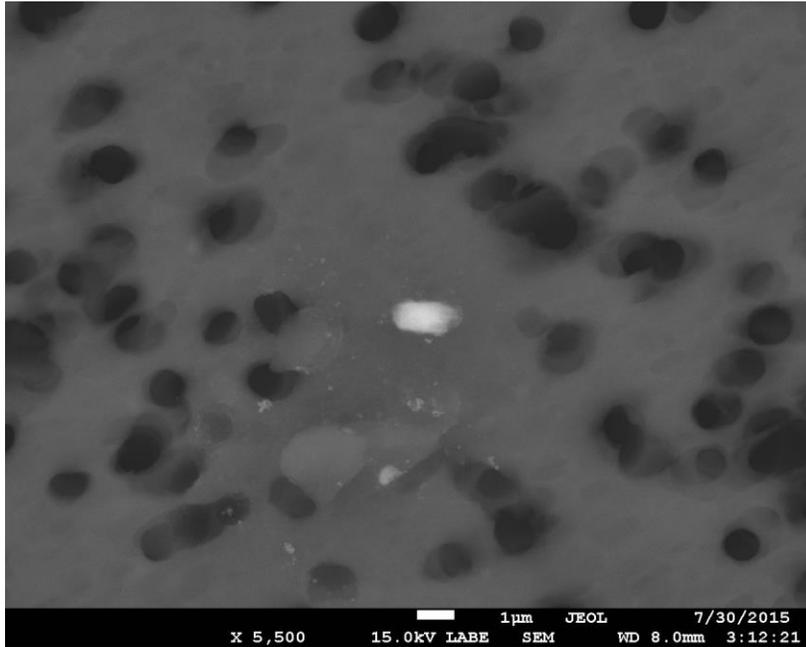


Full scale counts: 4573

U2158C(4)\_pt1

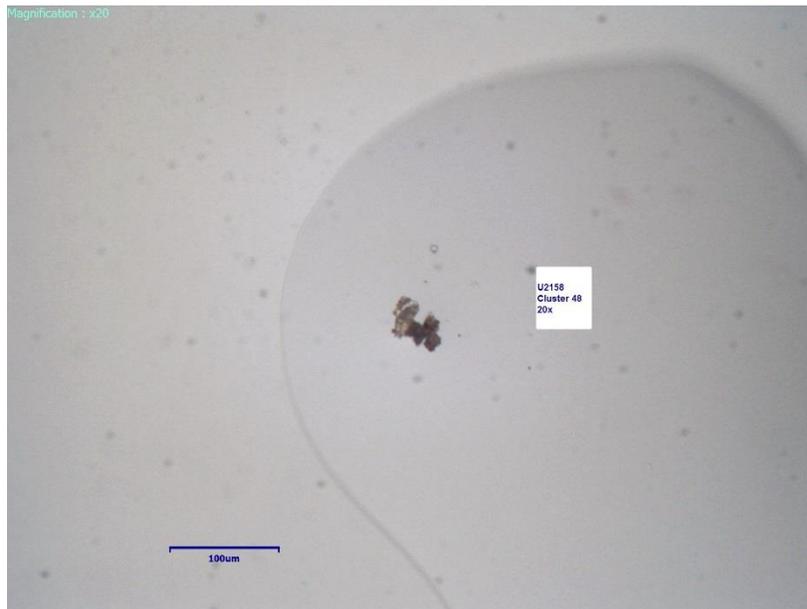


## U2158 C8



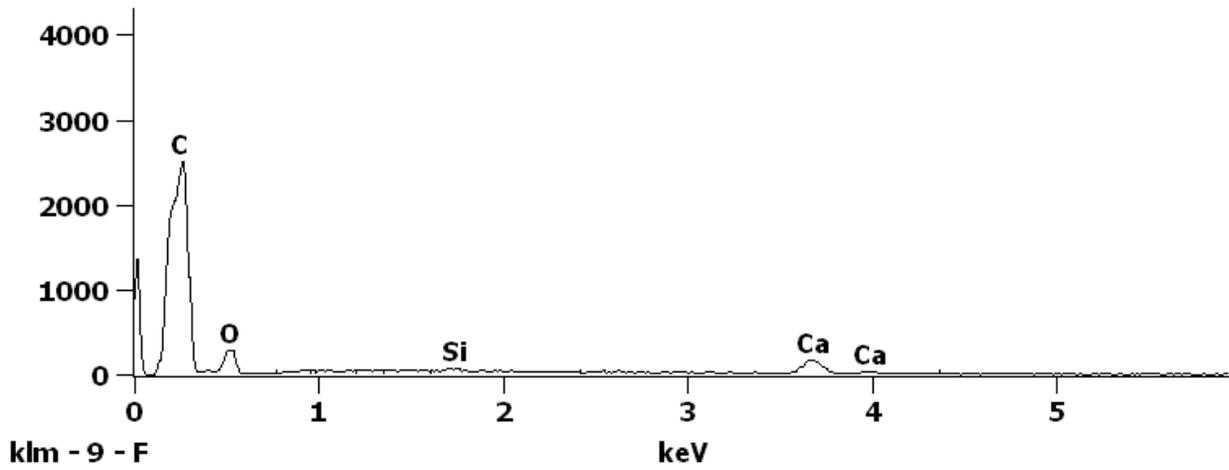
**Particle Size:** 12 μm  
**Shape:** Equidimensional  
**Transparency:** Translucent  
**Color:** Yellow  
**Luster:** Subvitreous  
**Particle Type:** Possibly Natural  
Terrestrial  
Contamination  
**Cluster No.:** 43  
**Comments:**

## Cluster of Origin: U2158 Cluster 43



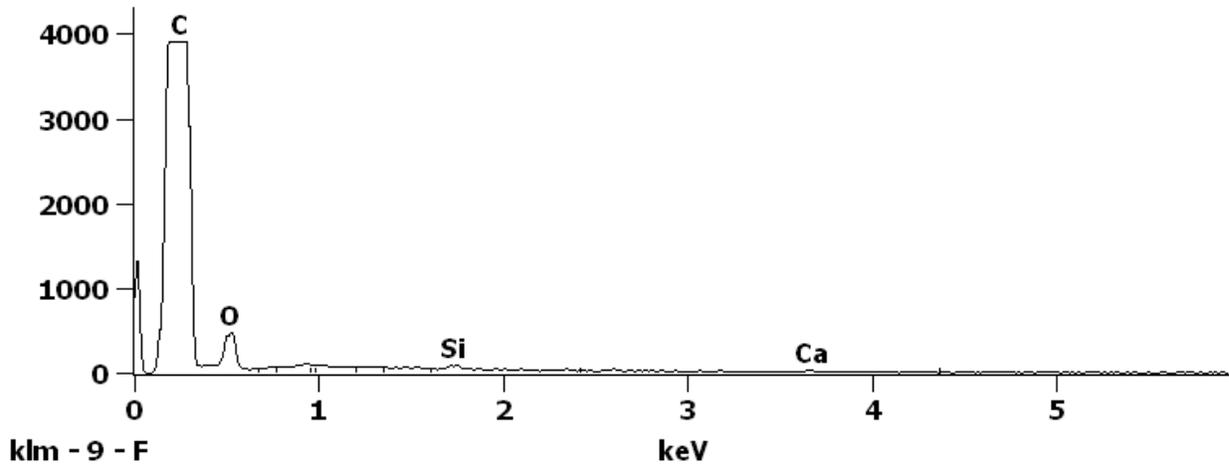
Full scale counts: 3901

U2158C(8)\_pt1

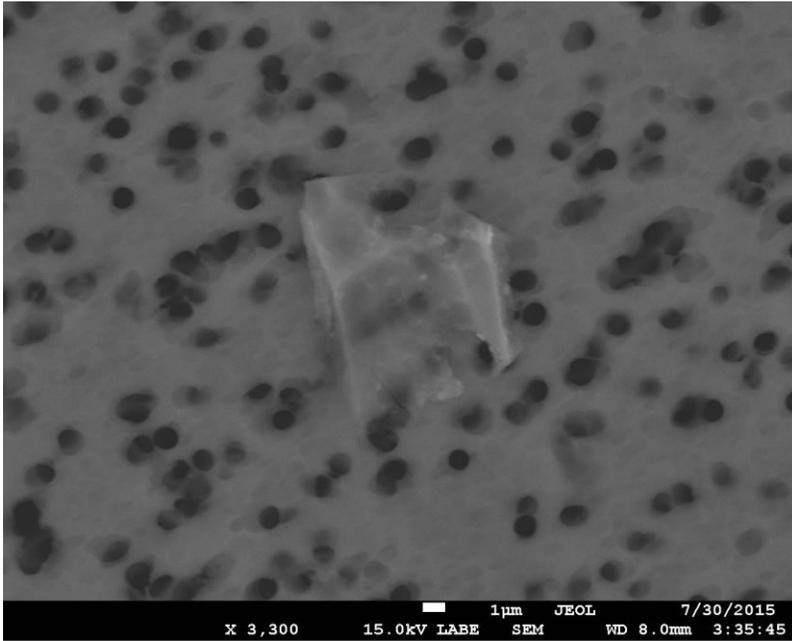


Full scale counts: 3901

U2158C(8)\_pt2

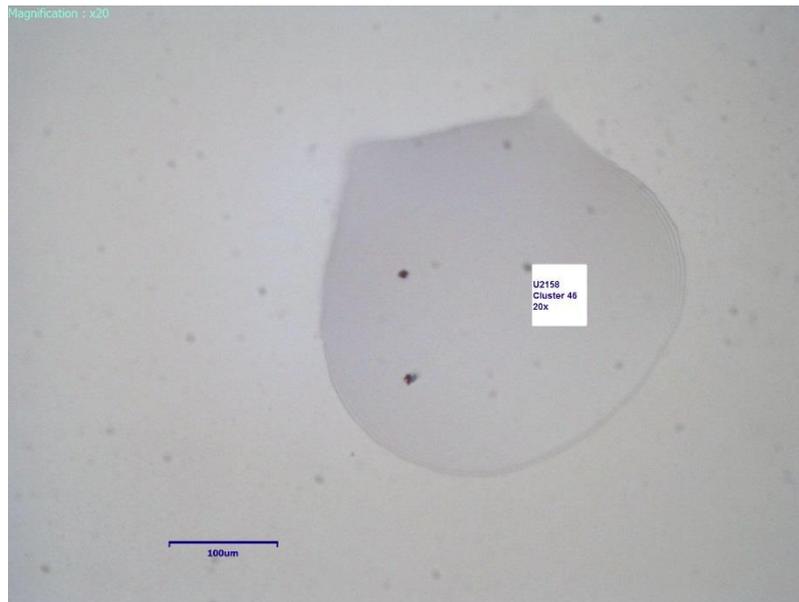


## U2158 C11



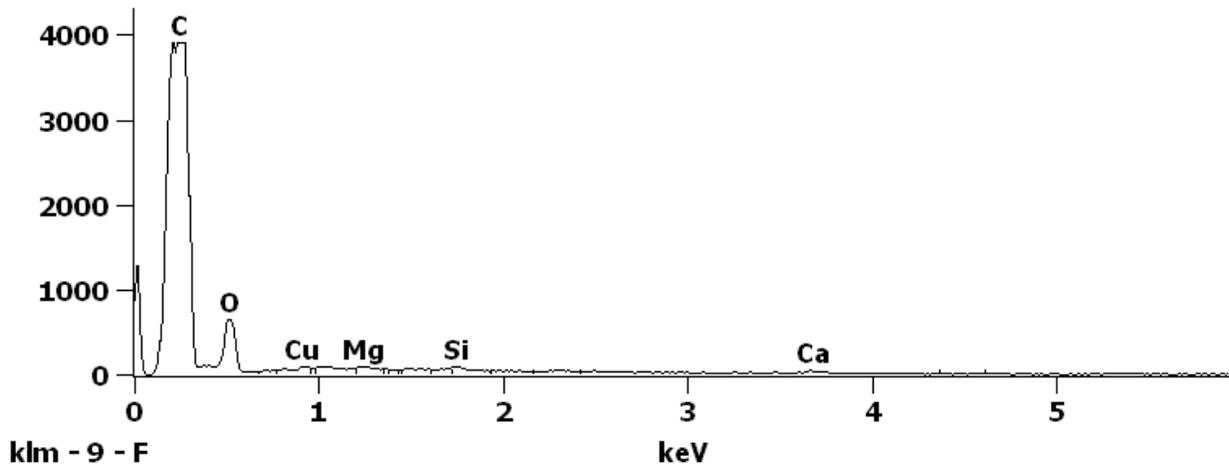
**Particle Size:** 11 µm  
**Shape:** Irregular  
**Transparency:** Translucent to Opaque  
**Color:** Brown, Red  
**Luster:** Subvitreous to Resinous  
**Particle Type:** Possibly Natural Terrestrial Contamination  
**Cluster No.:** 46  
**Comments:**

## Cluster of Origin: U2158 Cluster 46



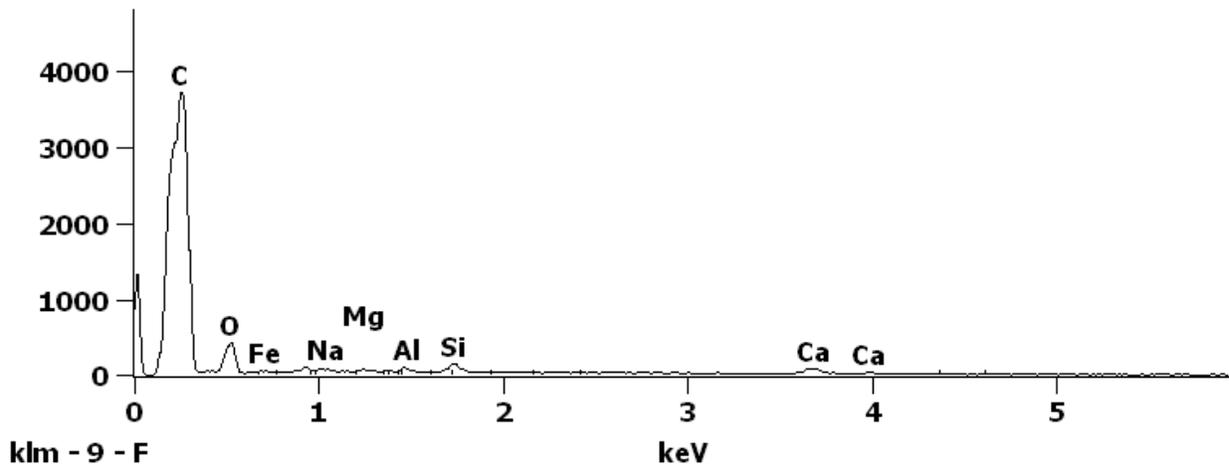
Full scale counts: 3901

U2158C(11)\_pt1

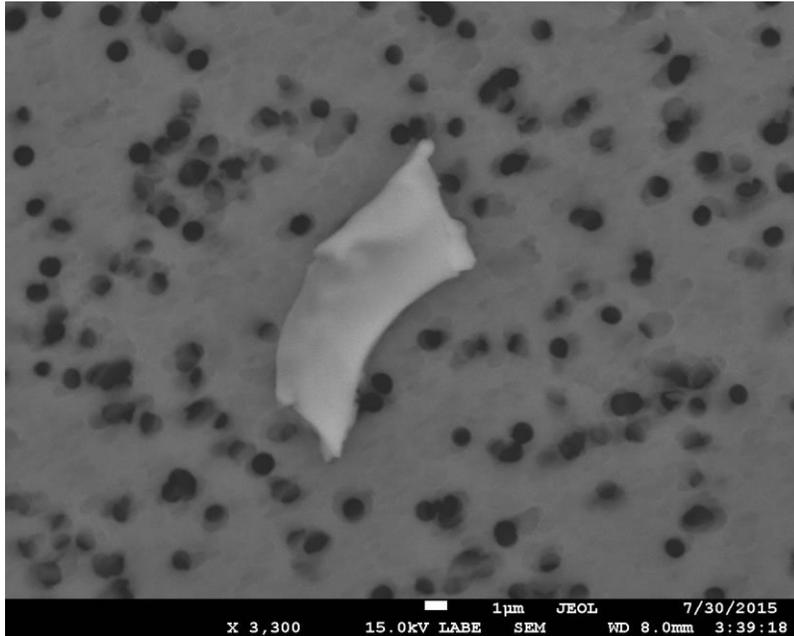


Full scale counts: 3901

U2158C(11)\_pt2



## U2158 C12



**Particle Size:** 13 µm

**Shape:** Irregular

**Transparency:** Opaque

**Color:** Black

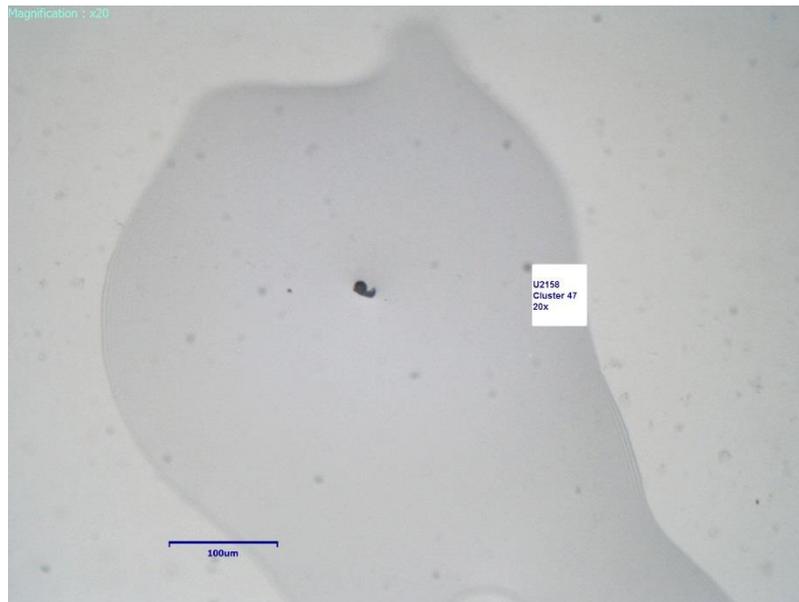
**Luster:** Dull

**Particle Type:** Possibly Natural  
Terrestrial  
Contamination

**Cluster No.:** 47

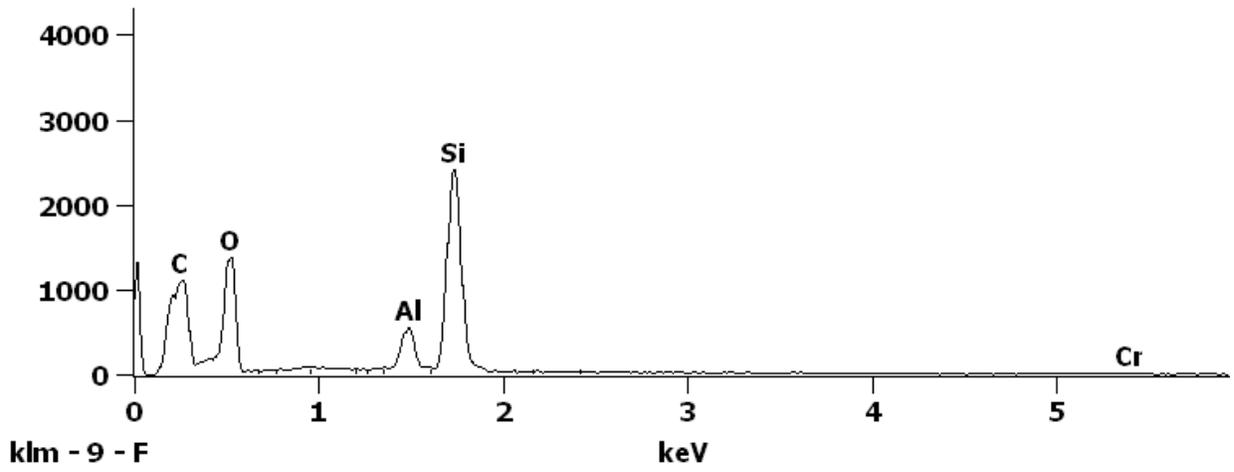
**Comments:**

## Cluster of Origin: U2158 Cluster 47

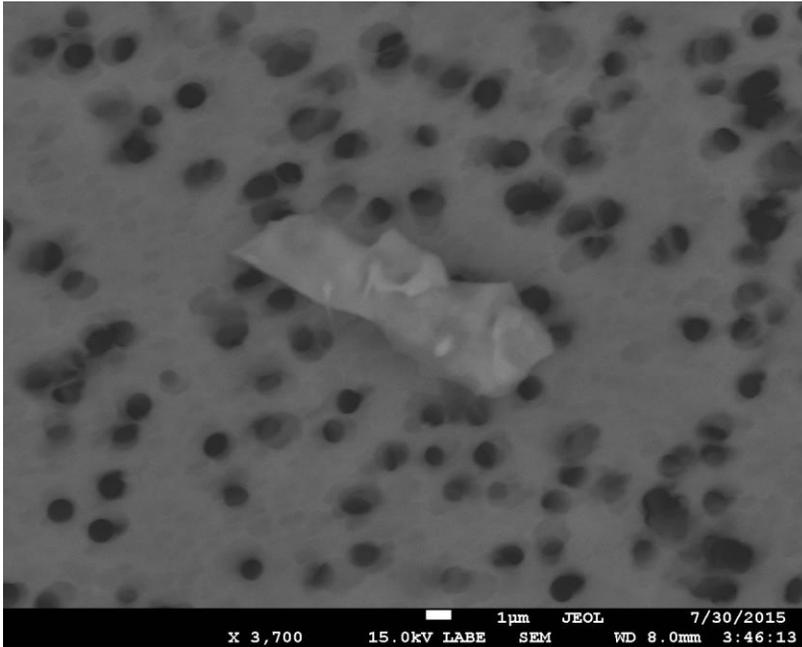


Full scale counts: 3901

U2158C(12)\_pt1



## U2158 C13



**Particle Size:** 3x6 µm

**Shape:** Irregular to Equidimensional

**Transparency:** Opaque

**Color:** Brown

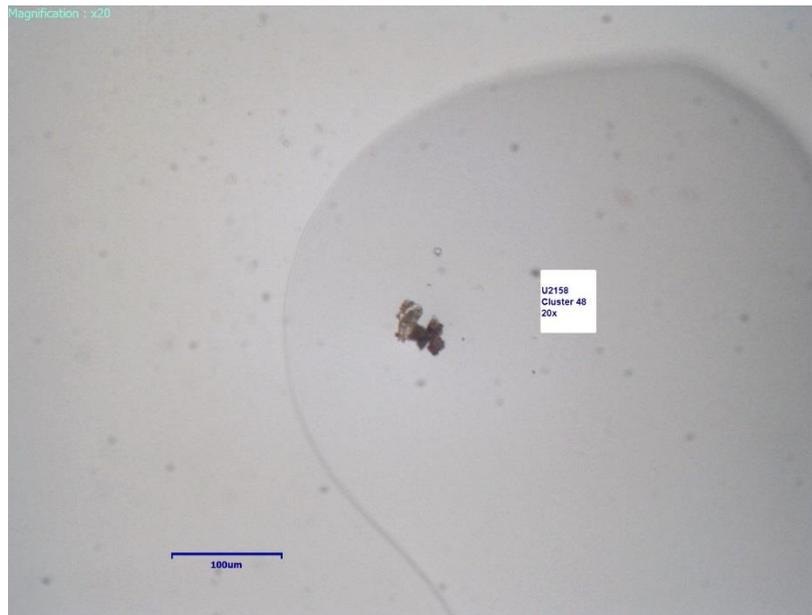
**Luster:** Dull

**Particle Type:** Possibly Natural Terrestrial Contamination

**Cluster No.:** 48

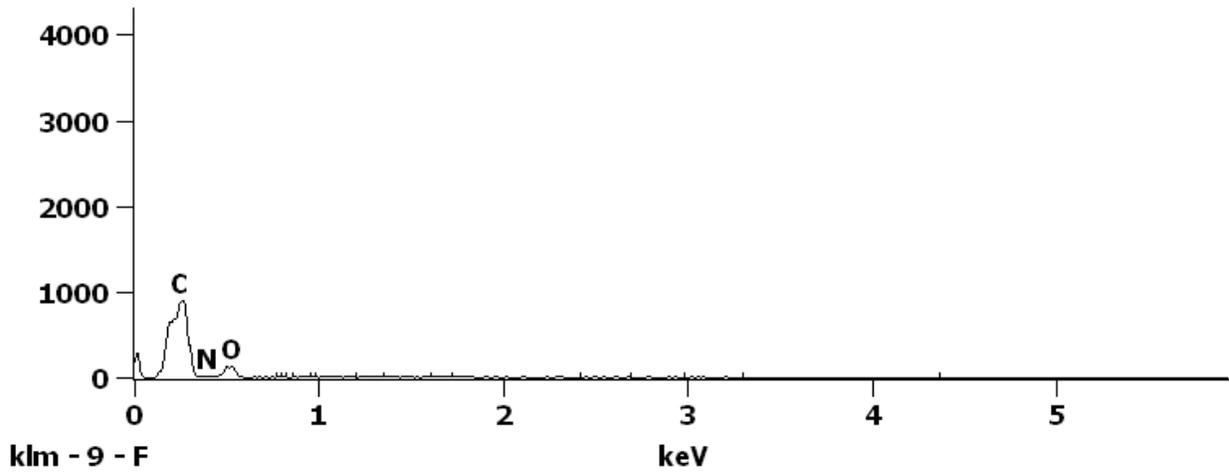
**Comments:**

## Cluster of Origin: U2158 Cluster 48



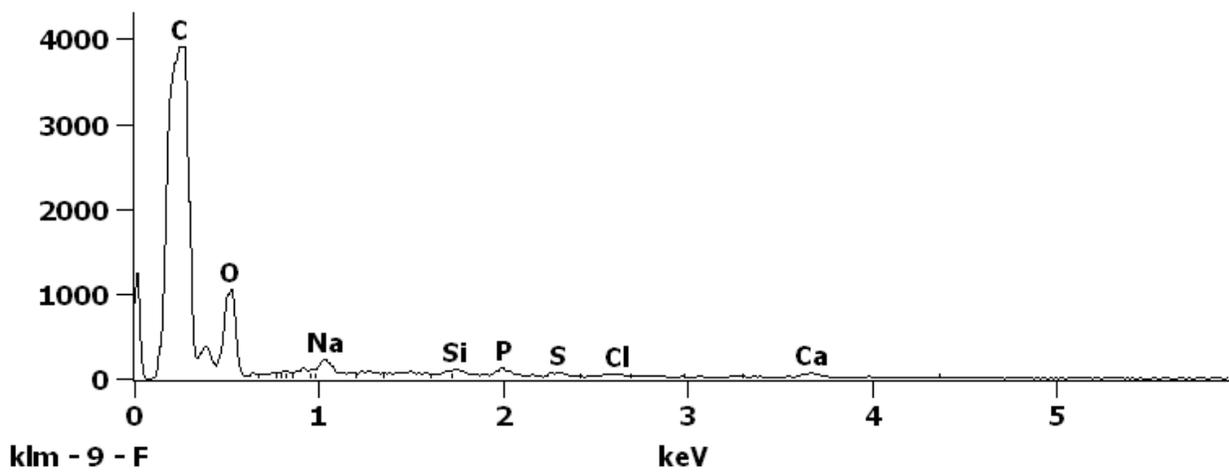
Full scale counts: 3901

U2158C(13)\_pt1

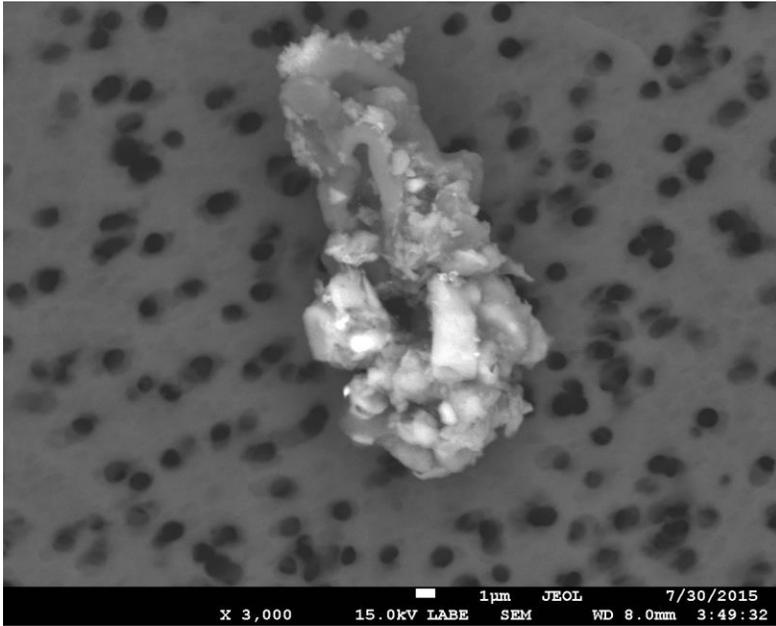


Full scale counts: 3901

U2158C(13)\_pt2



## U2158 C14



**Particle Size:** 25x11 µm

**Shape:** Spherical to Irregular

**Transparency:** Opaque

**Color:** Brown, Black, Gray

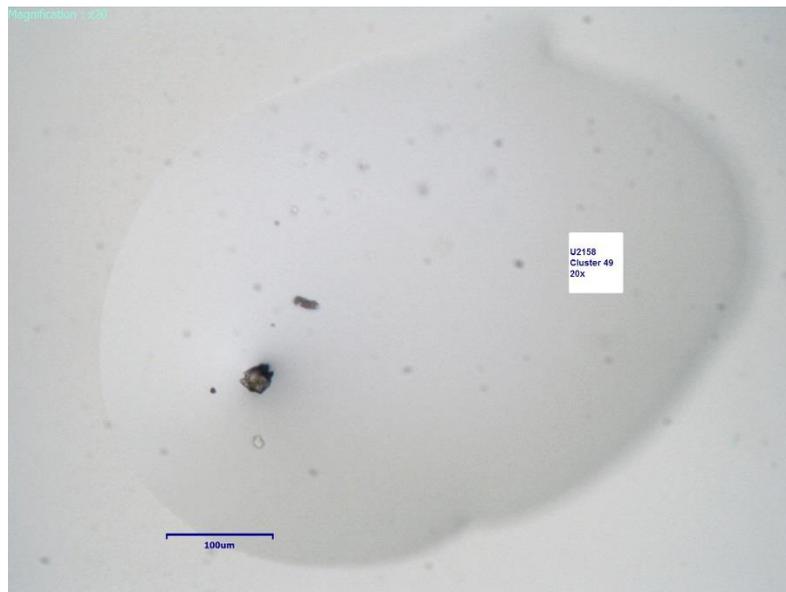
**Luster:** Dull

**Particle Type:** Possibly Natural  
Terrestrial  
Contamination

**Cluster No.:** 49

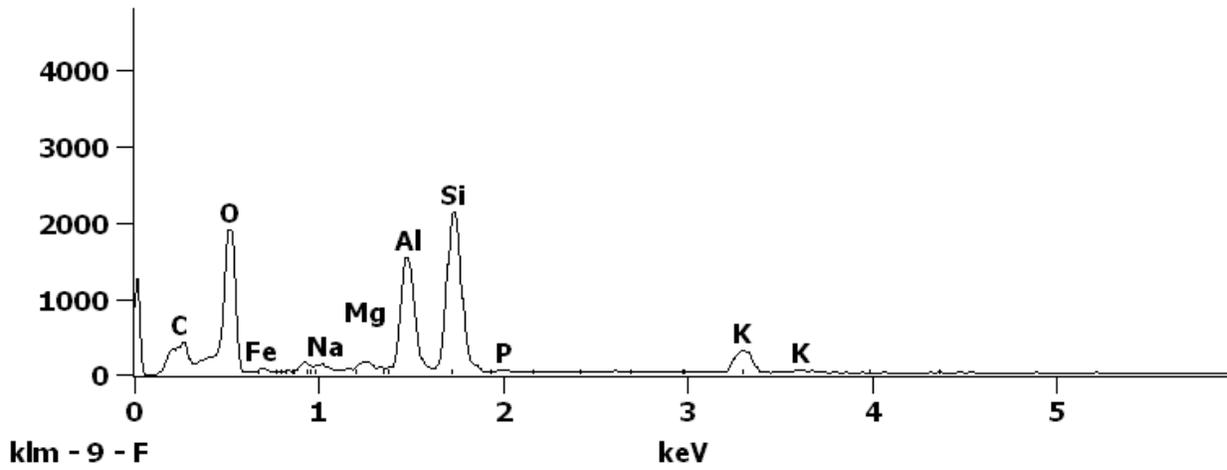
**Comments:**

## Cluster of Origin: U2158 Cluster 49



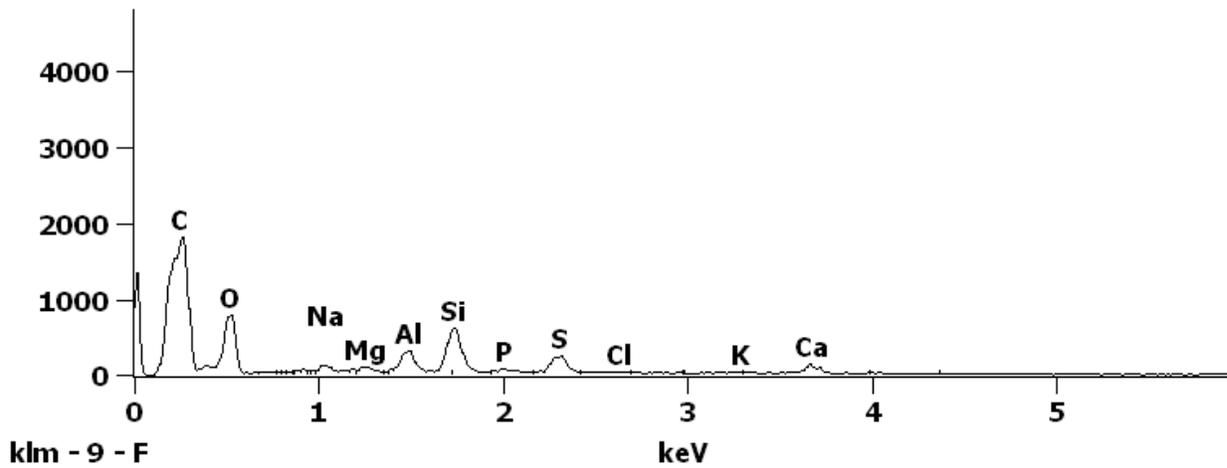
Full scale counts: 3901

U2158C(14)\_pt1

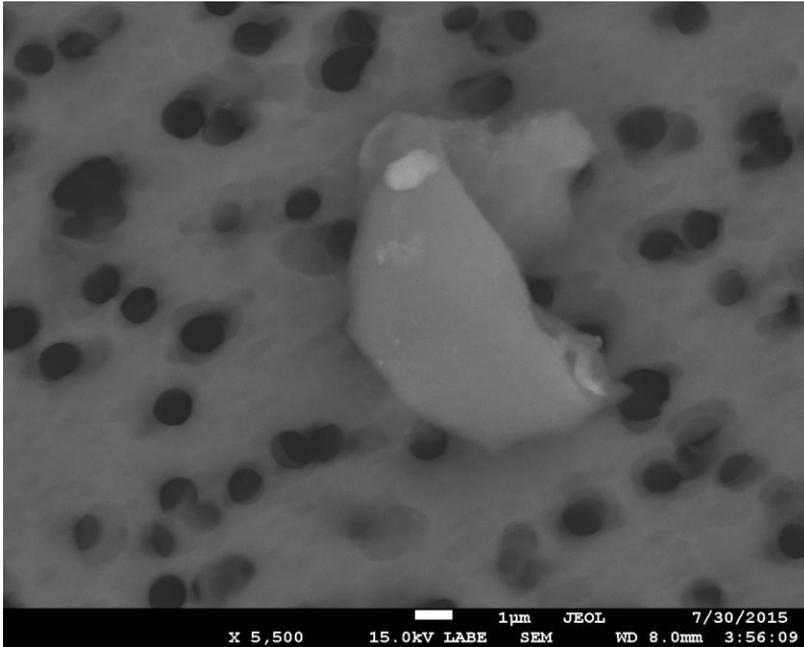


Full scale counts: 3901

U2158C(14)\_pt2

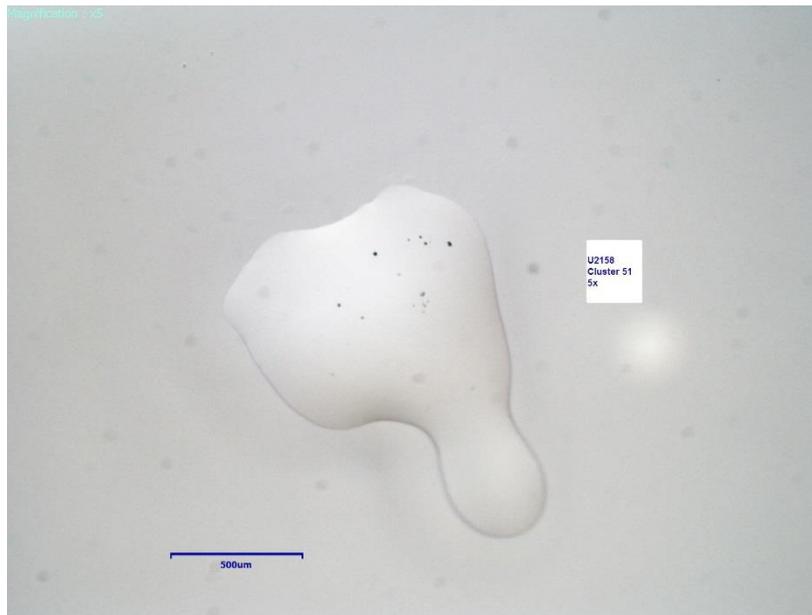


## U2158 C16



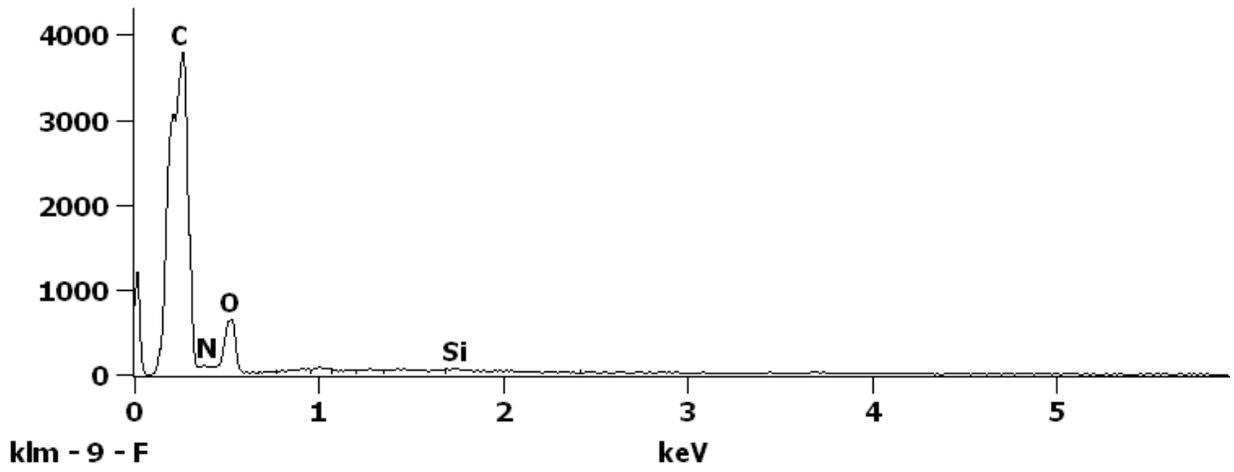
**Particle Size:** 6 µm  
**Shape:** Spherical  
**Transparency:** Opaque  
**Color:** Black  
**Luster:** Pearly to Dull  
**Particle Type:** Possibly Natural  
Terrestrial  
Contamination  
**Cluster No.:** 51  
**Comments:**

## Cluster of Origin: U2158 Cluster 51

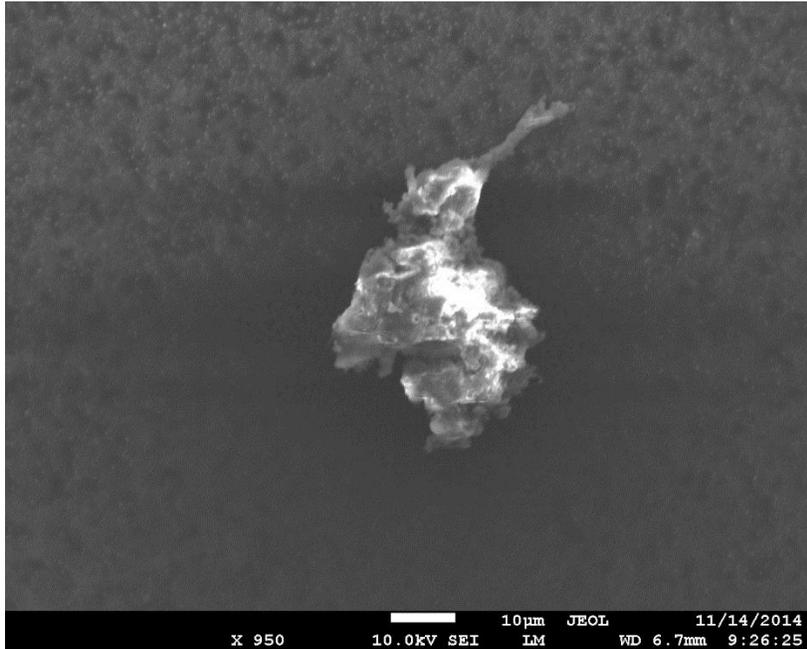


Full scale counts: 3901

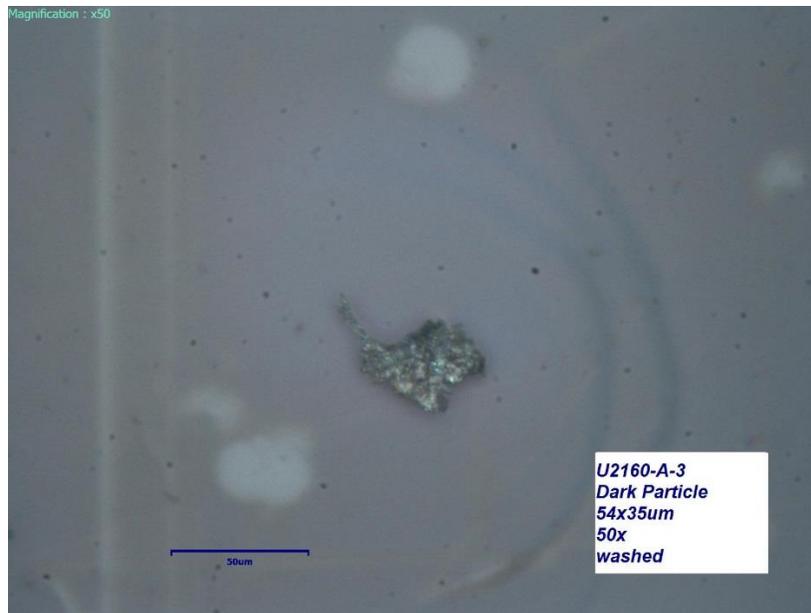
U2158C(16)\_pt1

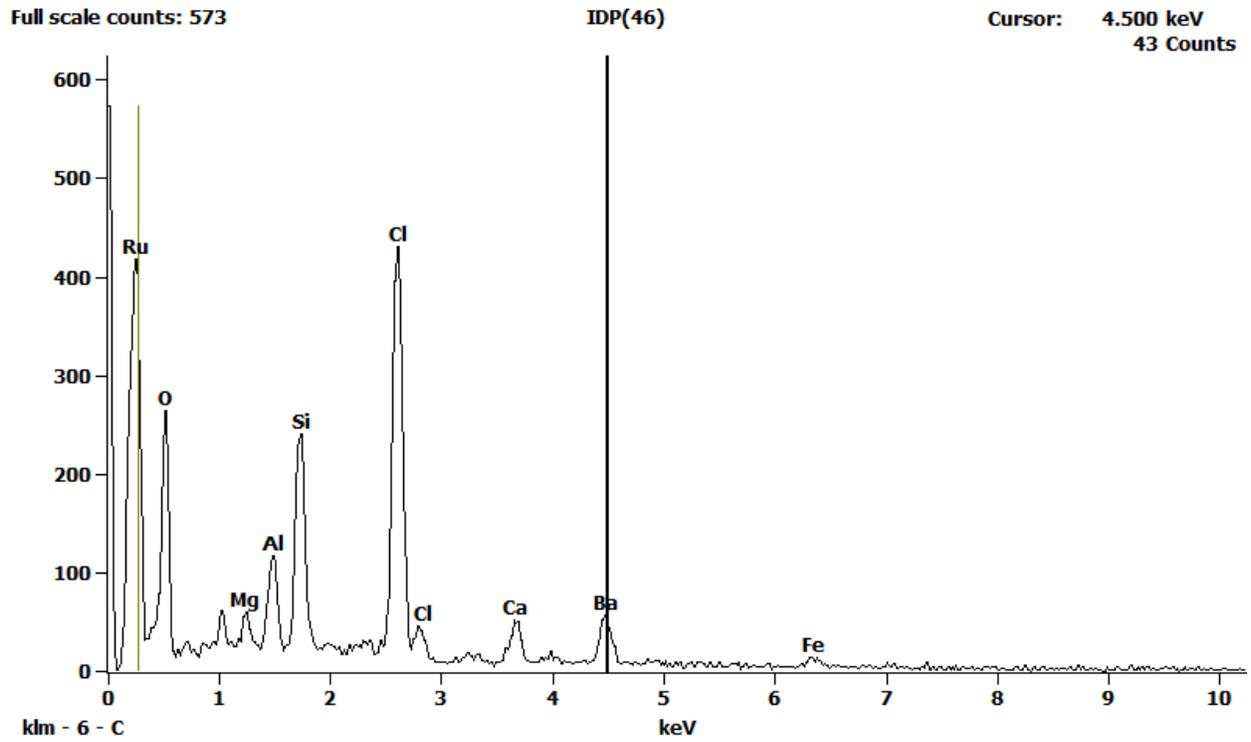


## U2160 A3

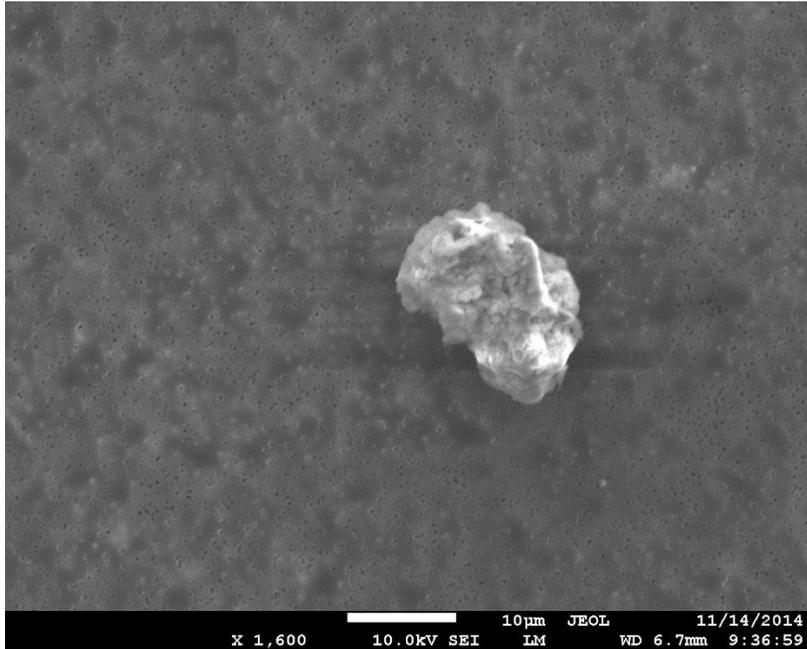


**Particle Size:** 54x35 µm  
**Shape:** Equidimensional to Irregular  
**Transparency:** Translucent  
**Color:** Multiple  
**Luster:** Pearly to Vitreous  
**Particle Type:** Possibly Natural Terrestrial Contamination  
**Cluster No.:**  
**Comments:**

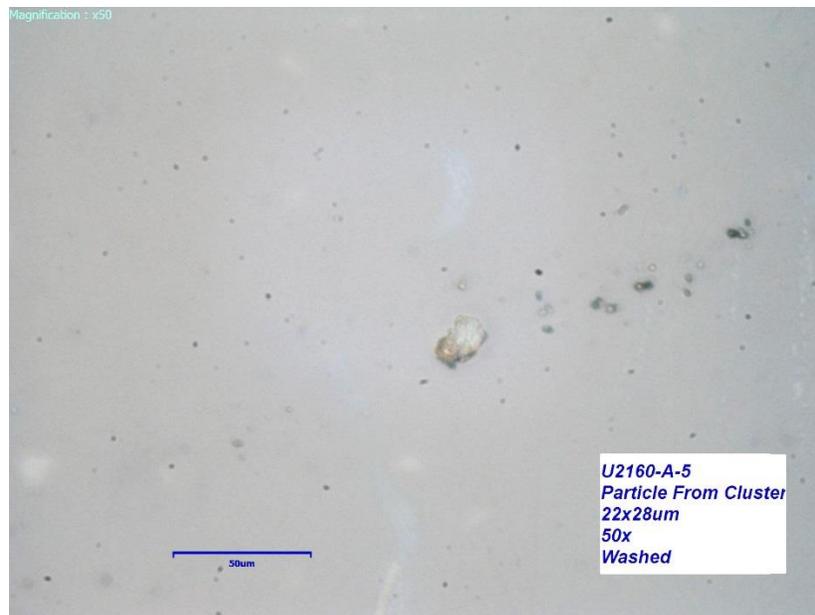




## U2160 A5



**Particle Size:** 15x20 µm  
**Shape:** Equidimensional  
**Transparency:** Translucent  
**Color:** Gray, Clear  
**Luster:** Pearly to Vitreous  
**Particle Type:** Possibly Natural Terrestrial Contamination  
**Cluster No.:** 1  
**Comments:** This appears to be terrestrial but chondritic CP-IDPs have been found in this cluster.



## Cluster of Origin: U2160 Cluster 1

