



Contamination Knowledge Report

OR-CKP-08-1-S and OR-CKP-09-1-S

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Summary

This report summarizes the properties of particles collected on mounts OR-CKP-08-1-S, 0 and OR-CKP-09-1-S, 0.

Scanning electron microscopy (SEM) examination of mount OR-CKP-08-1-S, 0 identified more than 180 particles/particle groups¹ ranging in size from ~ 0.1–100 μm with a single fiber ~ 250·20 μm in size. The most common particle type contained C as the most abundant element. Notably, on the lower right corner of this mount was a grouping of ~ 70 particles > 2 μm in size with a similar composition: major abundances of C, O, and Ti with minor/trace amounts of Mg, Al and Na. These particles have an unknown origin. The permissible C mass limit (1000 $\text{ng}\cdot\text{cm}^{-2}$) was approached (864 $\text{ng}\cdot\text{cm}^{-2}$) or exceeded (1651 $\text{ng}\cdot\text{cm}^{-2}$) depending on the model used to estimate particle volume (see Calculations). In addition to the C-rich particles, five contained minor amounts of Zn and seven were rich in Fe, Cr \pm Ni consistent with particulate stainless steel residue.

SEM examination of the mount OR-CKP-09-1-S, 0 identified ~ 20 particles/particle groups² ranging in size from ~1–40 μm . The most common particle types were C-rich. Of the largest three particles on the mount, two were C-rich (42·17 μm^2 & 35·38 μm^2) and the other was composed of Al (40·41 μm^2). Relative to other surfaces, this mount contains few particles.

Recommendation

Mount OR-CKP-08 shows the highest loading of carbonaceous particles on CK plates by a considerable margin. Since the mass of C/ cm^2 is approximately at the CC limit, we recommend that the source of the particles be investigated and that a summary of activities and relevant materials be provided to the sample WG.

Procedures

¹ Not including Si-only particles derived from the mount.

² Not including Si-only particles derived from the mount.

The mounts were introduced into a SEM for particle characterization. Image mosaics were obtained for each Si wafer (OR-CKP-08-1-S, 0 and OR-CKP-09-1-S, 0) taken at 150X with each frame acquired for 30 s using low-angle backscatter electron (LBE) imaging to emphasize atomic weight variations. All particles $\geq 0.05 \mu\text{m}$ in size were examined. All EDX spectra were acquired for 60 s at 15 keV.

Observations

The majority of particles on OR-CKP-08-1-S, 0 contain C as a major element. The particles are distributed relatively uniformly over the entire surface. The SEM image mosaic, shown in Figure 1, shows particle locations and EDX spectra names. Figure 2 shows shapes, textures and EDX spectra of 7 representative particles. The most common particle type is C-rich with a significant fraction also containing Ti. The majority of C-, Ti-bearing particles are located at the lower right mount corner and show a complex morphology composed of submicrometer-sized Ti/Ti-O grains embedded within a carbonaceous matrix. One Fe-, Cr-particle contained Ni; this is likely particulate residue from tweezers. Potassium was detected in 16 particles, the majority of which were siliceous. One fiber-like, C-rich particle ($250 \cdot 20 \mu\text{m}^2$) was observed. Although neither Ba nor Zn are diagnostic elements, one particle contained minor Ba and five contained Zn. Table 1 summarizes the size, shape and composition of particles located on this mount.

The particle population on OR-CKP-09-1-S, 0 consists mainly (~85% by number) of particles $< 10 \mu\text{m}$ in size. An SEM image mosaic of this mount displaying particle locations and spectra names is shown in Figure 4. The most common particle type was C-rich. Two Fe-, Cr-particles contained Ni; this is likely particulate stainless steel residue. Table 2 summarizes the size, shape, and composition of these particles.

Discussion

Key diagnostic elements: The Contamination Knowledge effort is monitoring the abundances of the following diagnostic elements in collected particles: C, K, Ni, Sn, Nd, and Pb. Below is a summary for each of these elements:

OR-CKP-08-1-S, 0

- C: C-rich particles were the most common particle type on the mount. Most were rich in C or C and O; none had typical elemental signatures of biological contaminants.
- K: K was observed as a minor/trace element in ~ 16 particles, the majority of which were siliceous.
- Ni: Minor Ni was observed in one Fe-, Cr-particle.
- Sn: Not observed
- Nd: Not observed
- Pb: Not observed

OR-CKP-09-1-S, 0

- C: Nearly half the particles on the mount were C-rich. None had typical elemental signatures of biological contaminants such as skin flakes or perspiration.

K: Minor K was present in one C-rich particle.
Ni: Minor Ni was observed in two Fe-, Cr-particles.
Sn: Not observed
Nd: Not observed
Pb: Not observed

Calculations

Assumptions: Composed of 100% C

Based on 141 C-rich particles

Estimated depth is an average of measured length and width parameters

Model using ellipsoid:

C density $\sim 1.5 \text{ g}\cdot\text{cm}^{-3}$ (average density of polymer/graphite)

Surface area is estimated to be $1 \text{ cm} \cdot 1.5 \text{ cm} = 1.5 \text{ cm}^2$

$$\Sigma \text{ volume C-rich grains} = 2.62 \cdot 10^{-12} \text{ cm}^3$$

$$\Sigma \text{ mass C-rich grains} = 1.296 \cdot 10^{-13} \text{ g}$$

$$\Sigma \text{ mass C-rich grains} = 864 \text{ ng} \cdot \text{cm}^{-2}$$

Model using cube:

C density $\sim 1.5 \text{ g}\cdot\text{cm}^{-3}$ (average density of polymer/graphite)

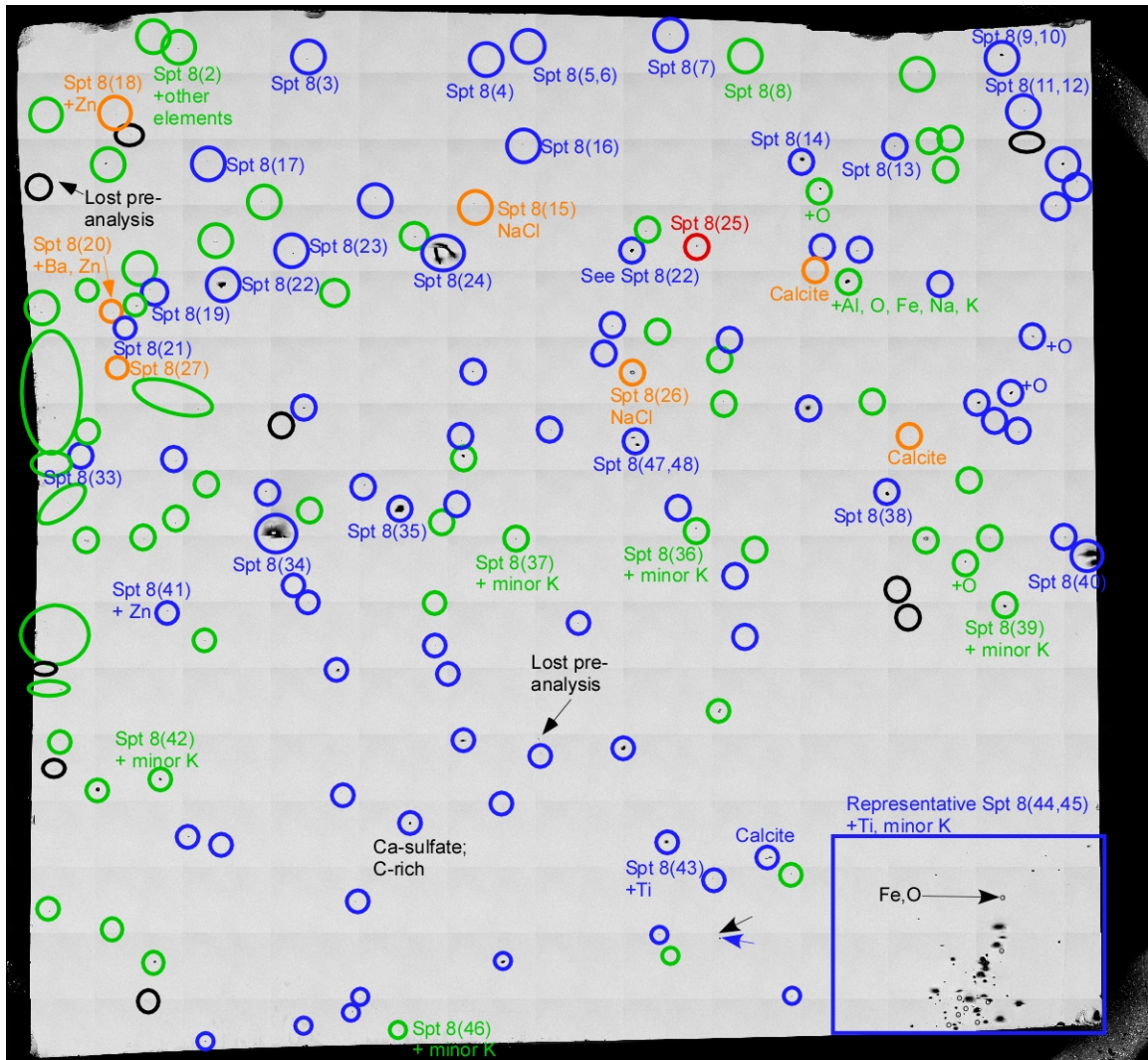
Surface area is estimated to be $1 \text{ cm} \cdot 1.5 \text{ cm} = 1.5 \text{ cm}^2$

$$\Sigma \text{ volume C-rich grains} = 7.5 \cdot 10^{-13} \text{ cm}^3$$

$$\Sigma \text{ mass C-rich grains} = 2.48 \cdot 10^{-6} \text{ g}$$

$$\Sigma \text{ mass C-rich grains} = 1650 \text{ ng} \cdot \text{cm}^{-2}$$

Figure 1: OR-CKP-08-1-S, 0 SEM montage, particle map. Numbers in parentheses correspond to EDX spectral file numbers (also see Table 1).



- Fe, Cr ± Ni
- C-bearing
- Si-bearing
- Al-bearing
- Other

Figure 2: LABE images and EDX spectra of four particles from OR-CKP-08-1-S ,0. Upper views: C-rich particle (left) and fiber (right). Lower: Siliceous particle with minor Ba (right) and NaCl particle (left).

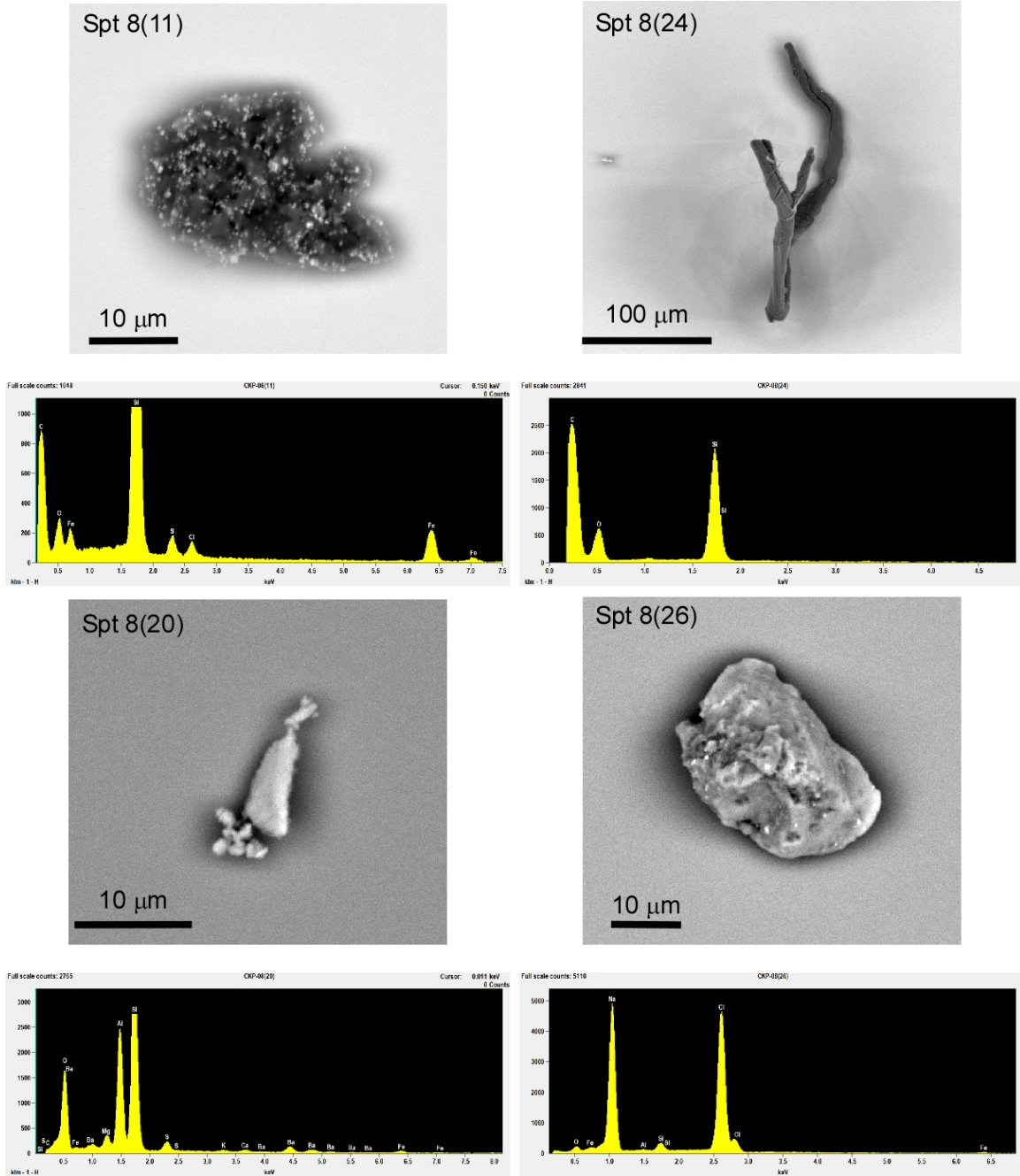


Figure 2, cont. LABE images and EDX spectra of three particles/particle groups from OR-CKP-08-1-S ,0. Upper views: C-rich particles with Ti. The mottled appearance is due to variation in atomic weight where the C-rich matrix is dark and the brighter regions are rich in Ti. Lower view: Likely feldspar grain (light) embedded in C-rich siliceous matrix (dark).

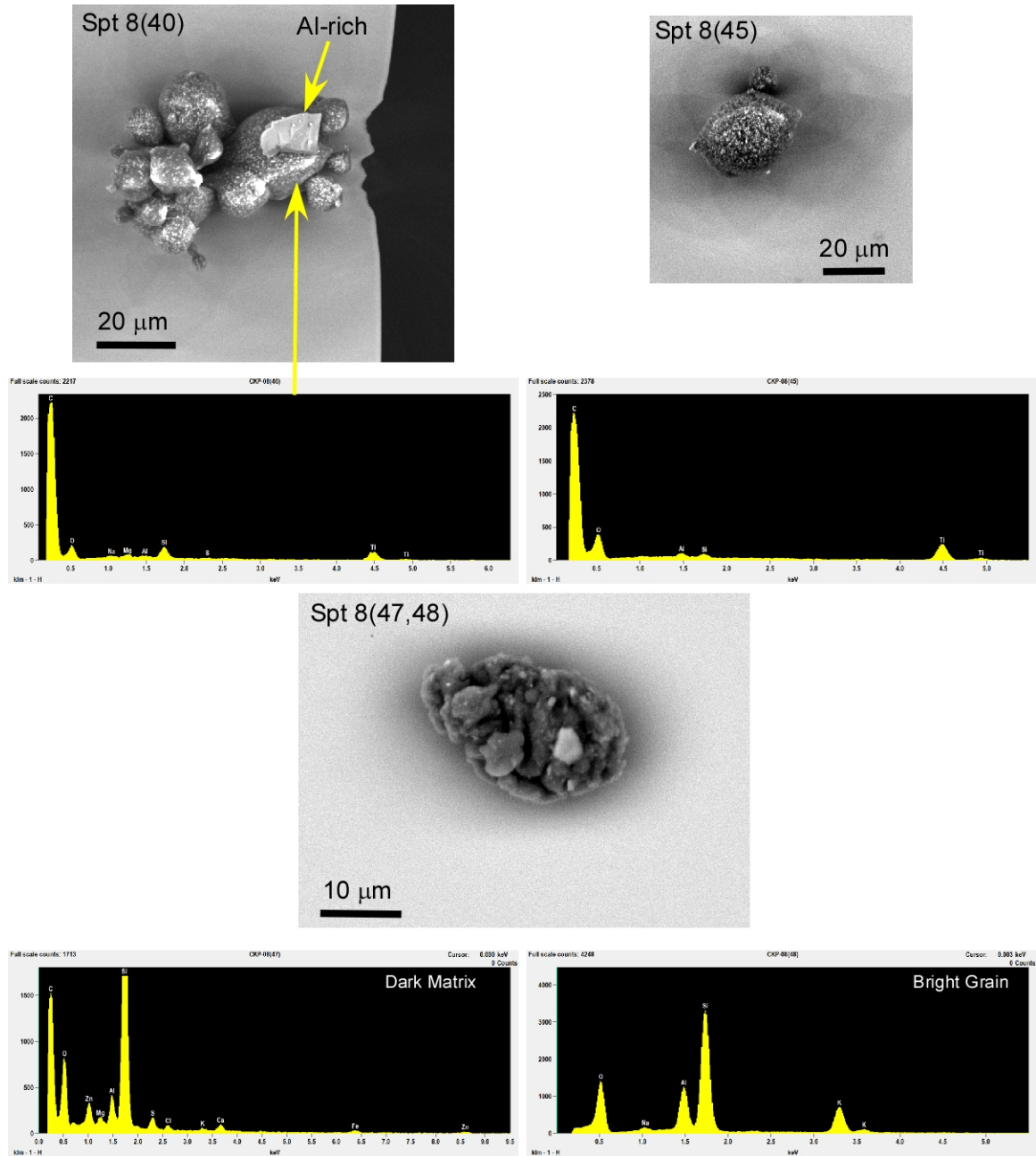
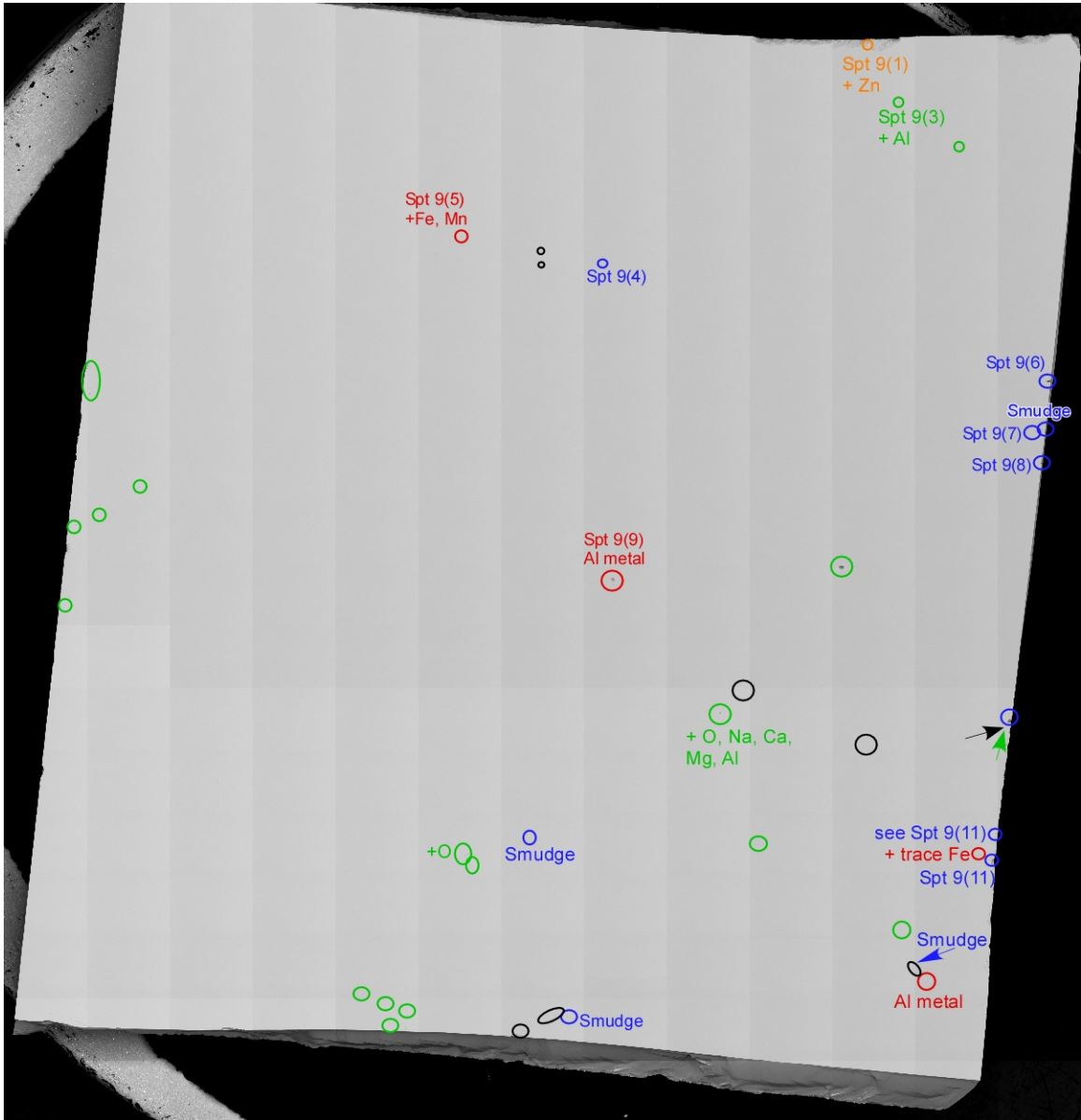


Figure 3 OR-CKP-09-1-S ,0 SEM montage, particle map. Numbers in parentheses correspond to EDX spectral file numbers (see Table 2).



- Fe,Cr (\pm trace Ni)
- C-bearing
- Si-bearing
- Al-bearing
- Other

Table 1³

Shape	Size (μm)	Chemistry	Spectrum Name
Background		Si	8(1)
Irregular	43x40	Si, O, Al, Na, Ca, K , C , S, Cl, Ti, Mg, Fe	8(2)
Irregular	15x16	C , O, S, Cl, Fe, Si	8(3)
Irregular	2x3	C , Si	8(4)
Irregular	3x4	C , O, Ca, Al, Mg, Na, K , S, Si O, Ca, C	8(5) Dark 8(6) Light
Irregular	8x6	C , O, Fe, S, Cl, Si	8(7)
Irregular	3x3	Si, O, Al, Ti, K , Mg, Fe	8(8)
Irregular	30x22	C , Ti, O, Al, Cl C , Ti, O, Al, Fe	8(9) Dark 8(10)Light
Irregular	8x10	C , Fe, O, S, Cl C , Fe, O, S	8(11) Dark 8(12)Light
Irregular	10 (largest)	Fe, Cr, Ni	
Irregular	17x15	C , O, Cl	
Irregular	2x2	C , O	
Irregular	7x4	C , O, Fe, Cl, S	
Irregular	5x5	C , O, Ca, Ti, Fe, S, Cl, Al, Na, Mg	8(13)
Irregular	25x26	C , Cl, O, Al, Na, Ti, Ca, S, Na, Fe	8(14)
Irregular	8	Na, Cl, O, Fe, Al, Ca, Si	8(15)
Irregular	3x3	C , O, Fe, Na, Cl, Si	8(16)
Irregular	2x2	Si, C	
Irregular	2x2	C , Fe, O, Si	8(17)
Irregular	6x2	Fe, Cr	
Irregular/flattened	3x3	Si, O, Mg, Zn, C , Cl, Fe	8(18)
Irregular/fluffy	3x3	C , Fe, S, Cl, O, Si	8(19)
Irregular Group	10x3 (largest)	Al, O, Mg, S, Ba, Fe, Zn, K , Ca, Si	8(20)
Irregular	2x3	C , O, S, Cl, Fe, Si	8(21)
Irregular	61x53	Si, C , O, S	8(22)
Irregular	8x7	C , Fe, S, Cl, O, Si	8(23)
Fiber	~250x20	C , O, Si	8(24)
Irregular	34x32	C , O, S	

³ Key elements are highlighted in red.

Table 1, cont.

Irregular	16x17	Al, Fe, O, S, Si	8(25)
Irregular	41x30	Si, Al, O, K, Fe, Zn	
Irregular	3x3	O, Ca, C	
Group	3x2; 8x1	C, O, S, Cl, Fe (dark) Si (light fiber)	Spatially associated
Irregular/fluffy	1x2	C, O, Fe, S, Cl	
Irregular	10x5	C, O, Si	
Irregular	8x3	C, Si	
Irregular	42x15	C, O	
Irregular/wrinkled	25x15	C	
Irregular	24x33	C, O, S	
Irregular/fluffy	7x9	Si, Al, O, Mg, Na, Ca, K, Fe	
Irregular	1x2	C, O, Mg, Ca, Na, Al	
Irregular	3x4	Si, O, Al, Mg, S, K, Fe	
Irregular	8x6	C, O, Si	
Irregular	3x3	C, O, S, Cl, Fe	
Irregular	24x25	Na, Cl, Si, O, Fe, AL	8(26)
Irregular/angular	18x8	C, Cl, O, S, Fe	
Irregular	12x10	C, Na, Cl, K, S, O	
Irregular	10x5	Fe, Cr	
Irregular	1x1	C, Fe, O, S, Cl	
Irregular	3x4	Fe, O, Cl, Si	8(27)
Irregular	3x3	C, Fe, Cl, S, O	8(33)
Irregular	6x7	C, O, Cl, Si	
Irregular	9x6	O, C, Ca, Na, Al, Mg, Cl, Fe	
Irregular	67x55	C, O, Si, Ti	8(34)
Irregular	1x1	C, O, Si	
Irregular	1.5x5	C, O, Fe, Si	
Irregular/wrinkled	73x54	Si, C, S	8(35)
Irregular	16x9	C, O, Al, Mg, Cl, Na	
Irregular	2x1.5	C, Si	
Irregular	9x6	Si, Al, O, Na, Ca, K	8(36)
Irregular/angular	5x10	Si, Al, K, O, C	8(37)
Irregular	3x3	C, O, S, Cl, Fe	
Irregular	4x2	C, O, Si	
Irregular	24x28	Cl, C, O, Na, Si, S, K, Ca	8(38)
Irregular	2x3	C, O, Ca	
Irregular	2x4	Si, Al, O, Mg, Cl, Ca, Fe	
Irregular	10x8	Si, O	
Irregular	4x8	Si, O, Mg, Ca, Al, Fe	

Table 1, cont.

Irregular	20x18	Si, O, Al, Na, K	8(39)
Irregular	7x7	Fe, O	
Irregular	4x2	Fe, O, Cl, Si	
Irregular	65x47	C , O, Si, Ti Al-rich	8(40) (similar texture and composition to 8(44, 45) Bright mineral
Irregular	6x7	C , O, Cl, Ca, Al, Mg	
Irregular	4x6	C , Cl, O, Ti, Na, S	
Irregular	4x4	C , O, S, Cl, Fe	
Irregular	6x4	C , O, Fe, S, Cl	
Irregular	3x3	C , O, Si	
Irregular	19x18	C , O	
Irregular	8x4	C , Zn, O, Cl, Fe, S, K , Ca, Si	8(41)
Irregular Group	2x1 (largest)	Fe, Cr	
Irregular	21x36	Si, O, Mg, Ca, Al, Fe	
Irregular	19x21	Si, Al, O, K, Fe	8(42)
Irregular	9x11	O, C , Na, Al, Cl, Ca, Fe	
Irregular	15x24	Ca, S, O Cl, C , O, Na, Al, S, Ca	Angular mineral Dark matrix
Irregular	38x8	C , O	
Irregular	4x3	C , O, S, Cl, Fe	
Irregular	31x31	O, C , Cl, Ca, Mg, Al, Na, Fe	
Irregular	6x5	C , O, Na, Mg, Al, Cl, Ca, S, K , Ti, Fe	
Irregular	17x17	Si, Ti, C , Al	8(43)
Irregular	47x25	O, Ca, C	
Irregular	4x3	C , O	
Irregular	11x13	C , O, S, Cl, Fe	
Irregular	2x3	Fe, Cr	
Irregular	7x3	C , O, Ti, Si, Mg, Al	
Irregular grouping in lower right corner	9x9, ~10x10 (9 particles), 12x10, 8x8, 12x12, 10x8, 8x9, 37x50, 28x39, 22x28,	C , O, Ti (\pm Mg, Al, Na)	8(44&45) Representative spectra

Table 1, cont.

	26x32, 29x34, 20x37, 31x32, 29x34, 26x31, 36x39, 32x53, 33x50, 60x98; <3x3 (46 particles)		8(44&45) Representative spectra
Spheres (total of 9) mixed with group (above)	10, 6, 3, 2, 2, 2, 2, 2, 1.5	Fe, O	
Irregular/particles in scratch	2x3 (ave)	Fe, Cr	
Irregular	7x8	C, Ti, Si	
Irregular	16x20	C, O, Al, Na	
Irregular	5x5	C, Si	
Irregular	5x4	C, O, Si	
Irregular	4x3	Si, O, Al, C, K, Mg, S, Fe	8(46)
Irregular	3x3	C, O, Si	
Irregular	10x6	C, O, Ca	
Irregular/particles in scratch	3x2 (ave)	Fe, Cr	
Irregular	23x18	C, O, S, Ca	
Irregular	3x2	C, O, Fe, S, Si	
Irregular	2x3	C, O, S, Cl, Fe, Si	
Irregular	26x18	Si, C, O, Al, S, Cl, K, Ca, Fe, Zn Si, Al, O, K, Na	8(47) Dark matrix 8(48) Light grain in center

Table 2⁴

Shape	Size (μm)	Chemistry	Spectrum Name
Irregular	9x8	Si, Al, Zn, O	9(1)
Background		Si	9(2)
Irregular	6x4	Si, Al, O	9(3)
Irregular	4x4	C, O, Si	9(4)
Irregular	2x2, 1x3	Fe, Cr, Ni	
Irregular	3x5	Al, Fe, Mn	9(5)
Rounded	42x17	C, O, Cl, S, Si	9(6)
Group (smudge)	5x9 (largest)	C, O, Cl, Al, S, Ca, K, Ti, Si	9(7)
Group (smudge)	8x15 (largest)	C, O, Ca, S, Si	9(8)

⁴ Key elements are highlighted in red.

Irregular	5x9	Fe, Cr, Ni	
Irregular	40x41	Al	9(9)
Irregular	10x7	Si, O, Na, Ca, Mg, Al	
Irregular	2x3	Fe, Cr	
Irregular	35x38	C, O	
Irregular	6x3	Fe, Cr	
Smudge	6x7	C	
Irregular	11x8	Al, Fe	
Irregular	4x6	Al	
Smudge	1x2	C	
Irregular	1x0.5, 2x3	Fe, Cr	
Group	2x2 (largest)	Fe, Cr	
Irregular	8x9	C, O, Ca	9(11)
Irregular	3x4	C, O, Ca	See 9(11)