

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



CEN21FA304

MATERIALS LABORATORY

Factual Report 22-079

November 18, 2022

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A. ACCIDENT INFORMATION

Location: Killeen, Texas
Date: July 4, 2021
Vehicle: Focke-Wulf FWP 149D (N9145)
Investigator: Andrew Todd Fox

B. COMPONENTS EXAMINED

Items from a Lycoming GO-480-B188 engine

1. Shop cloth with particulate debris collected from a filter screen (Figure 1).
2. Connecting rod: cap pieces, bolt and nut pieces, bearing pieces (big end).
3. Counterweight: washer pieces, snap ring pieces, rollers, bushing pieces, primary counterweight pieces, pieces of web between the two halves of the counterweight (Figure 12).
4. Crankshaft pieces: counterweight lug pieces, bushing pieces (Figure 12).

C. EXAMINATION PARTICIPANTS

Specialist Michael Budinski
 NTSB
 Washington, DC

Technician Edward Komarnicki
 NTSB
 Washington, DC

D. DETAILS OF THE EXAMINATION

The submitted shop cloth with particulate debris collected from a filter screen is shown in Figure 1. Three representative areas, labeled 1, 2, and 3 in the figure were examined and photodocumented using a digital microscope (see Figures 2-4). In general, the particles had a consistent appearance and size distribution at areas 1, 2, and 3. The particle morphology ranged from flat plate-like to ovoid and the major dimension of the particles ranged from 0.01 inch to less than 0.001 inch. Compositional analysis of the particles was performed on a sample from area 1 (see Figure 2). A piece of the shop cloth containing the particles was cut from area 1. The shop cloth particle sample was then mounted on a beryllium stub and examined using a field emission scanning electron microscope (SEM) with an energy dispersive spectrometer (EDS) (using standardless semiquantitative analysis). A scanning electron micrograph of the field of view examined is shown in Figure 5. False colors are used to identify the predominate elemental composition of the particles. A key to

the false colors is shown in Figure 6. Overall, the EDS analysis revealed the following primary elements: C, O, Al, Fe, Cu, and Pb.

The shop cloth sample with particles was then immersed in acetone under ultrasonic agitation to disperse the particles in the liquid. The acetone with particles was then vacuum filtered onto filter paper, dried, and the particles were deposited onto a beryllium stub. Isolated particles were then surveyed using an SEM with EDS. Figures 7 through 11 show images of the isolated particles and their respective compositional spectra. In general, the aluminum and iron particles are flat or platelike consistent with removal via skiving or milling action. The composition of the iron particle (Figure 8) is consistent with a chromium or chromium and molybdenum steel (the counterweights are fabricated from a chromium and molybdenum steel). Particles with high concentrations of lead and bromine are vestiges of the fuel additives in 100 octane low lead fuel (contains tetraethyllead and ethylene dibromide). The composition of the aluminum particle is consistent with an aluminum alloy with minor amounts of magnesium.

The pieces recovered from inside the crankcase are shown in Figure 12. Descriptions of the pieces and corresponding examination observations are listed in Table 1. Three pieces, shown in Figures 13, 16, and 19 exhibited curved surfaces and case cracking. The composition of the pieces was evaluated using a hand-held x-ray fluorescence spectrometer. All three pieces exhibited minor concentrations of nickel, chromium and molybdenum and major iron concentration (consistent with type 4340 steel alloy used for crankshafts). The case cracking is consistent with nitrided steel (crankshafts are fabricated from nitrided type 4340 steel). The curved surfaces are consistent with the geometrical features of a counterweight lug on the crankshaft (see Figure 22)

The crankshaft counterweight lug piece in Figure 13 (item 11a in Table 1) exhibited overstress fracture features on the left side of the piece (Figure 14) and progressive fracture features on the right side of the piece (Figure 15).

The crankshaft counterweight lug piece in Figure 16 (item 11b in Table 1) exhibited progressive fracture features on both the left and right side of the piece (Figure 17 and 18).

The crankshaft counterweight lug piece in Figure 19 (item 12 in Table 1) exhibited progressive fracture features on both the left and right side of the piece (Figure 20 and 21).

Table 1 Description and Observations of the Items in Figure 12

Item	Description	Observations
1	Pieces of connecting rod caps	Pieces exhibited gross plastic deformation and batter.
2	Pieces of connecting rod cap bolts and nuts	Pieces exhibited gross plastic deformation and batter. Remaining fracture surfaces exhibited overstress fracture features.
3	Pieces of connecting rod bearings	Pieces exhibited gross plastic deformation and batter.
4	Pieces of crankshaft counterweight (two pieces)	Pieces exhibited gross plastic deformation and batter. Full counterweight has been fractured into pieces. Bushing remains in the intact hole. The remaining fracture surfaces exhibited overstress fracture features. Composition consistent with type 4140 steel (via handheld x-ray fluorescence spectrometer).
5	Pieces of crankshaft counterweight	Pieces exhibited gross plastic deformation and batter. Full counterweight has been fractured into pieces. Bushing, retaining ring, and plate remain in one hole. Retaining ring remains in the other hole. Composition consistent with type 4140 steel (via handheld x-ray fluorescence spectrometer).
6	Internal retaining ring	Piece exhibited gross plastic deformation.
7	Pieces of washer	Pieces exhibited gross plastic deformation. Two of the washers exhibited overstress fracture features.
8	Counterweight rollers	Roller surfaces exhibited features consistent with batter.
9	Counterweight bushing pieces (0.29 inch wide)	Pieces exhibited deformation and batter, and fracture features consistent with overstress fracture.
10	Counterweight bushing pieces (0.34 inch wide)	Pieces exhibited deformation and batter. The fracture features are consistent with overstress fracture.
11a,b	Pieces from a crankshaft counterweight lug (Figure 22)	Pieces exhibited deformation and batter. The ends exhibited partial fracture features. 11a exhibited overstress fracture features on both ends and evidence of nitride case cracking on the machined surfaces. 11b exhibited progressive fracture features on both ends and evidence of nitride case cracking on the machined surfaces. Composition consistent with type 4340 steel (via handheld x-ray fluorescence spectrometer).
12	Piece consistent with a crankshaft counterweight lug (Figure 22)	Piece exhibited deformation and batter. Progressive fracture features are present on both ends and evidence of nitride case cracking on the machined surfaces. Composition consistent with type 4340 steel (via handheld x-ray fluorescence spectrometer).
13	Unknown, consistent with the web between the two halves of the counterweight (Figure 22)	Pieces exhibited deformation and batter. Composition consistent with type 4140 steel (via handheld x-ray fluorescence spectrometer).
14	Unknown, ferrous alloy pieces	Pieces exhibited batter and deformation. No remaining features to identify source of the pieces.
15	Unknown, aluminum alloy pieces	The large piece exhibited overstress fracture features. Composition of the large piece: aluminum alloy with Si, Cu, and Mg (via handheld x-ray fluorescence spectrometer).

Submitted by:

Michael K. Budinski
Chief, Materials Laboratory

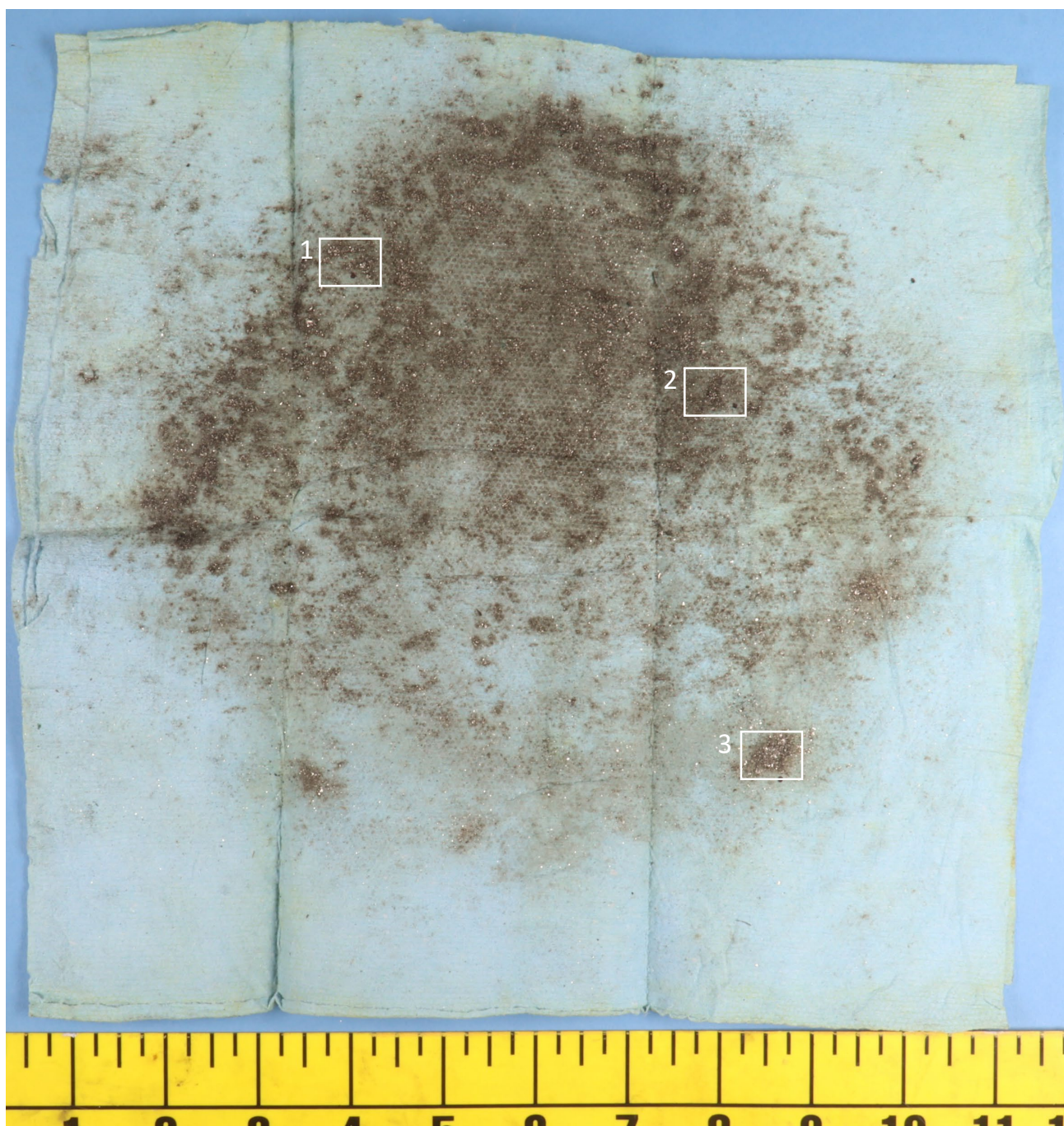


Figure 1. Image of the shop cloth with screen filter particulate.

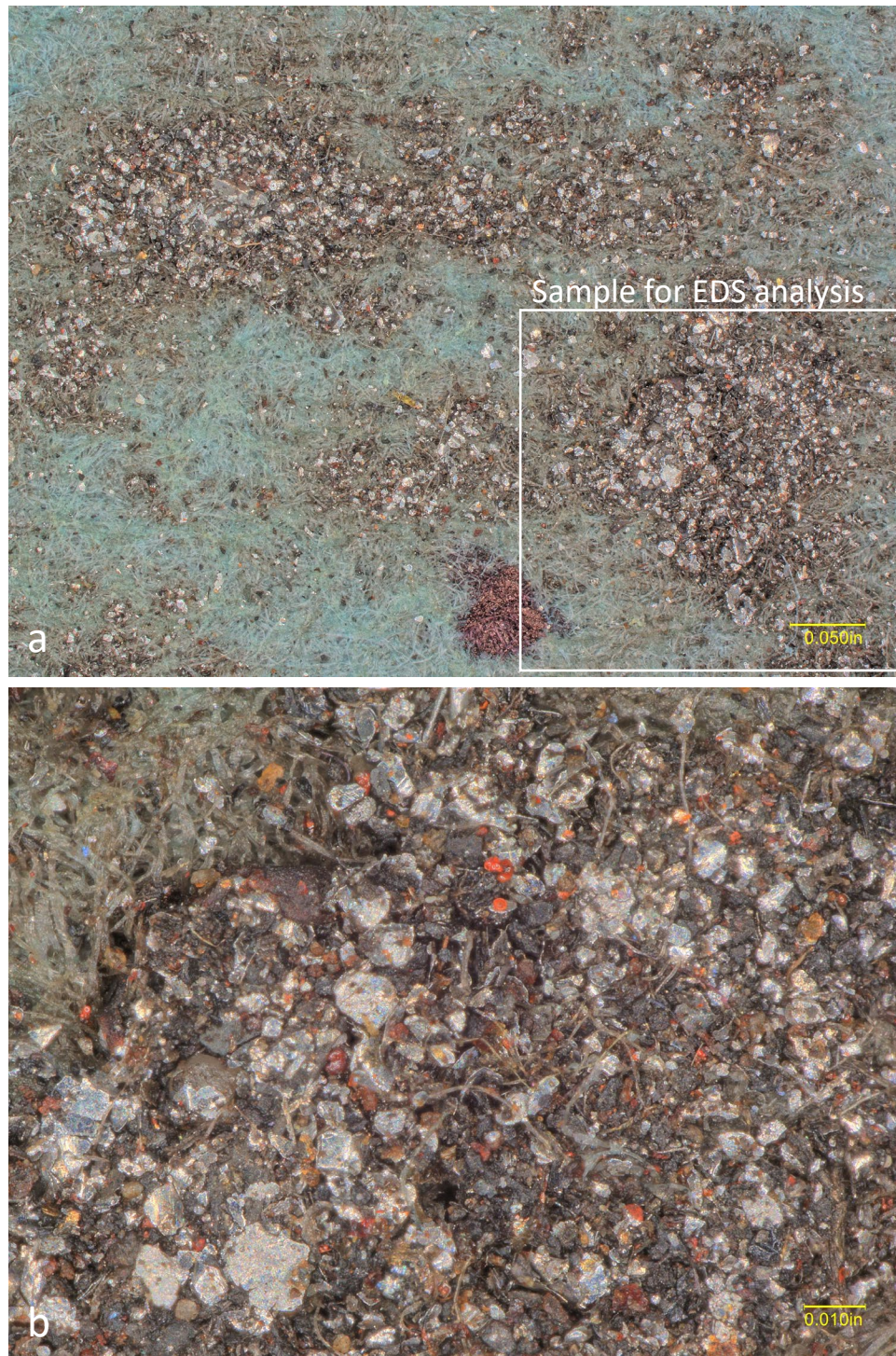


Figure 2. Close views of the filter particles at location 1 (See Figure 1). Compositional analysis by EDS was performed on the particles within the area labeled “sample for EDS analysis” in view a.

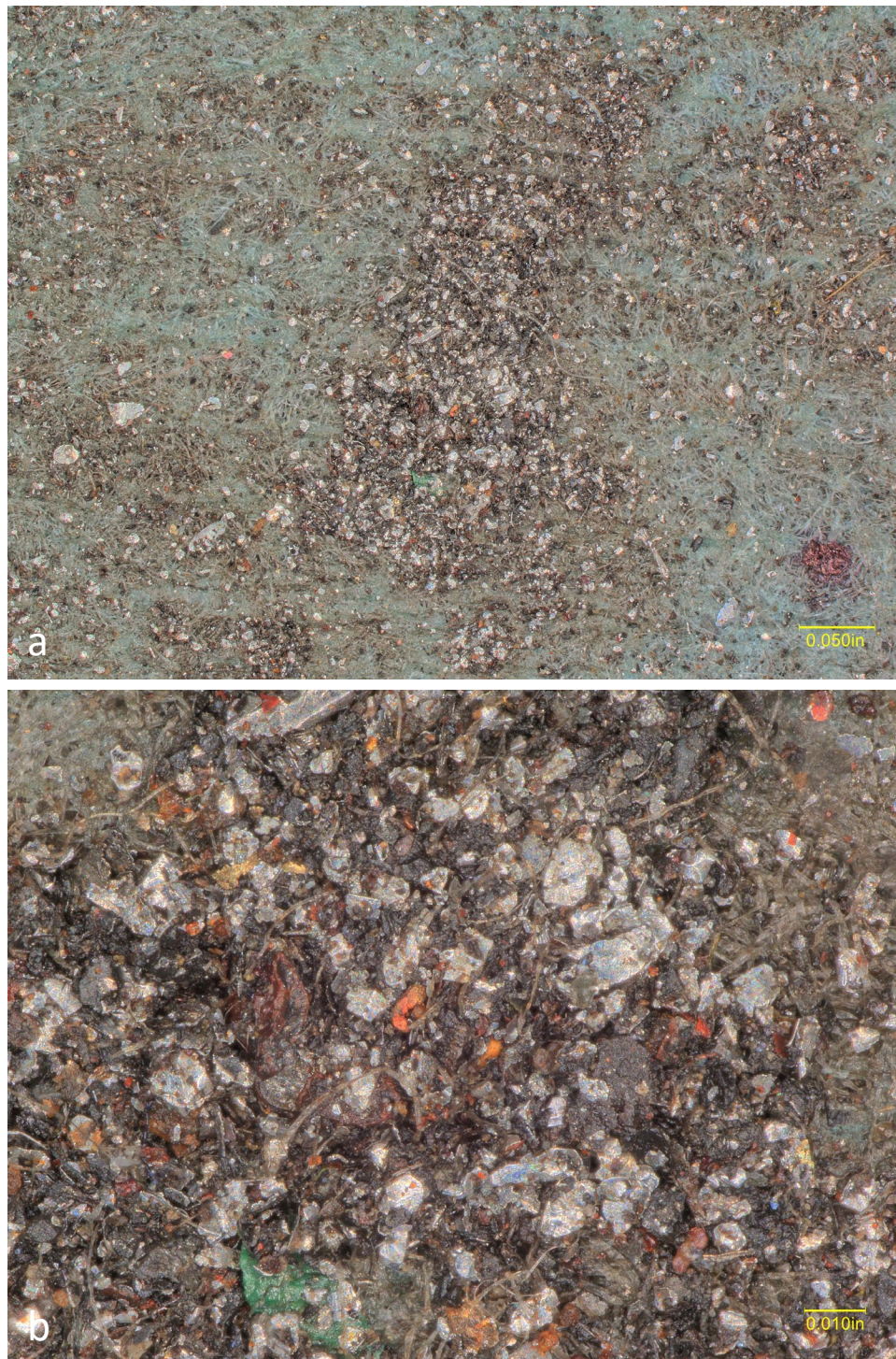


Figure 3. Close views of the filter particles at location 2 (See Figure 1).

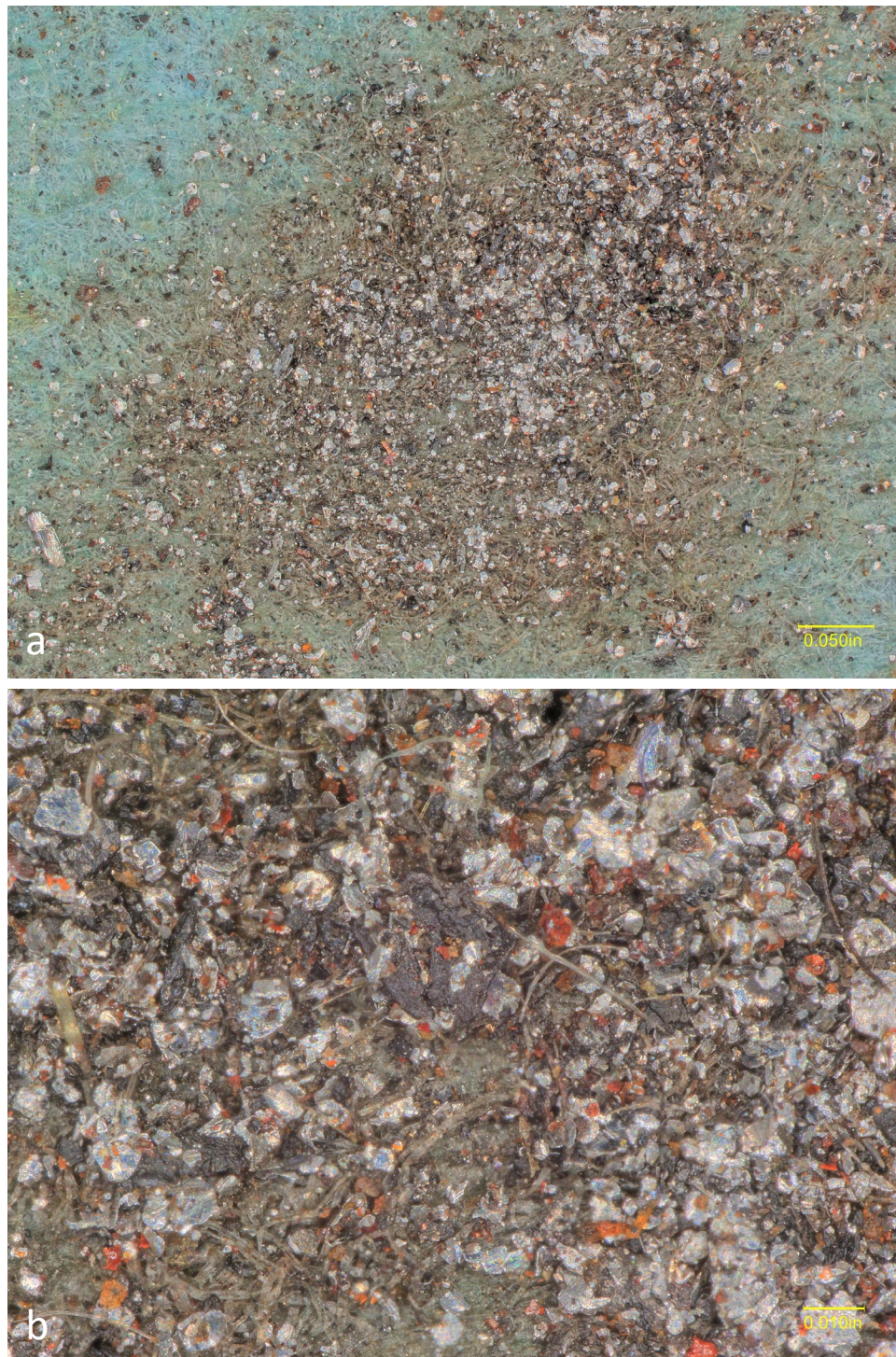


Figure 4. Close views of the filter particles at location 3 (See Figure 1)

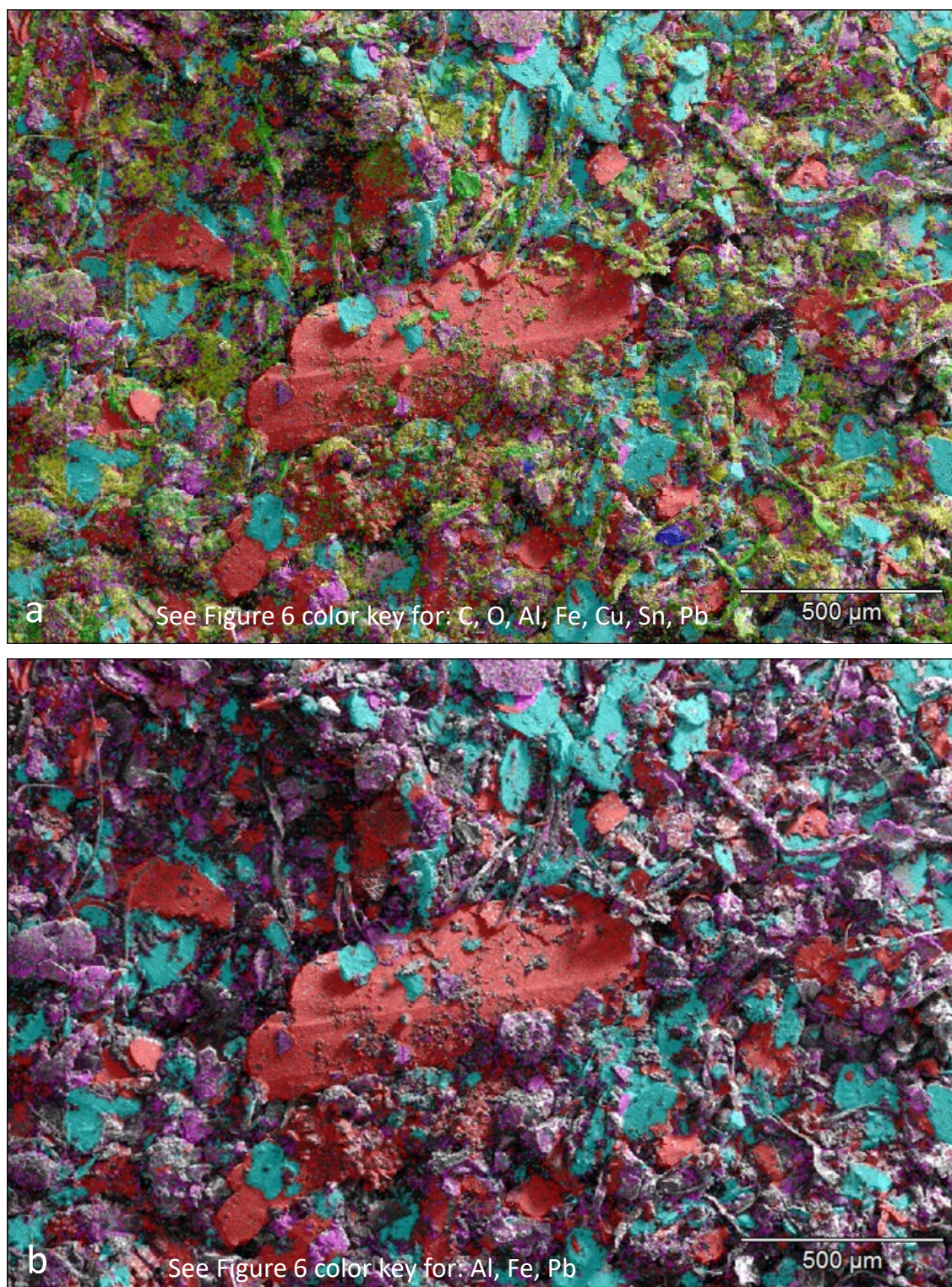


Figure 5. Scanning electron microscope images of a region within the Figure 2a inset area, shown with false colors to represent the primary elemental composition of the particles. A key to the colors is shown in Figure 6.

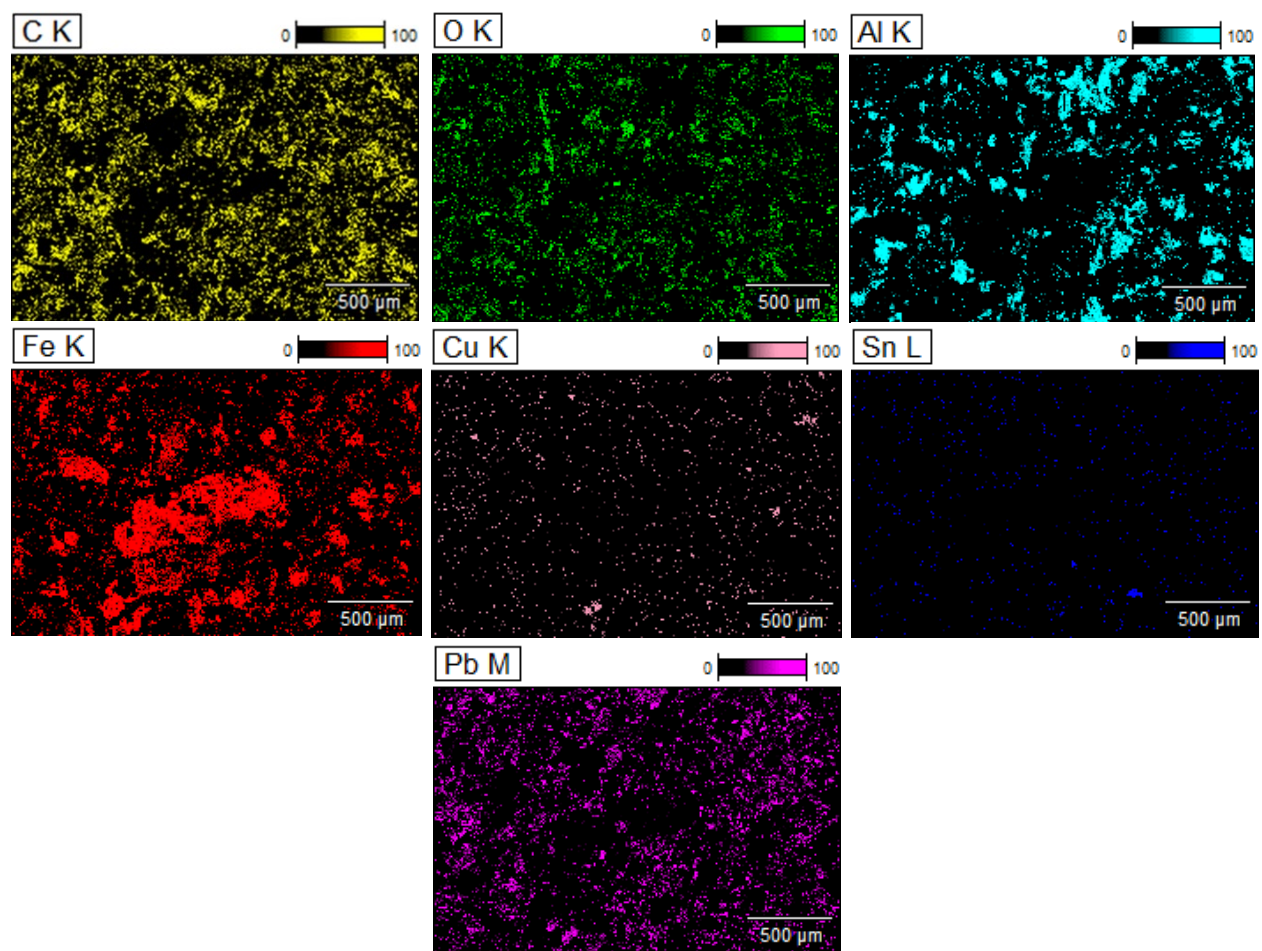


Figure 6. Images of the micrograph in Figure 5 showing the elements represented by the colors.

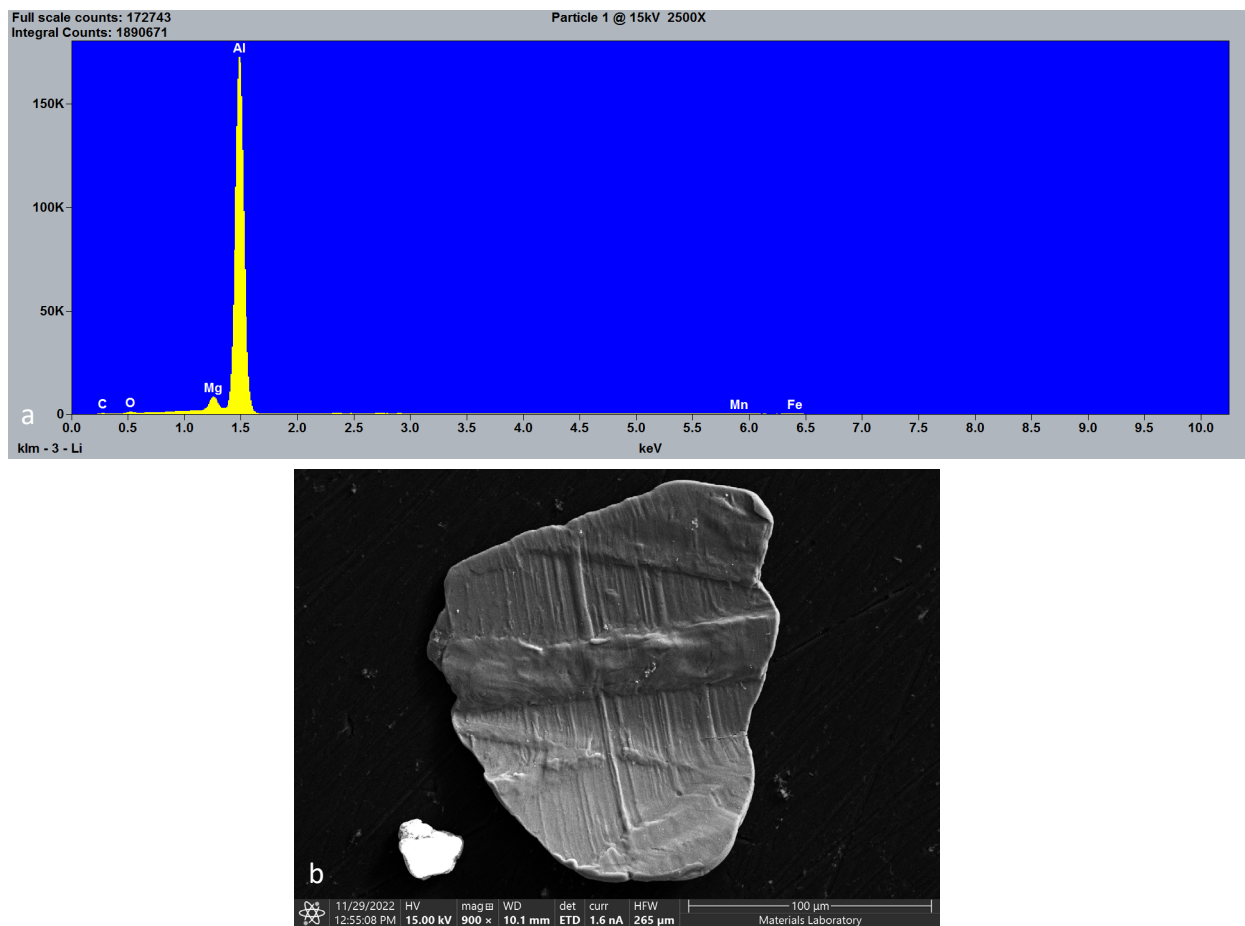


Figure 7. Spectrum and scanning electron microscope image (view b) of the larger particle comprising predominantly aluminum and magnesium.

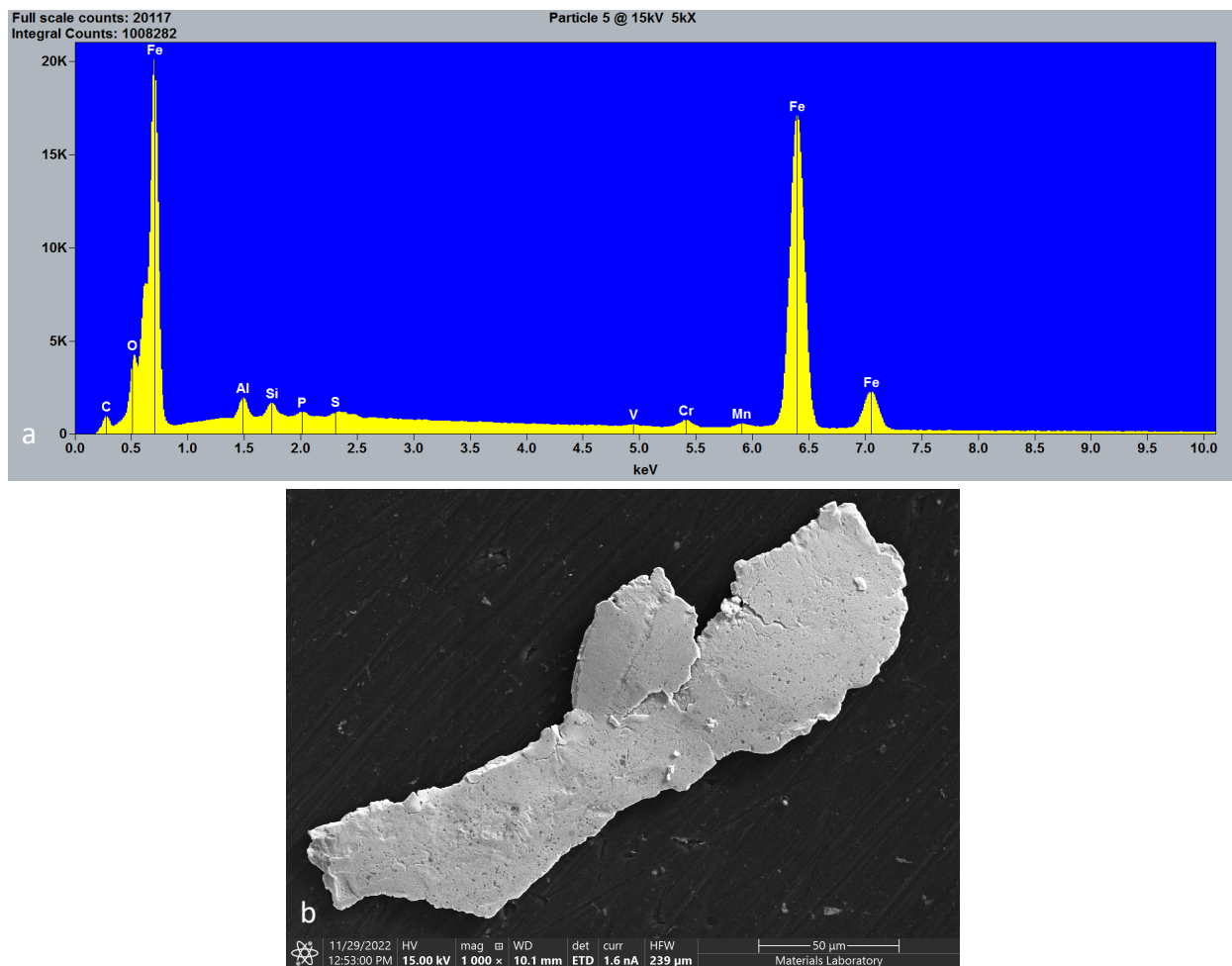


Figure 8. Spectrum and scanning electron microscope image (view b) of a particle comprising iron, aluminum, silicon, oxygen, carbon, chromium, phosphorous, sulfur, manganese, and vanadium.

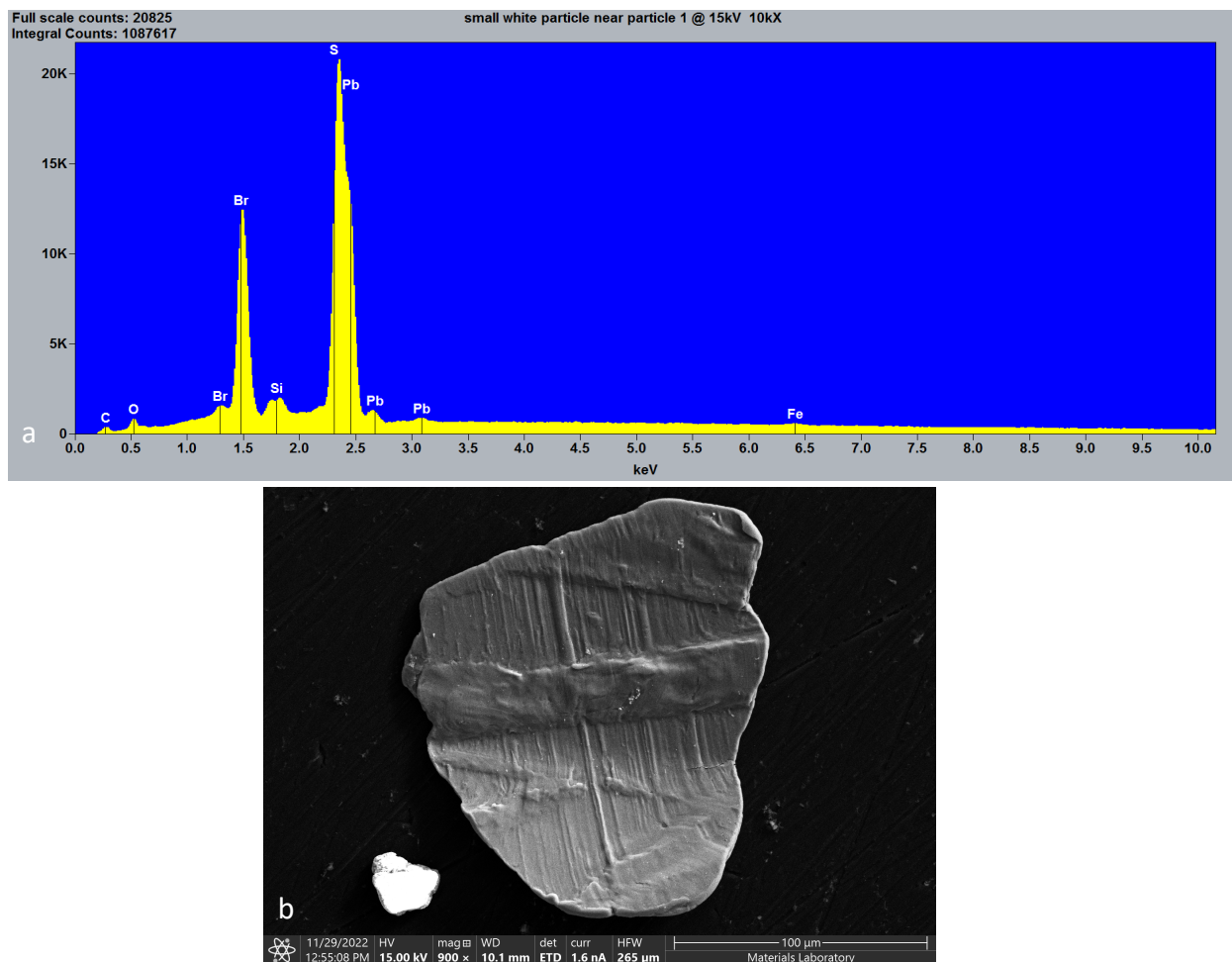


Figure 9. Spectrum and scanning electron microscope image (view b—bottom right smaller particle) of a particle comprising carbon, oxygen, silicon, bromine, lead, and trace iron.

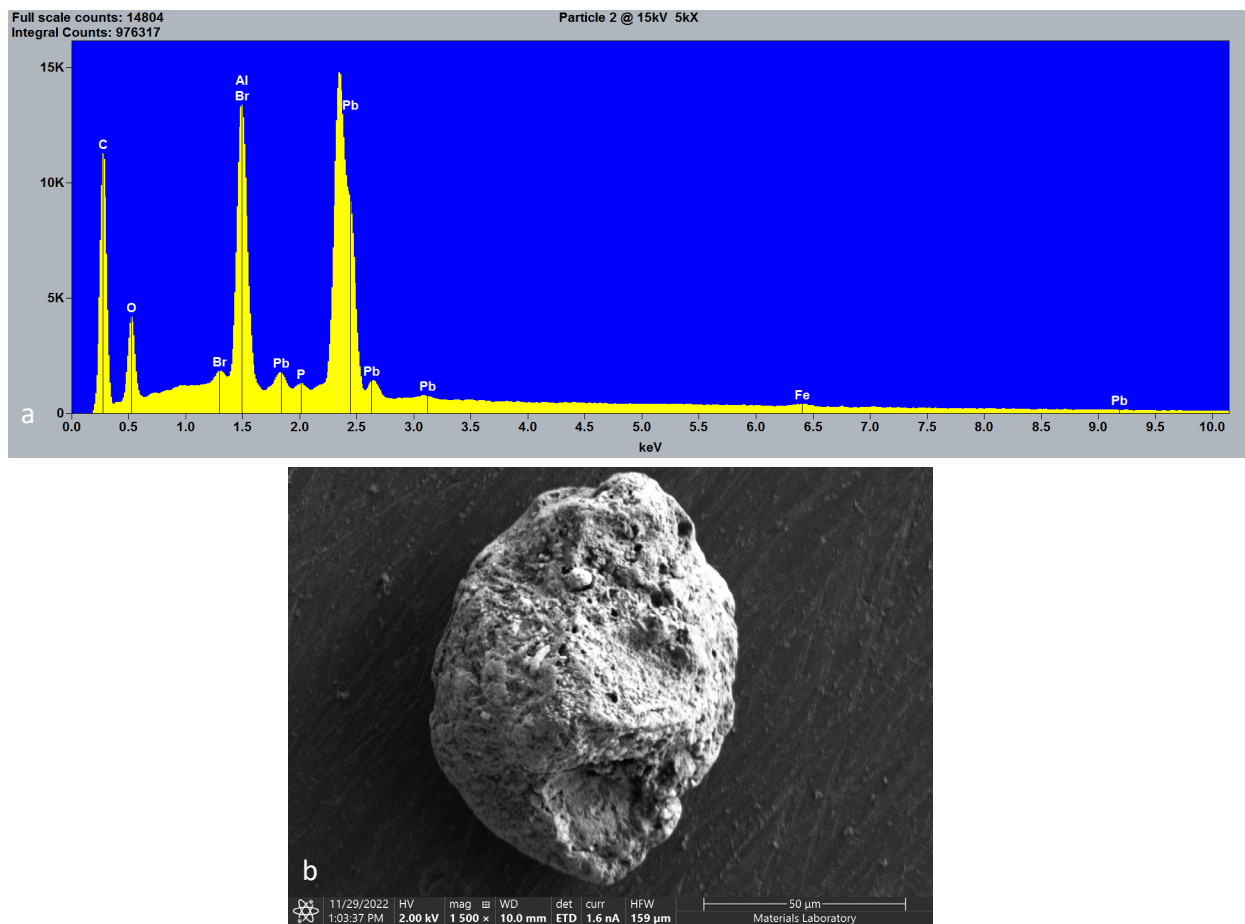


Figure 10. Spectrum and scanning electron microscope image (view b) of a particle comprising carbon, oxygen, bromine, lead, and trace iron.

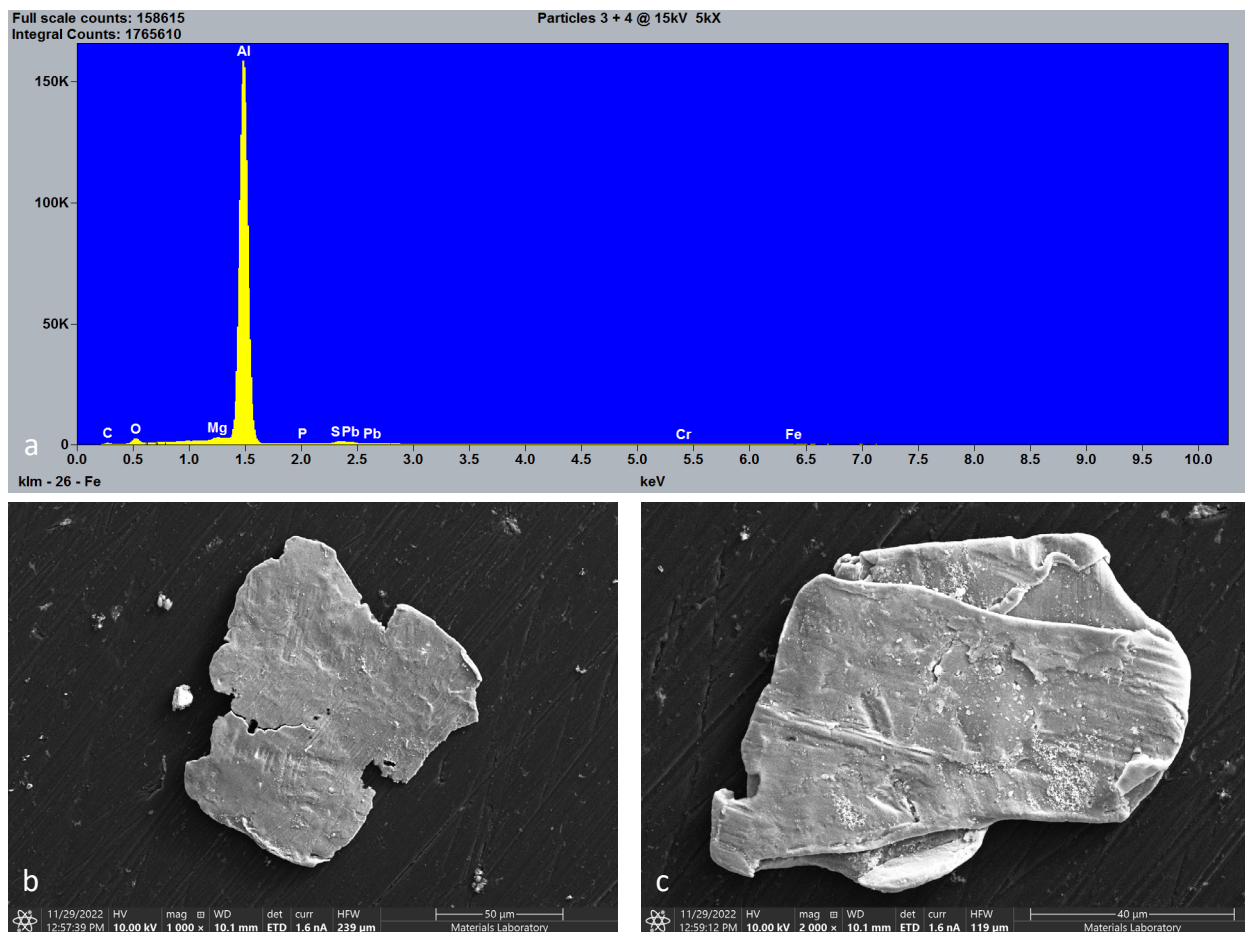


Figure 11. Spectrum and scanning electron microscope images (views b and c) of predominantly aluminum particles.



Figure 12. Image showing the pieces recovered from the engine after teardown. The pieces are approximately grouped according to their function. Table 1 provides a description of the pieces.

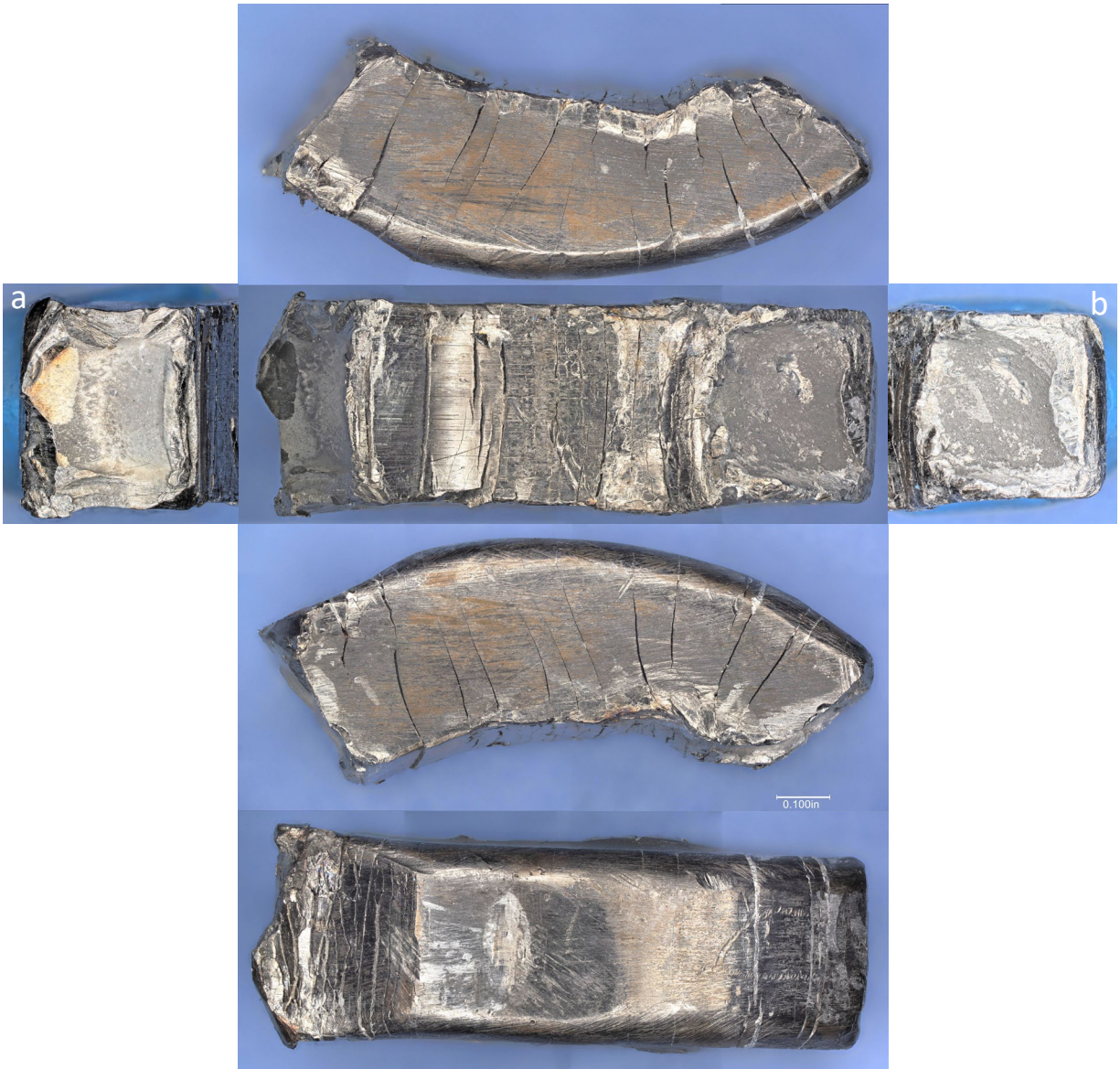


Figure 13. Close digital microscope images of item 11a in Figure 12. Left and right fracture faces are shown in views a and b, respectively.

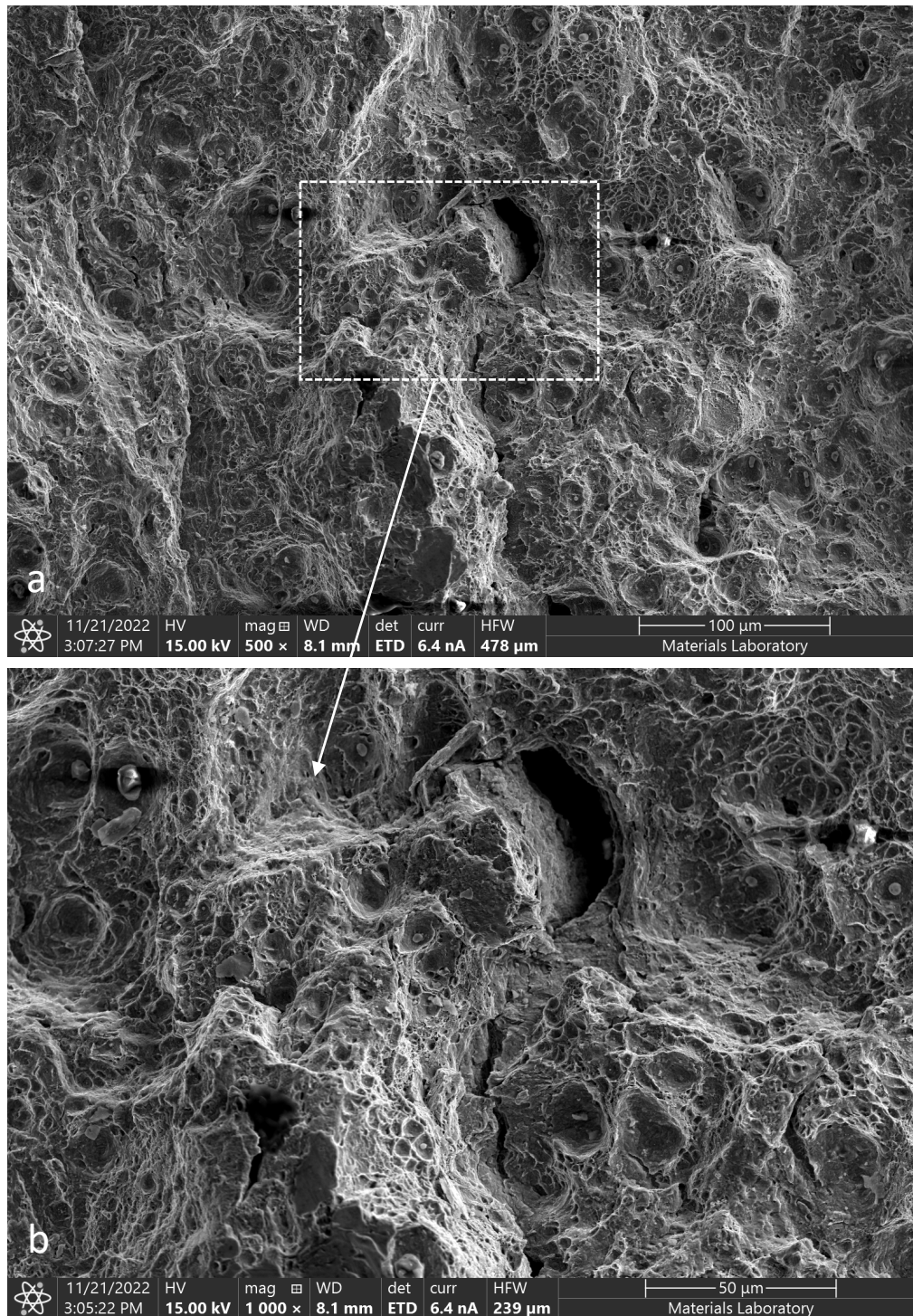


Figure 14. Secondary scanning electron fractograph of the fracture face on the left side of item 11a shown in Figure 13a. Dimpled rupture fracture features are observed.

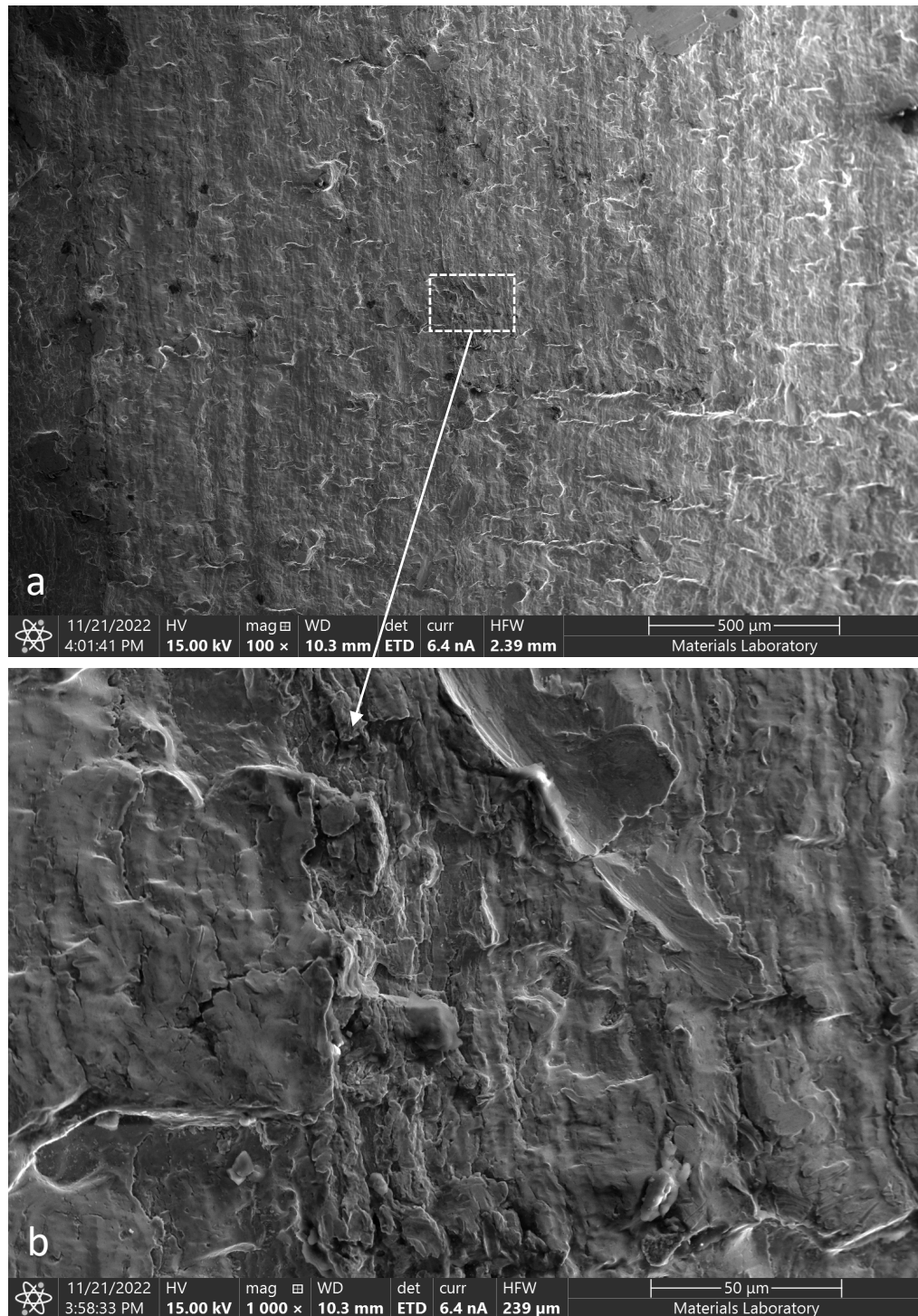


Figure 15. Secondary scanning electron fractograph of the fracture face on the right side of item 11a shown in Figure 13b. Progressive fracture features are observed.

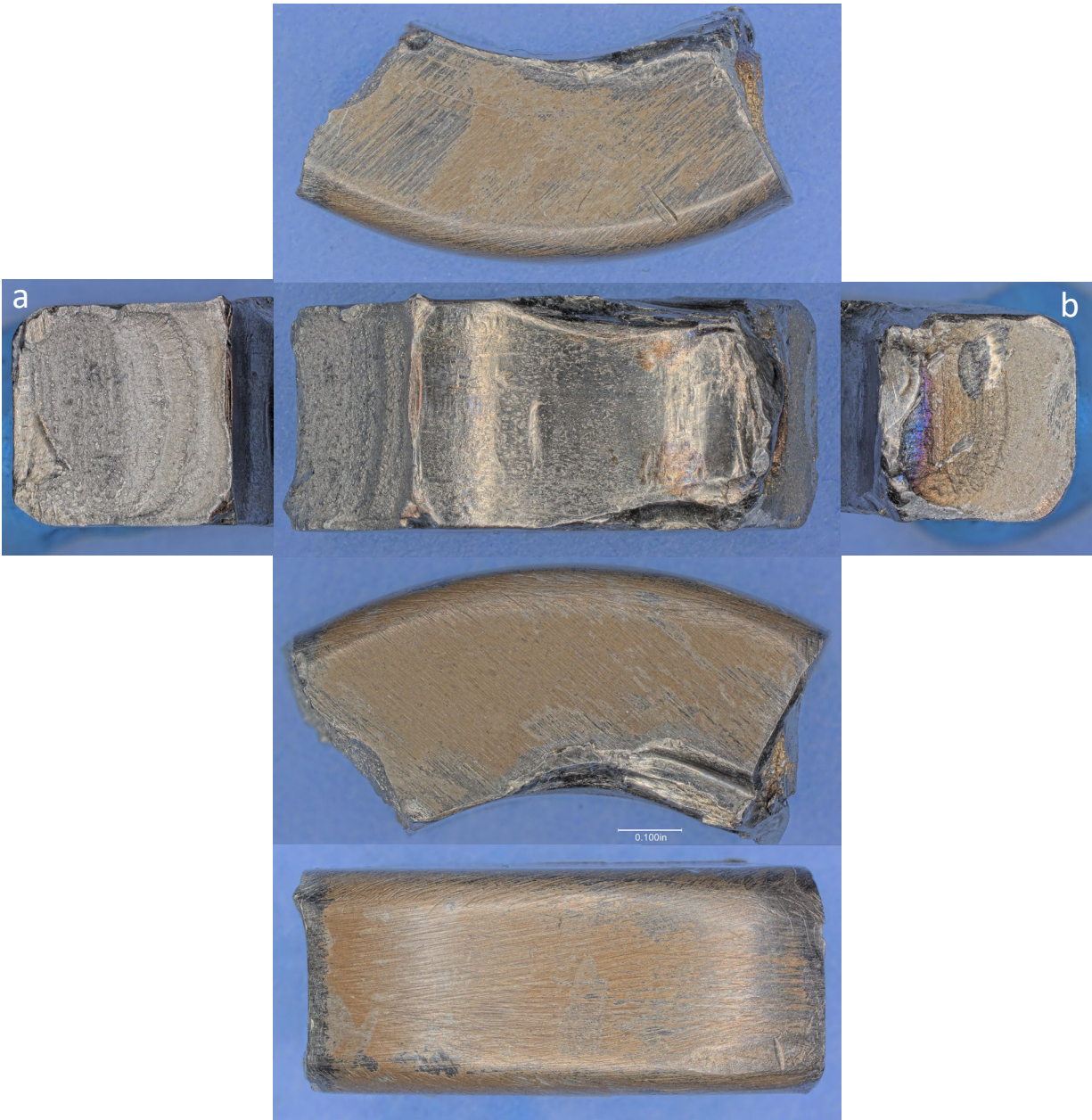


Figure 16. Close digital microscope images of item 11b in Figure 12. Left and right fracture faces are shown in views a and b, respectively.

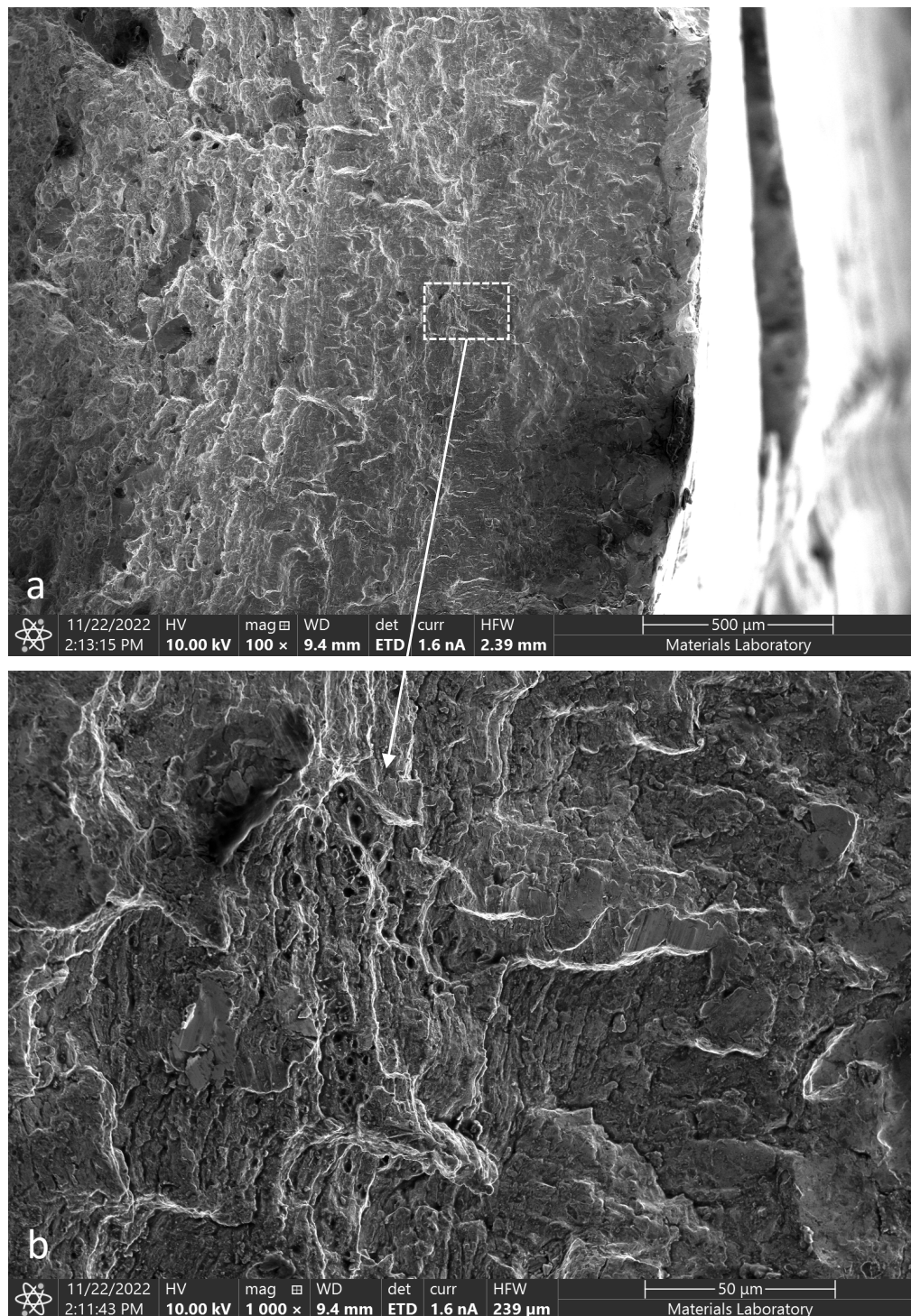


Figure 17. Secondary scanning electron fractograph of the fracture face on the left side of item 11b shown in Figure 16a. Progressive fracture features are observed.

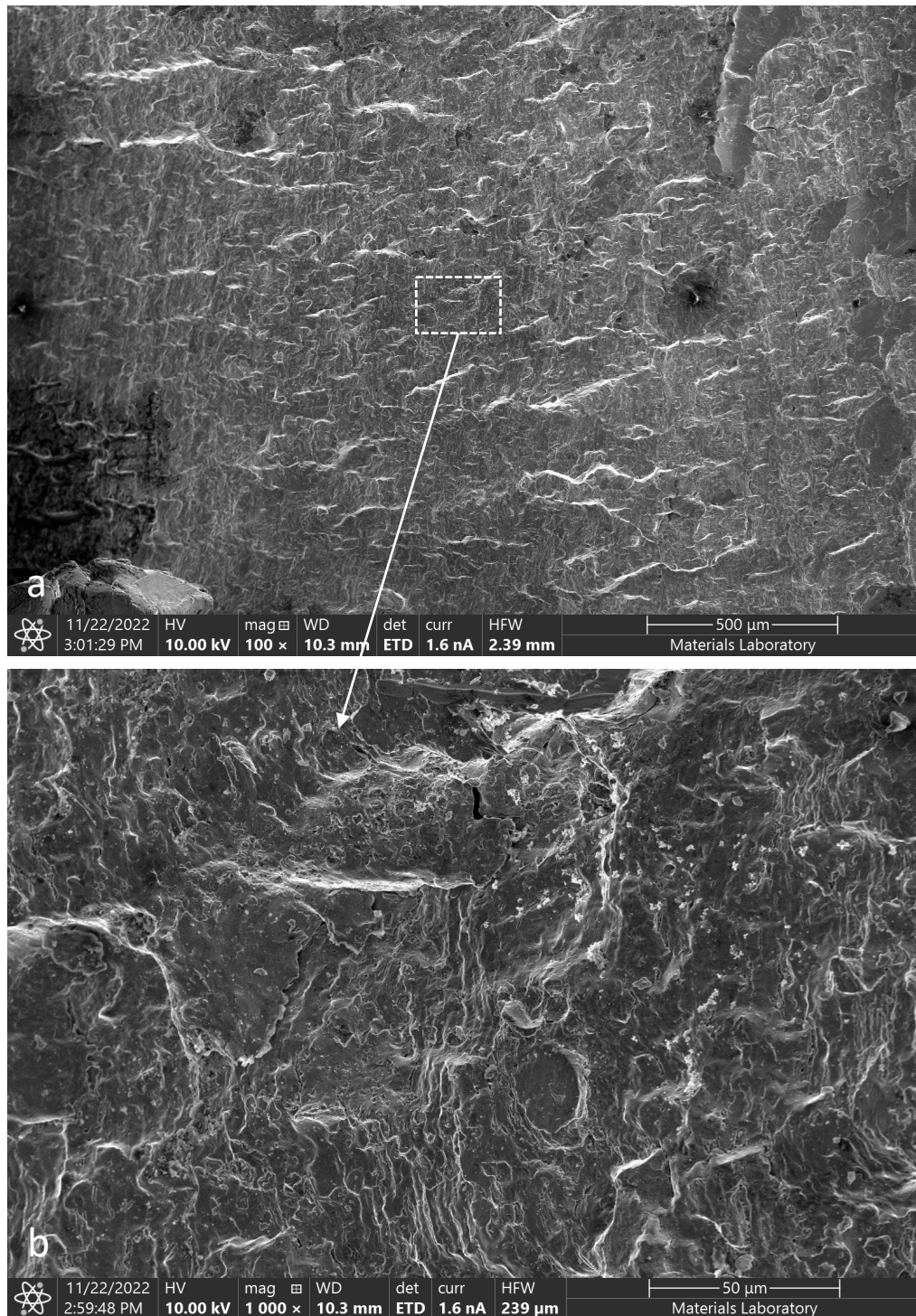


Figure 18. Secondary scanning electron fractograph of the fracture face on the right side of item 11b shown in Figure 16b. Progressive fracture features are observed.

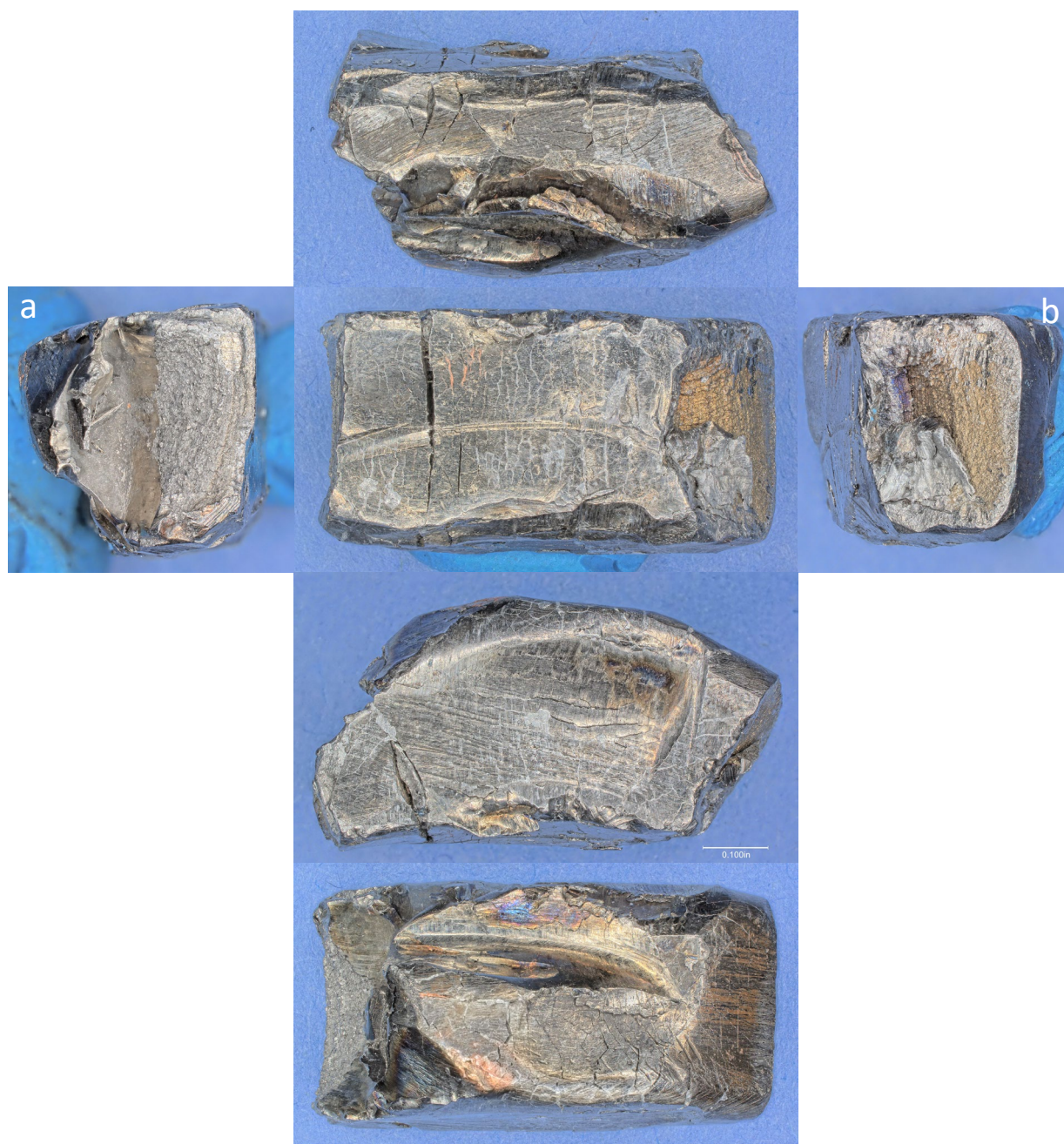


Figure 19. Close digital microscope images of item 12 in Figure 12. Left and right fracture faces are shown in views a and b, respectively.

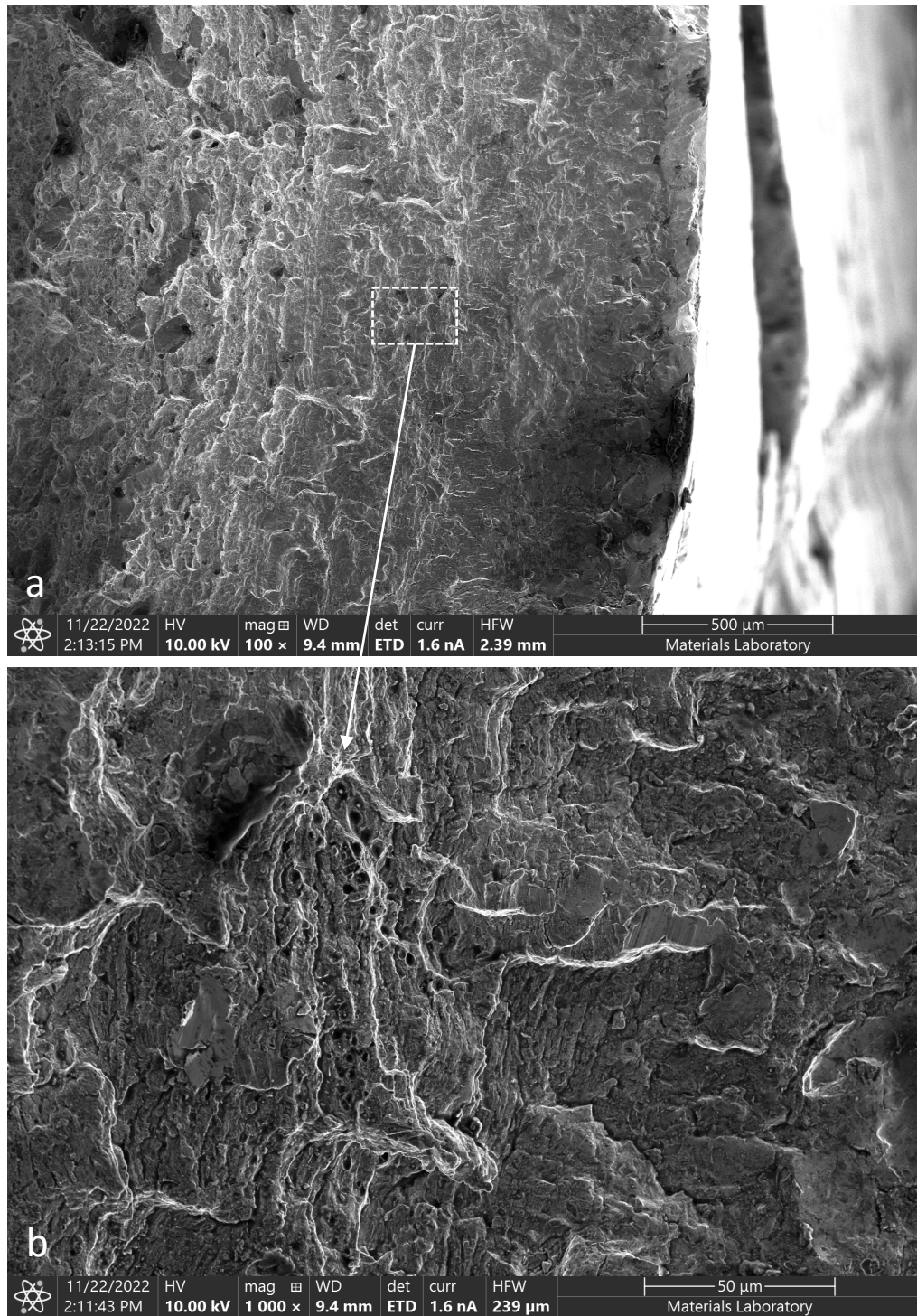


Figure 20. Secondary scanning electron fractograph of the fracture face on the left side of item 12 shown in Figure 19a. Progressive fracture features are observed.

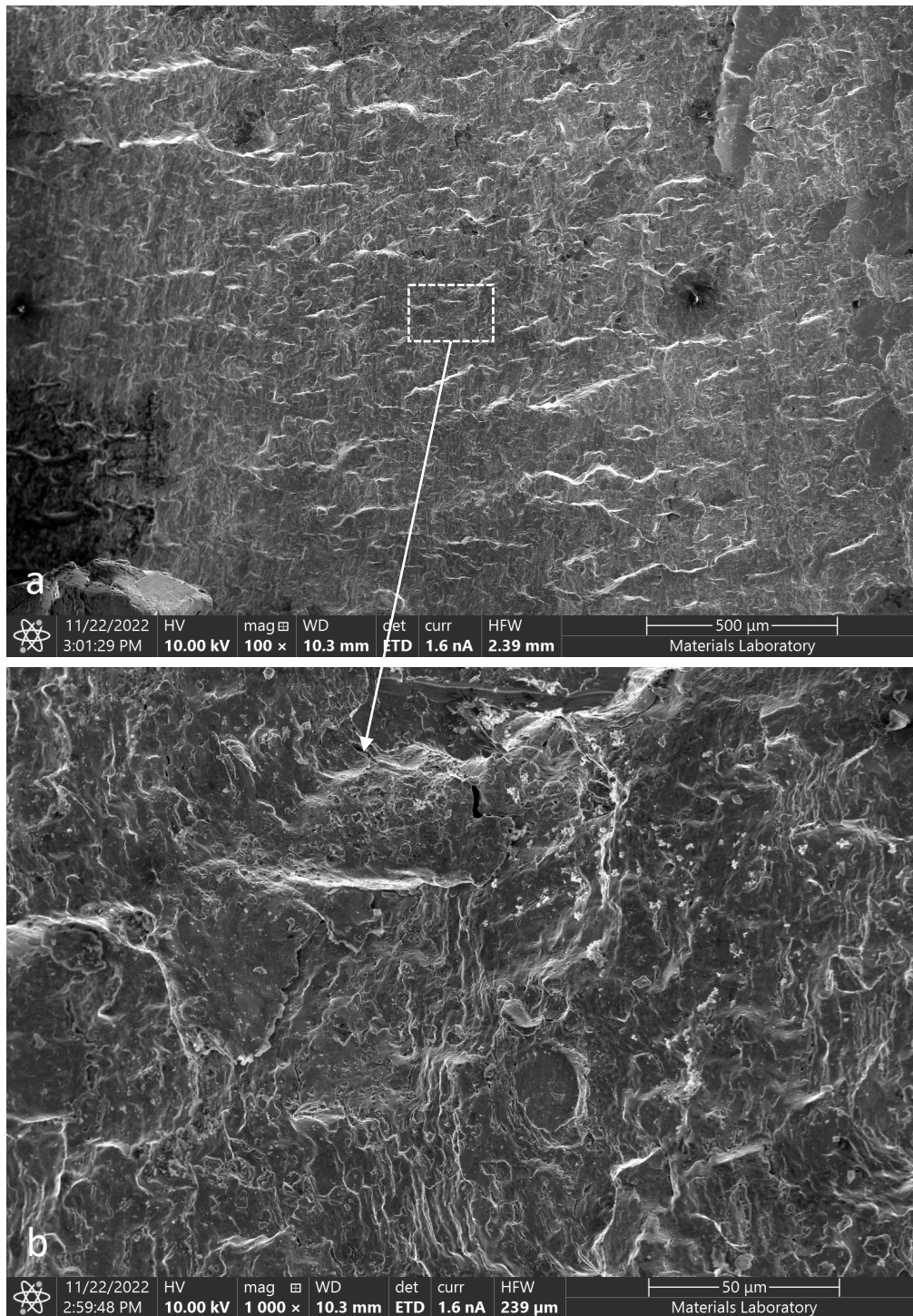


Figure 21. Secondary scanning electron fractograph of the fracture face on the right side of item 12 shown in Figure 19b. Progressive fracture features are observed.

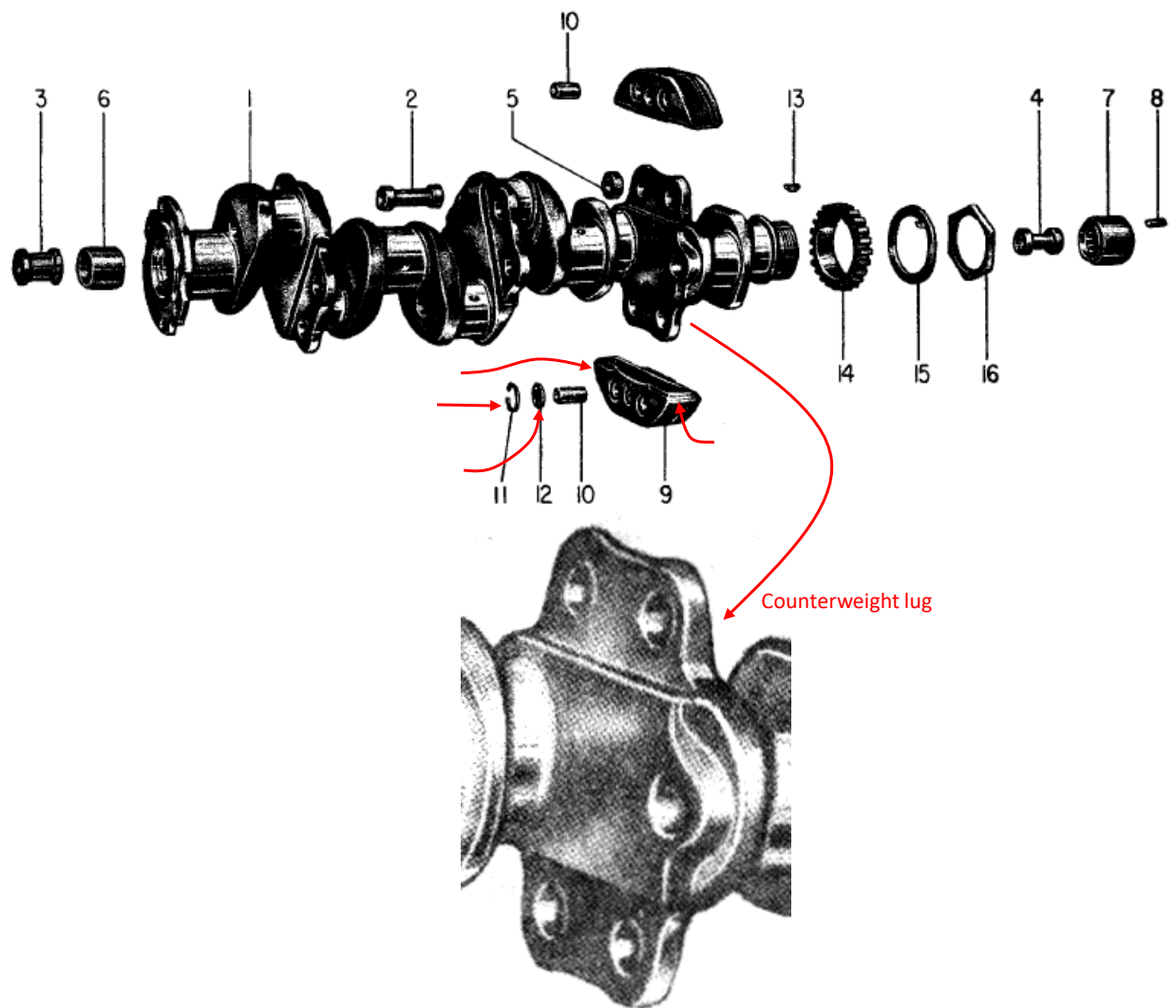


Figure 22. Images from the Lycoming Aircraft Engines Parts Catalog for GSO-480 and IGSO-480 Series Aircraft Engines with key components indicated.