NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

October 7, 2021

MATERIALS LABORATORY FACTUAL REPORT Report No. 21-068

A. ACCIDENT INFORMATION

Place	:	ANC21LA064
Date	:	July 23, 2021
Vehicle	:	Piper PA-14, N4206H
NTSB No.	:	ANC21LA064
Investigator	:	Shaun Williams, AS-WPR

B. COMPONENTS EXAMINED

Section of rudder post.

C. DETAILS OF THE EXAMINATION

An overall view of the submitted rudder post piece is shown in figure 1. The rudder post was cracked approximately ¼ inch above the upper hinge barrel. The crack extended around most of the circumference, and the upper portion of the post was bent to the left relative to the lower portion, thereby separating the crack faces at the right side. The cracked post section had been cut from the remainder of the rudder to facilitate shipment to the NTSB Materials Laboratory.

On the right side of the post, the fracture surfaces were on flat planes perpendicular to the longitudinal axis, features consistent with fatigue. Step-like features (ratchet marks) were observed between offset planes consistent with multiple origins at the outer diameter along the right side in the bracketed area shown in figure 1.

To further examine the fracture surfaces, the remaining ligament of bent tube wall on the left side of the post was fractured in the lab by overstress bending to complete the separation of the two sides of the crack. The rudder skin on the upper piece was then peeled away from the post. Next, a transverse cut was made through the upper piece approximately 1 inch away from the fracture surface. The piece with the upper side of the fracture was then submerged in Evapo-Rust[1] for approximately 15 minutes followed by light brushing of the surface using a soft-bristle brush dipped in Evapo-Rust. The resulting fracture surface is shown in figure 2. Radial features with crack arrest lines were observed consistent with fatigue from multiple origins at the outer diameter as indicated by unlabeled arrows in figure 2.

[1] Evapo-Rust is manufactured by Harris International Laboratories, Springdale, Arkansas.

Next, the two pieces of the cut upper portion of the post segment were soaked in Cee Bee A-202 epoxy and polyurethane stripper,[2] and the coatings were scraped away using wood and plastic scrapers. The resulting exposed metal surface on the upper cut piece is shown in figure 3. The surface had a uniform gray appearance with a surface finish consistent with a grit-blasted surface.

The piece with the upper side of the fracture was further examined using a scanning electron microscope (SEM). Multiple fatigue origins were identified on the right side including the area shown in figure 4. The fatigue originated from corrosion pits on the exterior surface such as the pit shown in figure 5. Sizes of corrosion pits were measured at two of the fatigue origins. The pit shown in figure 5 measured 0.0119 inch (302 micrometers) wide and 0.0014 inch (35 micrometers) deep. At a nearby origin area, a pit at that fatigue origin measured 0.0131 inch (332 micrometers) wide and 0.0018 inch (45 micrometers) deep.

The fracture surface showed damage including rubbing and pitting damage in the fatigue regions. However, fatigue striations were observed in undamaged areas such as the area shown in figure 6, which was imaged near the crack arrest line shown in figure 4. Fatigue fracture features were identified around approximately ¼ of the circumference on the right side, but the total extent of fatigue cracking could not be determined conclusively due to post-fracture contact damage on the surfaces.

The exterior surface adjacent to the fracture was also examined using the SEM, and a typical view of the exterior surface is shown in figure 7. Pockets of primer material remained on the surface, appearing both darker gray and bright white in figure 7.[3] Upon closer examination, faceted particles such as the one shown in figure 8 were observed embedded in the surface. The particles were analyzed using energy dispersive x-ray spectroscopy (EDS), and the resulting spectra showed high peaks of magnesium, silicon, and oxygen with smaller peaks of carbon, aluminum, calcium, and iron, consistent with olivine abrasive blasting media.

In the stripped area on the upper piece shown in figure 3, the thickness of the tube wall measured 0.0350 inch, and the outer diameter measured 0.871 inch. According to engineering drawings for the part number 40622-3 rudder post, the tube for the rudder post was specified as a 7/8-inch tube with a wall thickness of 0.035 inch.

One side of the upper rudder post piece shown in figure 3 was sanded with 240-grit abrasive paper to expose material below the grit-blasted surface, and the sanded area was then ground to a 600-grit finish. The sanded area was then tested using a Rockwell hardness indenter. Initial tests using the HRB scale were invalid due to the thickness of the wall and resulted in visible deformation around the indentation. Next, a nearby area was tested using the HR30T scale. The resulting measured hardness was

[2] Manufactured by McGean-Rohco, Inc., Cleveland, Ohio.
[3] The primer appears darker due to the difference in atomic weight between the coating and the underlying steel. The bright white areas are an artifact of SEM imaging called charging, where relatively high levels of electrons are emitted to the SEM detector by non-conductive materials.

76.3 HR30-TW (including a correction for convex curvature),[4] which is equivalent to 90 HRB.[5] The estimated tensile strength corresponding to the measured hardness is 89 ksi,[6] which is slightly below the expected minimum tensile strength of normalized AISI 4130 low-alloy steel.

The composition of the rudder post was analyzed using an Olympus Vanta C-Series alloy analyzer. The material associated with the rudder post was identified as carbon steel, consistent with AISI 1025 carbon steel originally specified for use in the rudder post until the material was changed to AISI 4130 low alloy steel in a Piper engineering change order dated June 3, 1974. The accident airplane was manufactured in 1948.

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[4] ASTM Standard E18-20, *Standard Test Methods for Rockwell Hardness of Metallic Materials*, ASTM International, West Conshohocken, PA, 2020, www.astm.org
[5] ASTM E140-12B(2019)e1, *Standard Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness*, ASTM International, West Conshohocken, PA, 2019, www.astm.org
[6] ASTM Standard A370-20, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*, ASTM International, West Conshohocken, PA, 2020, www.astm.org

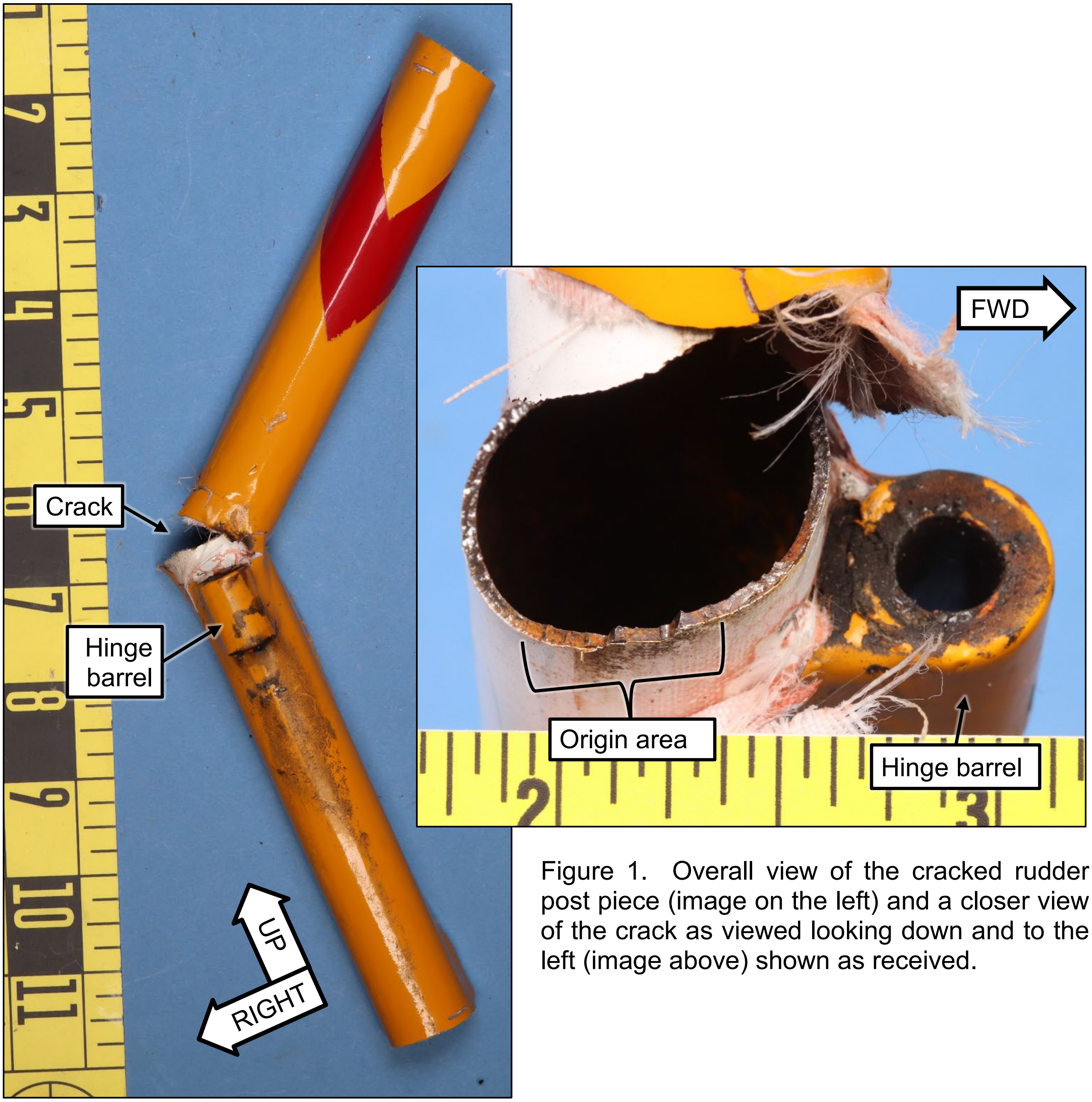

Figure 1. Overall view of the cracked rudder post piece (image on the left) and a closer view of the crack as viewed looking down and to the left (image above) shown as received.

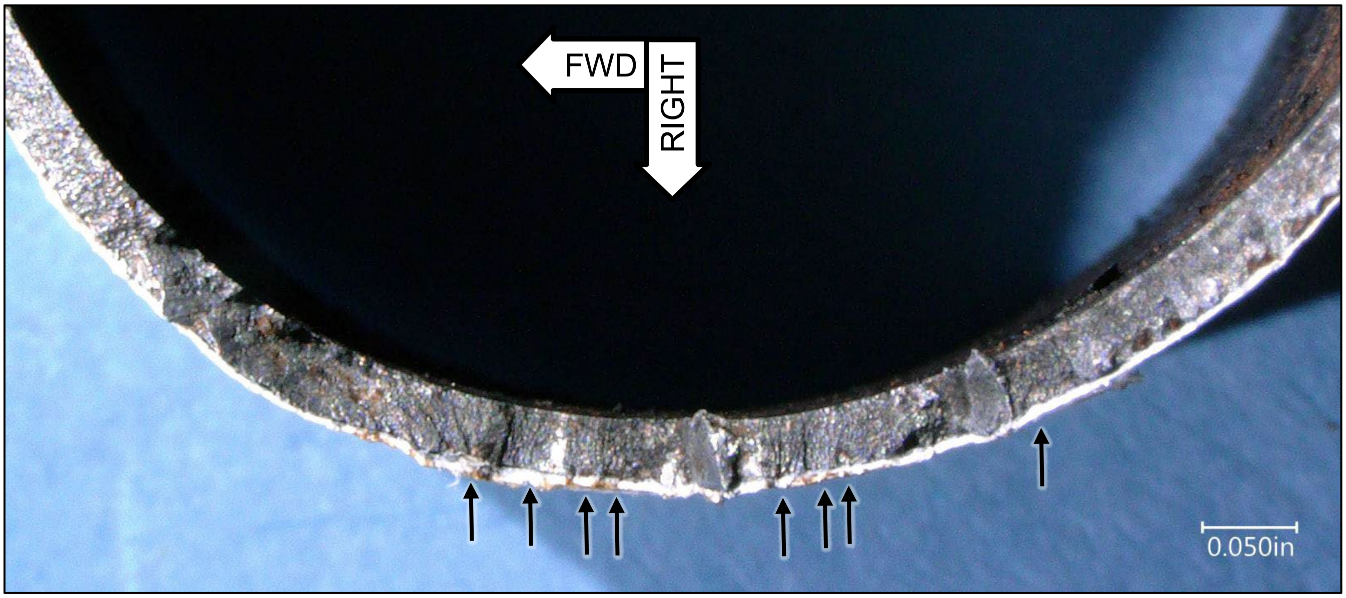

Figure 2. Upper side of the crack surface after the fracture surfaces were deoxidized. Unlabeled arrows point to multiple origins at the outer diameter on the right side.

Figure 3. Upper post section after paint and primer were stripped from the surface.

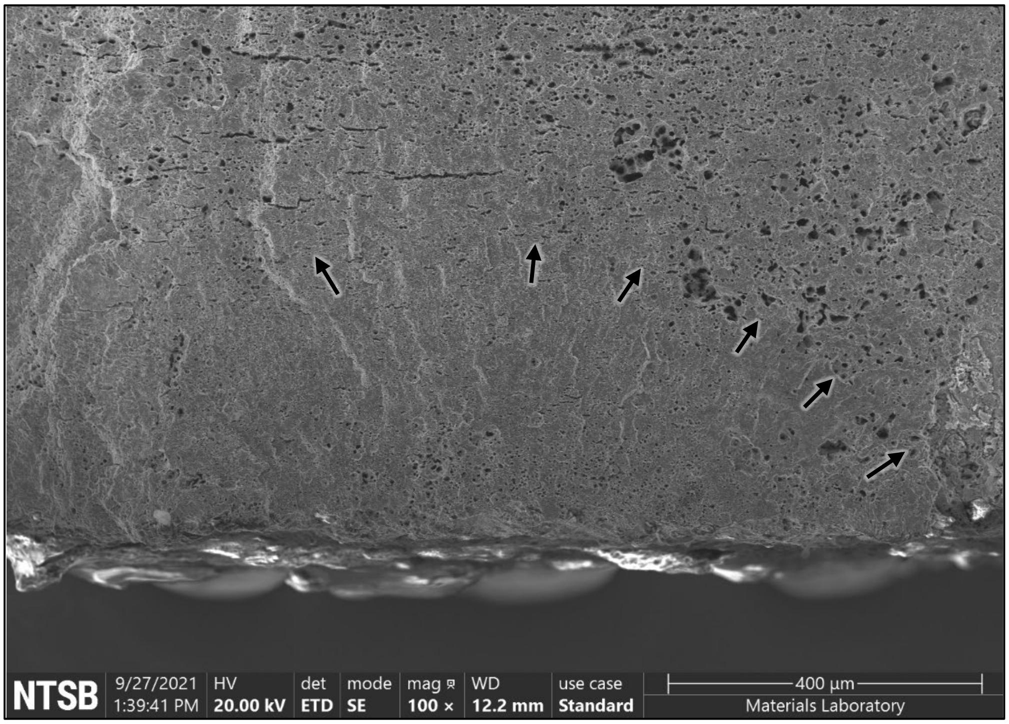

Figure 4. SEM image of one of the fatigue origin areas. Unlabeled arrows indicate a crack arrest line partially visible on the surface.

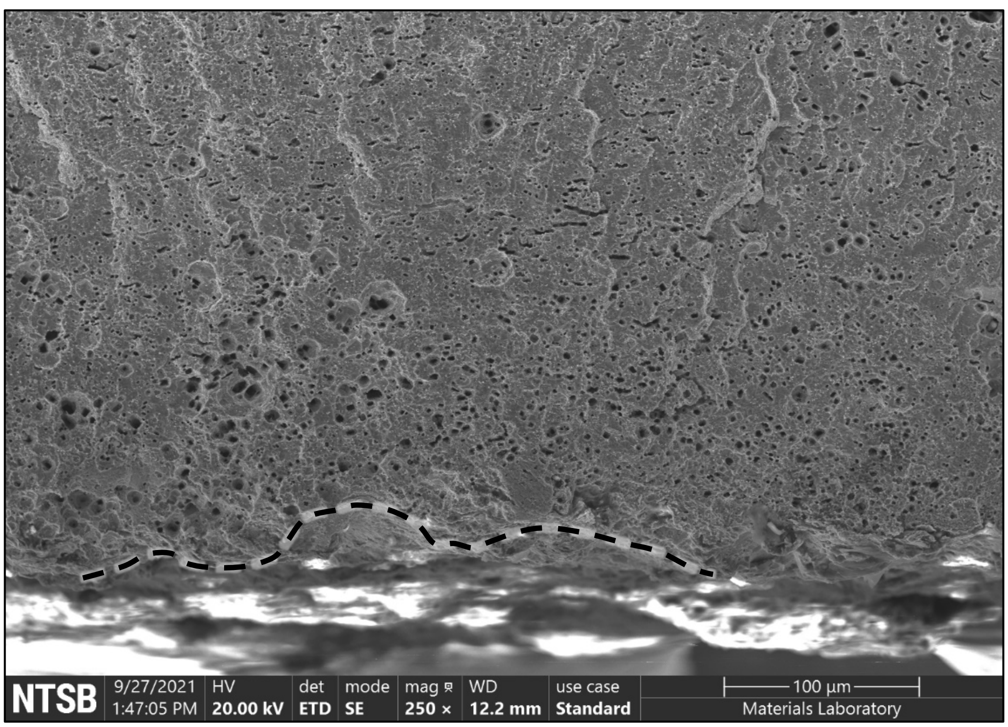

Figure 5. SEM image of the origin area at higher magnification showing a corrosion pit at the origin. A dashed line indicates the pit boundary.

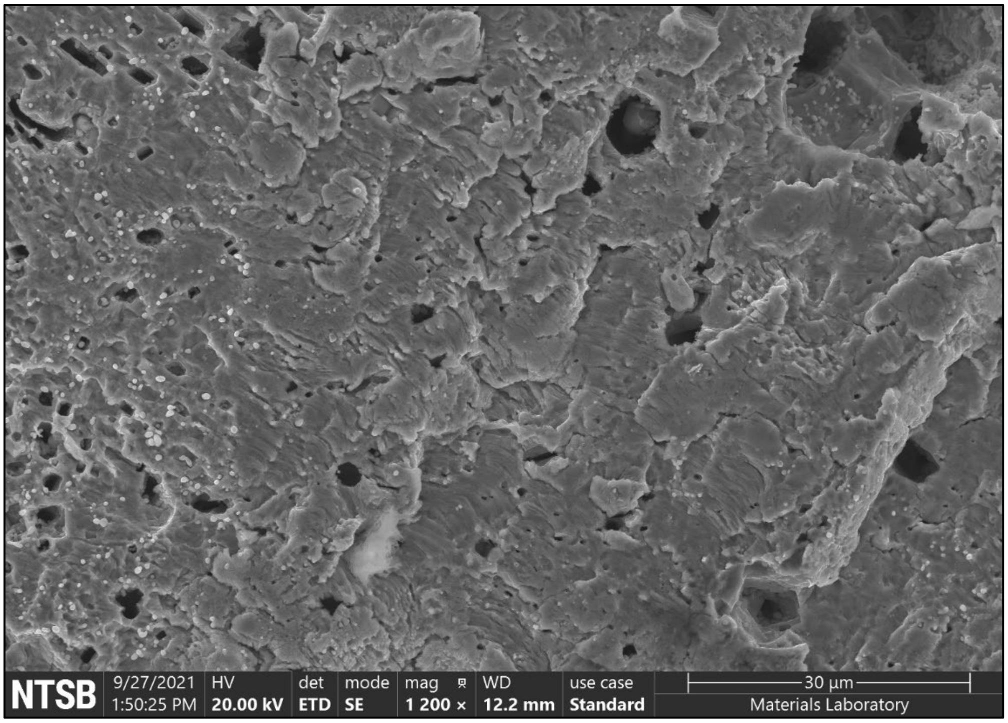

Figure 6. SEM image of fatigue features near the crack arrest line shown in figure 4.

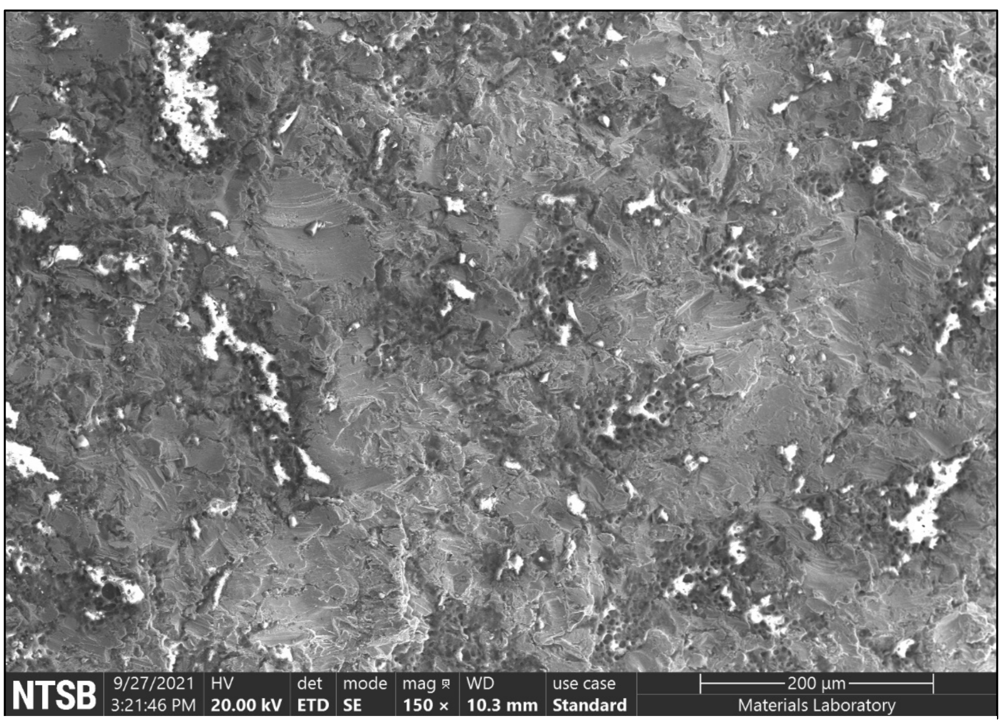

Figure 7. SEM image of the external surface on the post showing pockets of primer on the grit-blasted surface.

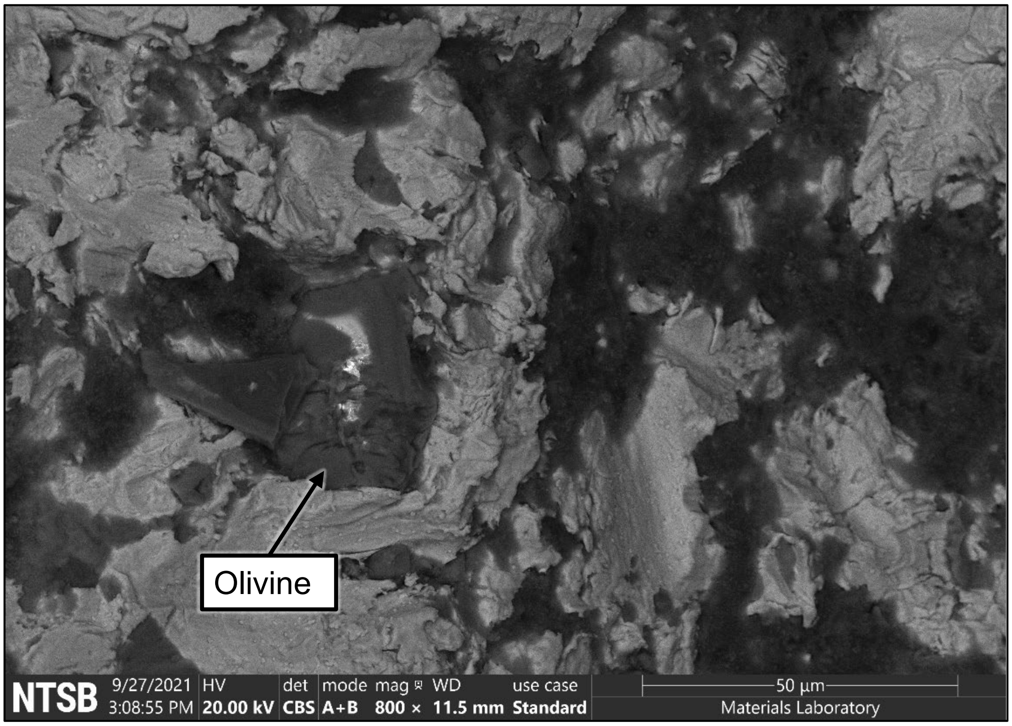

Figure 8. SEM image using a backscattered electron detector showing a particle having a composition consistent with olivine embedded in the surface.