SYNOPSIS:
Analysis of an Aluminum Specimen

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for the All-Domain Anomaly Resolution Office (AARO)

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Executive Summary

The All-Domain Anomaly Resolution Office (AARO) sponsored a series of measurements on drill shavings and a small sectioned piece from a metallic specimen. Oak Ridge National Laboratory (ORNL) independently performed multiple, cross-validated measurements showing that the material is a conventional, near-eutectic aluminum–silicon alloy (i.e., an ordinary aluminum alloy made for common applications). Its chemistry, microstructure, internal porosity, and lack of radiological signature are consistent with decades of known industrial practice, specifically falling within the profile of standard 300/400-series casting alloys that have been widely produced since at least the 1970s.

AARO requested a technical analysis of a metallic specimen with claimed association to an unidentified phenomenon occurring over central Ohio in the mid-1990s. ORNL was charged with evaluating specific assertions of unusual sample composition. ORNL received three bags of drill shavings and one small bulk piece of the specimen—integrating chemical assays, multiscale imaging, x-ray spectroscopy, and gamma spectroscopy to perform this evaluation.

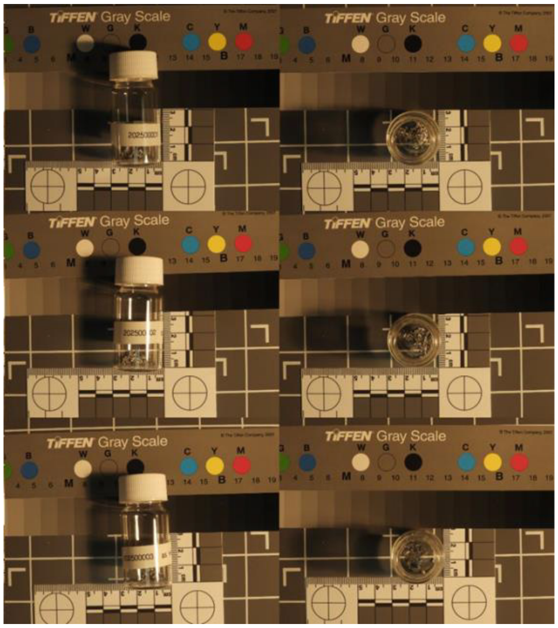
ORNL found the sample exhibits the following qualities: (1) aluminum composition with approximately 12% silicon by weight; (2) standard second phases and casting pores; (3) features indicating slow-cooling, consistent with conventional large casting in a mold; and (4) no abnormal gamma emission. Nothing in the data suggests novel physics or exotic origin.

Specifically, microscopy revealed silicon plates/needles, iron- and manganese-bearing intermetallic second phases, and shrinkage porosity—features that are typical of slow-cooled castings. The sample's chemical composition shows no evidence of elements outside those expected for conventional aluminum metallurgical engineering, and gamma spectroscopy showed no unexpected emission.

In conclusion, none of these data support claims of unusual characteristics. The evidence points to ordinary, terrestrial industrial metallurgy consistent with parts used in (late 20th century) automotive, aerospace, and consumer applications. These conclusions are robust for the samples provided and for the methods described herein.

1. Overview

AARO is congressionally mandated to investigate unidentified anomalous phenomena (UAP) incidents and publicly report its findings. AARO sponsored a series of measurements on a metallic alloy composed of primarily aluminum and silicon, claimed to have association with a UAP in or around 1995 and further asserted to have nonstandard composition. AARO secured science and technology partner ORNL, one of 17 US Department of Energy National Laboratories, to independently assess and perform thorough characterization studies on samples from the specimen, leveraging ORNL's 80-year history of world-leading materials science expertise.



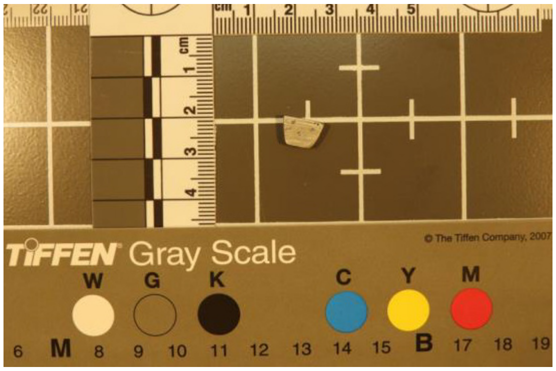


Figure 1. Photographs of the received samples. (Left) Metal shavings in their transfer vials. (Above) The main mass material.

The central charge to ORNL was to investigate (1) the composition of the metal, (2) whether the chemistry or structure is anomalous, and (3) whether it emits a gamma-ray signal. Drawing on established, peer-reviewed methods and side-by-side quality controls, ORNL found that the sample is a conventional near-eutectic aluminum–silicon alloy near the Al–Si eutectic composition.

A eutectic composition is an alloy that melts at a lower temperature than either of its individual components and typically exhibits superior castability and fluidity, making such alloys preferred for manufacturing applications where shaping of parts is critical. Eutectic compositions are thus well understood and common in manufacturing—details are documented on phase diagrams that show where an alloy in liquid form transforms into separate solid phases simultaneously upon cooling. Specifically, the sample in question can be best described as a eutectic aluminum–silicon alloy nearly, though not perfectly, matching American Society for Testing and Materials (ASTM) designations A413.1/369.1.

In addition to finding no evidence of unusual elements or chemistries that would imply novel mechanisms, ORNL found no evidence of rapid cooling or gamma emission.

The use of multiple, independent methods (with calibration against recognized standards) reduces the chance of a systematic error and increases confidence that these samples are representative of the source part. Additional pieces from different locations of the original component, or access to manufacturing records, could narrow the identification to a specific catalog grade and heat treatment, but such data are not necessary to support the central findings reported here, which indicate no behaviors inconsistent with ordinary cast aluminum.

2. Methods

To identify the alloy family and probe claims of unusual behavior, ORNL combined multiple complementary methods that analyze different size samples with cutting-edge precision.

2.1 **Bulk chemistry/elemental makeup —** Portions of the shavings were dissolved and analyzed by inductively coupled plasma (ICP) optical emission spectroscopy (OES) for major and minor elements and by high-resolution ICP mass spectrometry (MS) for trace elements. The bulk piece was analyzed by glow discharge (GD)-MS to cross-check the overall composition. *Chemistry is the primary fingerprint of an alloy; if an element were out of place or at an unusual level, it would appear here.*

2.2 **Structure from micro- to macroscale —** Individual shavings and polished cross-sections were examined by scanning electron microscopy energy dispersive x-ray spectroscopy (SEM-EDS) to visualize the distribution of elements and features such as grains and precipitates. X-ray computed tomography (CT) provided a 3D view of internal pores and their connectivity (i.e., casting features). *Structure reveals how a specimen was made—cast versus wrought, fast-cooled versus slow-cooled—and whether it resembles known industrial practice.*

2.3 **Signal detection/monitoring —** Gamma spectroscopy monitored three of the metallic samples for a period of approximately two days. This technique is sensitive to a wide band of isotopes and low levels of emission. *This evaluated whether unusual signals were emitted from the metal.*

3. Results

3.1 **Chemistry: An Al–Si alloy —** Results indicate that the sample is an aluminum–silicon (Al-Si) alloy near the Al–Si eutectic. The dominant elements are aluminum (~86 wt%) and silicon (~12 wt%), followed by iron (Fe, ~1 wt%), copper (Cu, ~0.37 wt%), magnesium (Mg, ~0.30 wt%), zinc (Zn, ~0.20 wt%), and manganese (Mn, ~0.20 wt%). Several other elements (lead [Pb], chromium [Cr], nickel [Ni], titanium [Ti], and gallium [Ga]) appear only at trace levels (tens to hundreds of parts per million). These are the expected elements within common casting grades and do not suggest exotic additives. The shavings and the bulk sample had identical chemistry for all elements measured, by multiple techniques, within the analytical uncertainties of the instruments. *This chemical composition is consistent with a near-eutectic Al–Si casting alloy—conventionally used when designing molten aluminum to flow easily into a mold and reproduce fine details.*

Table 1. Bulk composition summary (weight %). Values are rounded; trace elements shown for context. Analyses of the bulk sample and shavings were compositionally consistent.

Instrument	Element	wt%
GD-MS	Al	86.10
GD-MS	Si	11.90
ICP-OES	Fe	0.97
ICP-OES	Cu	0.37
ICP-OES	Mg	0.30
ICP-OES	Zn	0.20
ICP-OES	Mn	0.20
ICP-MS	Pb	0.04
ICP-MS	Cr	0.03
ICP-MS	Ni	0.03
ICP-OES	Ti	0.03
ICP-MS	Ga	0.01

3.2 **Shavings vs. cross-sectioned shavings: Impact of drilling changes —** The shavings given to ORNL show folding tool marks from drilling performed before AARO acquired the material. The undisturbed interior was exposed by embedding the sample in epoxy, cross-sectioning, and polishing. In the interior, ORNL observed a suite of phases consistent with standard cast Al–Si alloys: aluminum matrix, needle- and block-shaped silicon, Fe/Mn-rich intermetallics, and occasional Cu/Mg-bearing precipitates. Small Pb-rich pockets are present but scarce in both the bulk and shavings, most likely representing incidental impurities commonly seen at very low levels in industrial feedstocks and tooling. *This indicates that the alloy's chemical identity is not an artifact of machining: the bulk interior matches the chemistry and phase assemblage inferred from the shavings.*

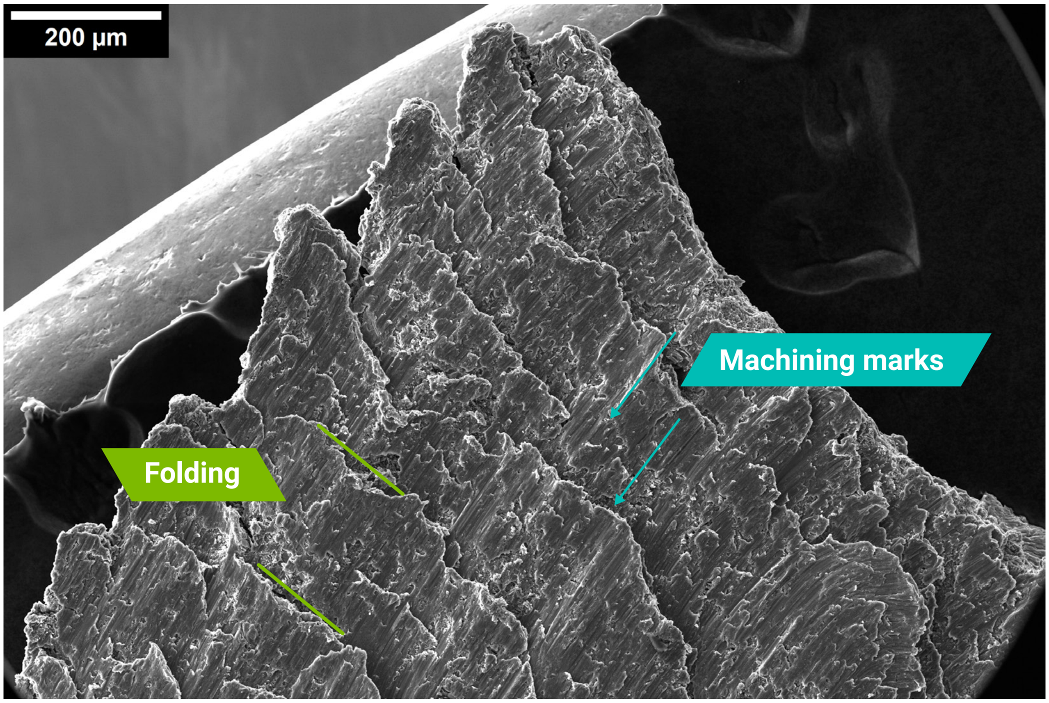


Figure 2. An individual shaving on a carbon sticky tape background and SEM stub, imaged at low magnification.
Machining marks and deformation are noted (20 kV, in-column electron detector).

3.3 Bulk piece and computed tomography: Slow-cooled with connected porosity — The specimen shows microstructure consistent with cast Al–Si: thin plates and needles of Si embedded in an aluminum matrix; small particles rich in Fe and Mn; and Mg–Si–Cu precipitates. The spacing and size of these features (several hundred micrometers), together with the pattern of interconnected pores, indicate slow cooling—likely in a mold, as in a large sand or permanent-mold casting. Fast quenching (i.e., rapid cooling) produces a much finer microstructure (tens of micrometers) that was not observed.

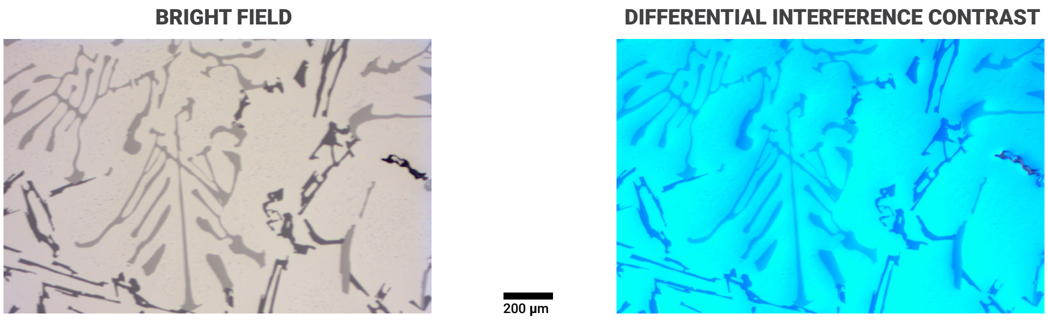


Figure 3. Optical micrographs of the polished bulk section.
Background is aluminum; darker shading shows precipitates.

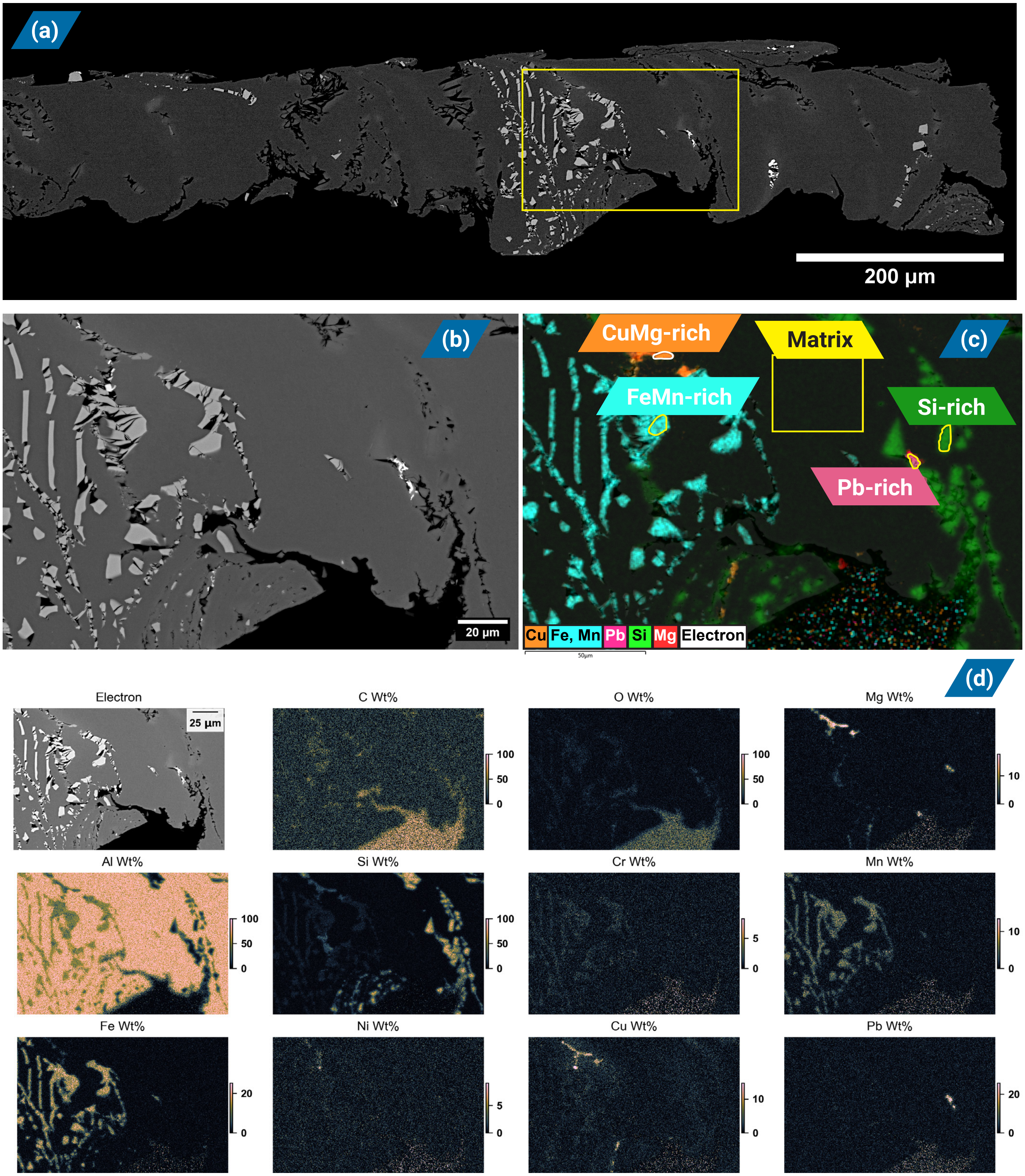


Figure 4. 20 kV electron beam, polished shavings sample. (a) Low-magnification concentric backscatter electron image showing a surface of one end of a shaving. (b) Area denoted in the yellow box of (a), showing multiple phases from the epoxy (black), matrix (dark), and various intermetallics and second phases (medium gray to white). (c) False-color x-ray map denoting the major phases; marked areas are quantified. (d) Quantitative X-ray mapping of the major and minor elements. The metal atoms' speckle in the epoxy region is noise. Rough compositions in weight percent of the marked regions in (c): **Cu-rich**: 46Al, 22Si, 19Mg, 13Cu. **Matrix**: 98Al, 2Si, trace Cu. **FeMn-rich**: 61Al, 22Fe, 10Si, 6Mn, possible trace Cu. **Si-rich**: 79Si, 21Al. **Pb-rich**: 35Al, 33Pb, 13Si, 12O, 6Mg, trace others.

The bulk specimen's interior contains clusters of winding, interconnected pores—a typical pattern of interdendritic shrinkage that occurs as castings solidify and contract. The large pore size (from 0.5 mm to over 1 mm) suggests a relatively slow cooling rate, which is typical of thick-section or larger molds. *Together, the porosity, intermetallics, and Si features are consistent with a sample that was gradually cooled from a large cast.*

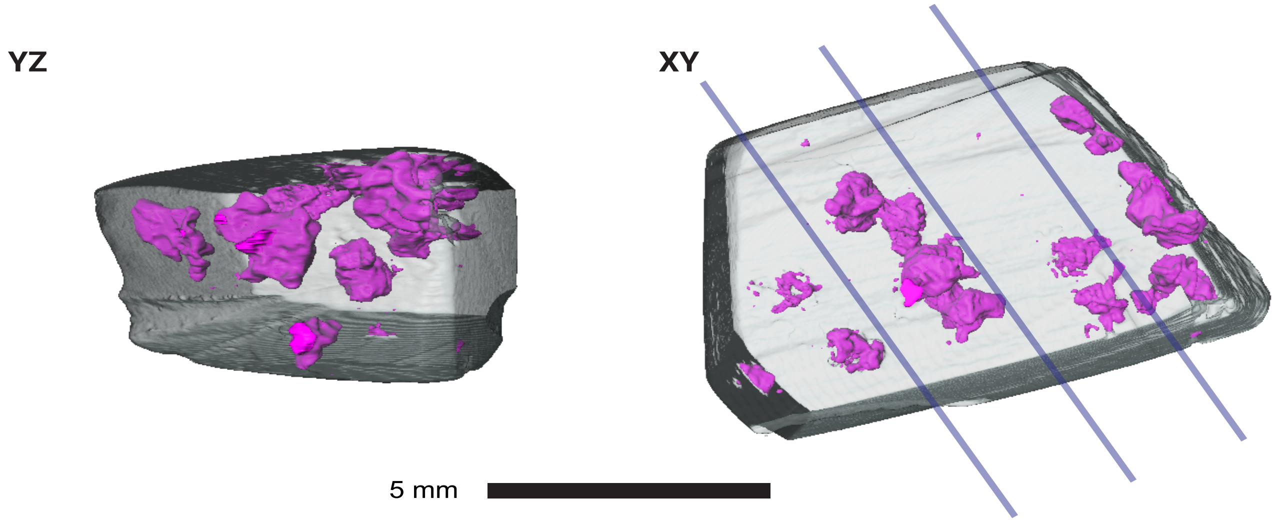


Figure 5. Two renderings from the XCT data. The purple surfaces are the pores. Light blue lines are the approximate location of the sectioning cuts.

Table 2. Microstructure at a glance.

Silicon (Si) precipitates	These appear as plates or needles in the aluminum matrix. Because silicon improves castability, such structures are common features in industrial manufacturing.
Fe/Mn-rich intermetallics	Small, bright "Chinese-script" features common to Al–Si castings, introduced for improved mechanical properties; their chemistry can shift with trace additions but their presence is standard.
Cu/Mg-bearing precipitates	Typically very fine, these contribute modest strengthening effects—again consistent with well-known alloy families.
Lead-rich pockets	Observed in minute amounts as isolated pockets/smears; compatible with trace elements and not indicative of unusual chemistry.

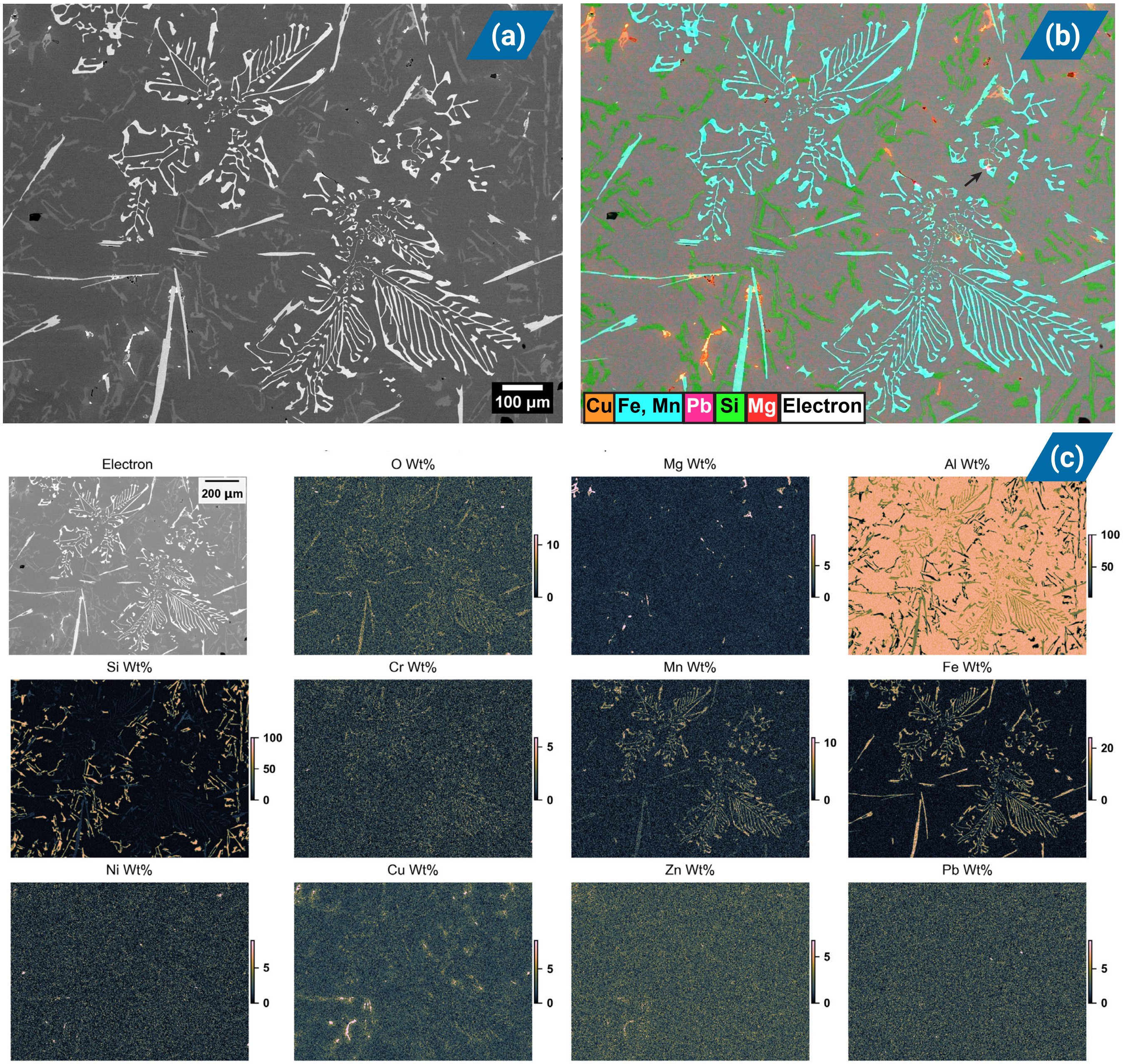


Figure 6. 15 kV electron beam, bulk sample. (a) Backscatter and (b) False-color X-ray denoting the major phases. (c) Quantitative X-ray mapping of the major and minor elements.

3.4 Gamma spectroscopy: No unusual signal emissions — Gamma spectroscopy results indicate no radioactivity emitted by the metal flake material. Background spectra were acquired for count times almost 50% longer than the samples. The resulting spectra were compared to background and found to be indistinguishable from background spectra when count time normalization was applied. No radioactive emissions were detected in any sample. Figure 7 shows the results from one of the metal flakes, which is representative of the other metal flake spectra. *This is consistent with expected behavior of a typical aluminum casting: it does not radiate on its own.*

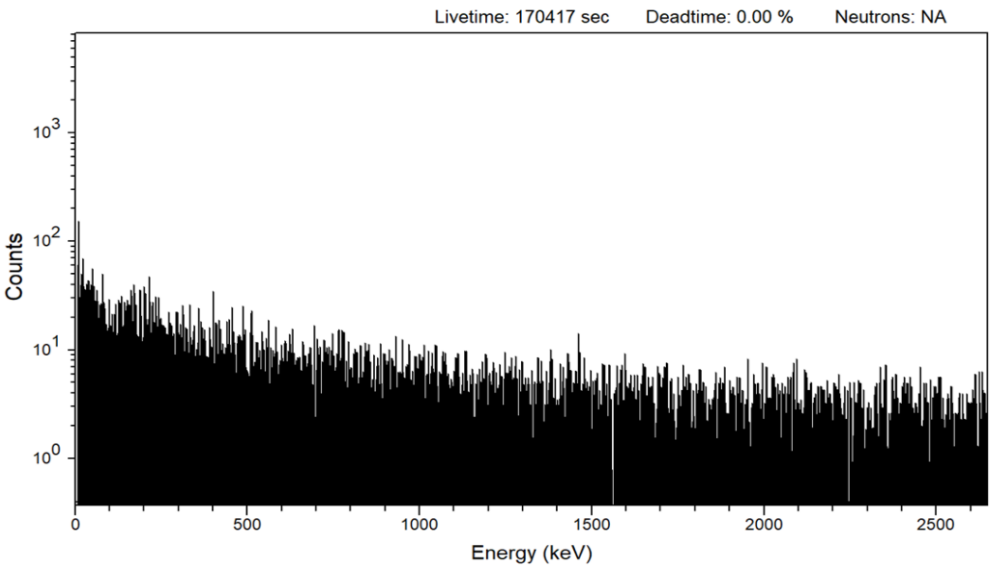


Figure 7. Gamma spectroscopy of metal flakes. Energy emission (keV) plotted vs total counts plotted for one of the metal flakes. The spectra show no emission above background across the range of energies.

3.5 Comparison to industry standards — When compared to catalog grades, the sample best matches A413.1 and 369.1 (with similarities to 361.1/365.1/4032 as well). These eutectics are long-established aluminum–silicon casting alloys used across automotive, aerospace, and consumer sectors. Because melts and castings vary by foundry practice, a one-to-one element-by-element match is not necessary to assign the alloy family. It is common for castings to deviate slightly from catalog numbers depending on melt practice, heat treatment, and the location within a large part. The overall chemistry and microstructure of the sample fall within the expected envelope for these standards.

Table 3. Measured alloy composition compared to important industrial standards. Bold text denotes outside the standard specification. Broadly speaking, silicon content is most informative of alloy identification and intended application, so silicon is emphasized in **red**.

Measured	Alloy (reference)									
	A319.0	319.1	319.2	360.2	361.1	A365.1	369.1	A413.1	4032	4047
	ASTM B969	ASTM B179	ASTM B179	ASTM B179	ASTM B179	ASTM B179	ASTM B179	ASTM B179	ASTM B211/ B211M	MIL-DTL-32495A
Al 86.099 ± 1.663	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance
Cr 0.03 ± 0.003	–	–	–	–	**0.2-0.3**	–	**0.3-0.4**	–	0.1 max	–
Cu 0.369 ± 0.019	**3-4**	**3-4**	**3-4**	**0.1 max**	0.5 max	**0.02 max**	0.5 max	1 max	**0.5-1.3**	**0.30 max**
Fe 0.97 ± 0.075	1 max	**0.8 max**	**0.6 max**	0.7-1.1	**0.8 max**	**0.15-0.20**	1.3 max	1 max	1.0 max	**0.80 max**
Ga 0.012 ± 0.002	–	–	–	–	–	–	–	–	–	–
Mg 0.298 ± 0.09	**0.1 max**	**0.1 max**	**0.1 max**	**0.45-0.6**	**0.45-0.6**	0.15-0.60	0.3-0.45	**0.1 max**	**0.8-1.3**	**0.10 max**
Mn 0.198 ± 0.012	0.5 max	0.5 max	**0.1 max**	**0.1 max**	0.25 max	**0.3-0.6**	0.35 max	0.35 max	–	**0.15 max**
Ni 0.029 ± 0.003	0.35 max	0.35 max	0.1 max	0.1 max	**0.2-0.3**	–	0.05 max	0.5 max	**0.5-1.3**	–
Pb 0.044 ± 0.005	–	–	–	–	–	–	–	–	–	–
Si 11.902 ± 2.175	**5.5-6.5**	**5.5-6.5**	**5.5-6.5**	**9-10**	**9.5-10.5**	**9.5-11.5**	11-12	11-13	11.0-13.5	11.0-13.0
Sn <0.01	–	–	–	0.1 max	0.1 max	–	0.1 max	–	–	–
Ti 0.025 ± 0.004	0.25 max	0.25 max	0.2 max	–	0.2 max	0.10 max	–	–	–	–
Zn 0.203 ± 0.014	1 max	1 max	**0.1 max**	**0.1 max**	0.4 max	**0.07 max**	0.9 max	0.4 max	0.25 max	0.20 max
Others Total	0.5 max	0.5 max	0.2 max	0.2 max	0.15 max	0.15 max	0.15 max	0.25 max		0.15 max
Others Each					0.05 max	0.05 max	0.05 max			0.05 max

4. Conclusion

Analysis of the sample indicates it is a conventional, terrestrial aluminum alloy produced using standard methods available since at least the late 1970s. The alloy families aligned with the sample (Table 3) are widely used for cast housings, brackets, pump or compressor bodies, gear cases, and similar applications where castability and good dimensional fill are prioritized. The microstructure of both the bulk sample and shavings suggests the material was slow-cooled, consistent with origination from a larger original part.

Specifically, the specimen is consistent with industry standards such as A413.1/369.1, conventional near-eutectic aluminum–silicon casting alloys. Based on multiple analytical approaches, its features align with ordinary aluminum metallurgy, and no data indicate anomalous emissions or extraordinary origin.

As with any forensic materials assessment, our conclusions apply to the samples examined. Our conclusions reflect the characteristics and composition of these samples, within the agreed scope of work.

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