Report to

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The Above Network, LLC

Review of Prior Data for

Teardrop-Shaped Metal Sample

Anon

Reference #080105

1/16/08

1.0 Summary

The Above Network contracted with this metallurgist to review data generated to date that had been performed by several facilities on a teardrop-shaped piece of metal. The questions to be answered are: 1) how old is the piece of metal, 2) how was it manufactured, and 3) is it of terrestrial origin. This scope of work entailed reviewing documents generated to date, determining if the data and results are consistent among the various test facilities, and determining what further tests, if any, would answer the above questions and complement prior work.

The recommendation is not to pursue any additional testing since the object possesses low quality metallurgical properties, exhibits low quality processing, and test results show that it originated from the Earth.

2.0 Analysis

Several reports supplied by Mr. Allin were reviewed, which included, a Los Alamos National Lab (LANL) report (Dunn 1996), a report by New Mexico Tech, Socorro NM (Fuierer 1996), an analysis by Delta State Univ. in Cleveland, OH (Scarborough 2004), an isotopic analysis by Scripts Lab (Isaac 1999), and excepts from Master of Science thesis by Chris Ellis while at Kansas State University, Manhattan, KS (Ellis 1996). In addition, a broad literature search was conducted to aid in understanding all the findings and to determine what additional testing, if any, to perform (based on the opinion of this reviewer).

The reviewer is a Metallurgist with a Nuclear Engineering background and does not claim to be a physicist or a chemist or an expert in meteorites or other space-related fields of study.

3.0 Results

This section will summarize the data generated to date as it pertains to the above three questions.

3.1 How old is the piece of metal?

Age of minerals and metals can be determined via isotopic analysis. The basic concept is determining the various ratios of parent-daughter isotopes that are formed through the natural process of radioactive decay (Dickin 1995). Most ferrous materials use the measurements of Mn and Cr isotopes and their ratios (Birck and Allegre 1988; Shukolyukov and Lugmair 2004). Measurements of Al and Mg isotopes can be used to determine age via the same technique as Mn and Cr (Wu and Browne 1997; Chavda 1999; Zinner 2002; Rudraswami and Goswami 2007).

Cosmic radiation is capable of creating radioactive isotopes that can decay into stable products (parent isotope decays into daughter products) (Shukolyukov and Lugmair 2004). Si isotope systematics has been used to identify meteorites and differentiate between terrestrial and extraterrestrial objects (Stone, Hutcheon et al. 1991; Pillinger 1992; Stadermann, Croat et al. 2005). Ti and Sr are usually used in combination for the same differentiations (Niederer, Papanastassiou et al. 1981; Heydegger, Foster et al. 1982; Leya, Schonbachler et al. 2007). There other isotope systems that include, but are not limited to; Be, Cl, Cr, Rb, Pb, Sm; all of which have unique characteristics. This question was not addressed in the prior studies (Dunn 1996; Fuierer 1996; Scarborough 2004); the focus was on the more important question – is the object of terrestrial origin.

3.2 How was it manufactured?

This is a challenging question to answer. It is much easier to make a statement regarding this question when control samples are processed from the same batch of material. Then differences in microstructure and morphology are more readily apparent.

Splat quenching and gas atomization are rapid quenching techniques; the gas atomized particles can be splat-quenched to generate a fine, uniform microstructure. The report by New Mexico Tech (Fuierer 1996) mentions flow lines and the presence of Si-rich particles approximately 0.5 µm in diameter. Microstructural study at LANL (Dunn 1996) showed splat-to-splat bonding with entrained, unmelted spherical particles (10-15 µm in diameter) with the same composition as the matrix. The use of particles that are 10-15 µm in diameter is common in powder metallurgy. The presence of unmelted particles (Figure 5 of LANL report) is also common if the processing parameters are not properly controlled. The presence of spherical, unmelted particles entrained in a matrix indicates the metal was manufactured.

Porosity is present as stated in both metallurgical evaluations (Dunn 1996; Fuierer 1996) and its distribution is rather fine and uniform, with a slight increase in porosity towards the outside surface. Metal processing in microgravity (Nogi and Aoki 1997) results in uniform distribution of small size porosity. Porosity generated during microgravity processing can create flow lines as the metal solidifies (Nogi and Aoki 1997; Barsi, Kassemi et al. 2004; Savas and Kayikci 2007; Unuvar, Fredick et al. 2007).

Teardrop-shaped particles can be produced by the gas atomization method (Shue and Yeh 1994). That study characterized flake morphology as a function of droplet size and impact velocity. They noticed some of the flakes had serrated edges. Teardrop-shaped meteorites do not exist (Korotev 2007). However, teardrop-shaped tektites are produced from Earth's material due to the interaction with a meteorite upon impact.

Figure 4 in LANL report (Dunn 1996) shows a sharp transition in microstructure from the center region to the perimeter, but no explanations were offered and it is unclear if the transition is associated with splats or if there is a core that the splats adhere to.

Chemical analysis by Delta State (Scarborough 2004) did not show the presence of aluminum (the copy provided for the review of the data was incomplete). The chemical results of two other tests (Dunn 1996; Fuierer 1996) show that aluminum is the major element.

Comments (Isaac 1999) after performing isotope tests stated that the object was manufactured due to its high aluminum composition.

3.3 Is it of terrestrial origin?

The Earth's atmosphere blocks a large amount of cosmic radiation and prevents its effects from occurring on the Earth's surface. Conversely, if an object resides in space it is unprotected from cosmic rays that can alter the material at an atomic level. This is similar to the concern regarding the health of airline pilots and flight attendants, since they spend a large amount of time in the upper atmosphere where the protective layer is considerably thinner. The cosmic radiation is capable of creating radioactive isotopes that can decay into stable products (parent isotope decays into daughter products) (Shukolyukov and Lugmair 2004). Measuring the isotope abundance of the radioactive species would indicate where the metal had resided; under the cover of the protective atmosphere or in space exposed to radiation (Koeberl, Shukolyukov et al. 2007).

Silicon (Si) isotope systematics has been used to identify meteorites and differentiate between terrestrial and extraterrestrial objects (Stone, Hutcheon et al. 1991; Pillinger 1992; Stadermann, Croat et al. 2005). Titanium (Ti) and Strontium (Sr) are usually used in combination for the same differentiations (Niederer, Papanastassiou et al. 1981; Heydegger, Foster et al. 1982; Leya, Schonbachler et al. 2007). Additional decay schemes that are extinct and would provide the same information are ^{129}I to ^{129}Xe, ^{107}Pd to ^{107}Ag, ^{53}Mn to ^{53}Cr, and ^{60}Fe to ^{60}Ni (Dickin 1995).

Tests were conducted using Sr and Ti (Isaac 1999) and Si (Dunn 1996) that showed the metal to be terrestrial.

4.0 <u>Discussion</u>

4.1 Age

Scientists have agreed that the distribution of elements throughout the solar system is rather uniform (Zinner 2002). Therefore, measurement of radionuclides (parent-daughter ratios) is an important tool in determining age and origin. Some of the preferred elements include Al-Mg, Mn-Cr, Sm-Nd, Rb-Sr, and Pb-Pb depending on the composition, origin of sample, and sensitivity of the measuring equipment (Wadhwa and Lugmair 1996; Wadhwa, Shukolyukov et al. 2003).

The age of this object has not been determined, which is a moot point if the object is of terrestrial origin.

4.2 Processing

Table 1 lists the possible aluminum alloys (all are castings due to high Si levels) and shows that alloy 360 is the most similar in composition. However, the metal is considerably softer than expected. Based on Vickers hardness tests (VH=60) (Fuierer 1996), which is approximately 70 Brinell, which is approximately 35,000 psi Ultimate Tensile Strength (UTS), and is typical for an Al-Si alloy. Given the fine microstructure due to rapid quenching, a higher hardness might be expected, even higher than shown for alloy 360 listed in Table 1. The lower strength values suggest that the metal has been heat treated (Kearney 1990).

Aluminum has a relatively low melting temperature of about 1200^{o}F (660^{o}C). NASA has developed a program that analyzes risk of space debris travelling through the atmosphere and striking the Earth (Rochelle, Kinsey et al. 1997). The heat may be sufficient to cause ablation, which would perturbate the object's surface or even consume its entire volume. However, another NASA website documents debris, some of which is aluminum, from satellites and rockets that have fallen to the Earth's surface and remained intact (Anon 2005). These fabricated components tumbled as they fell through the atmosphere and were typically hollow. European researchers have studied various features of aluminum debris as it re-enters Earth' atmosphere, including, aspect ratios (length to diameter) and alignment of long axis with velocity vector upon re-entry in Earth's atmosphere (Coradini, Giblin et al. 1994; Giblin, Martelli et al. 1998).

Excessive amount of impurities are known to cause a high volume fraction of porosity (Stefanescu and Ruxanda 2004). The reports by LANL and New Mexico Tech each identify the presence of different particles, one finds large particles of the same composition of the matrix and the other finds small Si-rich particles. However, neither one refutes the other. Rapid quenching is capable of freezing porosity in-place even in the presence of gravity.

This object does not have remarkable metallurgical properties and exhibits low quality processing.

4.3 Space

Exposure to cosmic radiation can be measured via absolute determinations of Si isotopes, where the moon and the Earth have similar contents, but meteorites possess different absolute values (Georg and Halliday 2007). One set of results (Isaac 1999) showed that the object is of terrestrial origin based on Sr and Ti isotopic analysis. Another set of results (Dunn 1996) concluded that the object is of terrestrial origin, also. The measurements of ^{22}Ne, ^{25}Mg, and ^{26}Mg may provide more definitive information (Mewaldt, Spalding et al. 1980; Chieffi and Limongi 2002) depending on equipment sensitivity. Koeberl states, "…precise measurements of Cr can unequivocally distinguish terrestrial from extraterrestrial materials…" (Koeberl, Shukolyukov et al. 2007) in the context of sorting through meteorite impact and the various ground debris generated. These results indicate that the object is of terrestrial origin. Further testing might not refute the data generated to date.

This reviewer does not recommend further testing, since two prior tests reported the object to be of terrestrial origin.

5.0 Recommendations

Based on results to date it is the opinion of this reviewer that further testing would not be beneficial. Tests have been conducted using Sr, Ti, and Si that showed the metal to be terrestrial. This object does not have remarkable metallurgical properties and exhibits low quality processing. The manufacturing process could be a synergistic effect of any number of events that routinely occur.

There are questions that remain unanswered and may never be answered. If one were to persist in the quest to obtain more results (at the expense of time and money), then the following thoughts might be considered, since they arose during the review process. However, they will probably not provide any more information than what already exists: 1) obtain services of an expert in isotope systematics to critique prior test results, 2) review metallographic samples to clarify splat interactions, 3) determine if remelting or ablation occurred on feathery edges, and 4) characterize shape and surface morphology of objects that penetrate or originate in the Earth's atmosphere.

6.0 References

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Table 1. Aluminum alloy comparison of properties.

	A	B	C	D	E	F	G	H	I	J
1		**Teardrop sample**	**301.0 Aluminum Composition Spec**	**303.0 Aluminum Composition Spec**	**364.0 Aluminum Composition Spec**	**385.0 Aluminum Composition Spec**	**Aluminum 360.0-F Die Casting Alloy**	**Aluminum 380.0-F Die Casting Alloy**	**Aluminum 413.0-F Die Casting Alloy**	**Aluminum C443.0-F Die Casting Alloy**
2	**Physical**									
3	Density (lb/in³)	0.0892	--	--	--	--	**0.0968**	0.0997	0.0961	0.0972
4	**Mechanical**									
5	Hardness, Brinell ()		--	--	--	--	**75**	80	80	65
6	Tensile Strength, Ultimate (psi)	35000	--	--	--	--	**43500**	46000	42900	33100
7	Tensile Strength, Yield (psi)		--	--	--	--	**24700**	23100	21000	14100
8	Elongation at Break (%)		--	--	--	--	**2.5**	2.5	2.5	9
9	Modulus of Elasticity (ksi)		--	--	--	--	**10300**	10300	10300	10300
10	Poissons Ratio ()		--	--	--	--	**0.33**	0.33	0.33	0.33
11	Charpy Impact (ft-lb)		--	--	--	--	**--**	3	--	--
12	Fatigue Strength (psi)		--	--	--	--	**20000**	20000	18900	16700
13	Machinability (%)		--	--	--	--	**50**	50	30	10
14	Shear Modulus (ksi)		--	--	--	--	**3840**	3840	--	3840
15	Shear Strength (psi)		--	--	--	--	**27600**	28300	24700	21000
16	**Electrical**									
17	Electrical Resistivity (ohm-cm)	0.000029	--	--	--	--	**0.0000046**	0.0000064	0.0000044	0.0000046
18	**Thermal**									
19	Heat of Fusion (BTU/lb)		--	--	--	--	**167**	167	167	167
20	CTE, linear 20°C (µin/in-°F)		--	--	--	--	**11.6**	11.8	11.3	12.3
21	CTE, linear 250°C (µin/in-°F)		--	--	--	--	**12.7**	12.5	12.4	13.4
22	°F)		--	--	--	--	**0.23**	0.23	0.23	0.23
23	Thermal Conductivity (BTU-in/hr-ft²-°F)		--	--	--	--	**784**	756	840	1010
24	Melting Point (°F)		--	--	--	--	**1030 - 1100**	1000 - 1100	1070 - 1080	1070 - 1170
25	Solidus (°F)		--	--	--	--	**1030**	1000	1070	1070
26	Liquidus (°F)		--	--	--	--	**1100**	1100	1080	1170

	A	B	C	D	E	F	G	H	I	J
27		**Teardrop sample**	**301.0 Aluminum Composition Spec**	**303.0 Aluminum Composition Spec**	**364.0 Aluminum Composition Spec**	**385.0 Aluminum Composition Spec**	**Aluminum 360.0-F Die Casting Alloy**	**Aluminum 380.0-F Die Casting Alloy**	**Aluminum 413.0-F Die Casting Alloy**	**Aluminum C443.0-F Die Casting Alloy**
28	**Processing**									
29	Processing Temperature (°F)		--	--	--	--	**1200 - 1400**	1200 - 1400	1200 - 1400	1200 - 1400
30	Aging temperature (°F)		--	--	--	--	--	350 - 500 500 - 700	--	--
31	Casting Temperature (°F)		--	--	--	--	**1175 - 1300**	1175 - 1300	1175 - 1300	1175 - 1300
32	**Material Components**									
33	Aluminum, Al (%)	85.1	81.3 - 85.0	85.9 - 88.8	**87.1 - 92.0**	75.9 - 87.0	**85.1 - 90.6**	79.6 - 89.5	82.2 - 89.0	**89.6 - 95.5**
34	Beryllium, Be (%)		--	--	0.020 - 0.040	--	--	--	--	--
35	Chromium, Cr (%)	0.028	--	--	**0.250 - 0.500**	--	--	--	--	--
36	Copper, Cu (%)	0.18	**3.00 - 3.50**	<= 0.200	<= 0.200	**2.00 - 4.00**	**<= 0.600**	**3.00 - 4.00**	<= 1.00	<= 0.600
37	Iron, Fe (%)	1.83	**0.800 - 1.50**	**0.800 - 1.50**	**<= 1.50**	<= 2.00	**<= 2.00**	<= 2.00	<= 2.00	<= 2.00
38	Magnesium, Mg (%)	0.15	**0.250 - 0.500**	**0.450 - 0.700**	**0.200 - 0.400**	<= 0.300	**0.40 - 0.60**	<= 0.100	<= 0.100	<= 0.100
39	Manganese, Mn (%)	0.058	**0.500 - 0.800**	**0.500 - 0.800**	<= 0.100	<= 0.500	**<= 0.350**	<= 0.500	<= 0.350	<= 0.350
40	Nickel, Ni (%)	0.051	**1.00 - 1.50**	--	<= 0.150	<= 0.500	**<= 0.500**	<= 0.500	<= 0.500	<= 0.500
41	Other, each (%)		<= 0.0300	<= 0.0300	<= 0.0500	--	--	--	--	--
42	Other, total (%)		<= 0.100	<= 0.100	<= 0.150	<= 0.500	**<= 0.250**	<= 0.500	<= 0.250	<= 0.250
43	Silicon, Si (%)	9.1	9.50 - 10.5	9.50 - 10.5	7.50 - 9.50	**11.0 - 13.0**	**9.00 - 10.0**	7.50 - 9.50	**11.0 - 13.0**	**4.50 - 6.00**
44	Tin, Sn (%)	0	--	--	<= 0.150	<= 0.300	**<= 0.150**	<= 0.350	<= 0.150	<= 0.150
45	Titanium, Ti (%)	0.047	<= 0.200	<= 0.200	--	--	--	--	--	--
46	Zinc, Zn (%)	0.079	<= 0.0500	<= 0.0500	<= 0.150	<= 3.00	**<= 0.500**	<= 3.00	<= 0.500	<= 0.500