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A Spectral Analysis of the Massalia Asteroid Family to Evaluate the L-Chondrite Source Hypothesis

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A SPECTRAL ANALYSIS OF THE MASSALIA ASTEROID FAMILY TO EVALUATE THE L-CHONDRITE SOURCE HYPOTHESIS C. A. Strom[1], S. K. Fieber-Beyer[1,2], M. J. Gaffey[1,2], and J. T. Germann[1] [1]Dept. of Space Studies, Box 9008, Univ. of North Dakota, Grand Forks, ND 58202. [2]Visiting astronomer at the IRTF under contract from the NASA, which is operated by the Univ. of Hawaii Mauna Kea, HI 97620. caleb.strom@und.edu,

Introduction: A major research objective within asteroid science is to identify the source bodies of the meteorites. So far, possible or probable parent bodies have only been identified for a few meteorite types. These meteorite types include the H-type ordinary chondrites [1,2], HEDs [3,4], pallasites [3], and mesosiderites [5]. Identifying the parent bodies of meteorites helps to determine the location within the solar nebula where the geochemical processes, recorded in meteorites, took place. This has significantly increased our understanding of the evolution of the solar nebula and the early solar system [6].

Among the many meteorite types whose parent bodies are unknown are the L-chondrites. L-chondrites exhibit evidence of a shock event that occurred around 470 Ma, which implies that the L-chondrites resulted from an impact event which may have disrupted the L-chondrite parent body. This evidence is corroborated by fossil L-chondrite meteorites found in Ordovician sedimentary rocks dating to the same time period [7-12]. This suggests that if the source outcrop of the L-chondrites stills exists today, it is within an asteroid family.

The Massalia asteroid family has been suggested to be a possible source of the L-chondrites [13]. We are currently testing this hypothesis. So far, we have observed fourteen Massalia family asteroids, analyzed their spectra, and interpreted their spectra to determine their meteorite analogues in an effort to see whether or not the analogues support our hypothesis. This abstract reports the initial results for seven of these bodies.

Methods: Near-infrared spectra of 17473 Freddiemercury, 20264 Chauhan, 15701 (1987 RG1), 12146 Ostriker, 15458 (1998 YW9), 14747 (2541 P-L), and 24097 (1999 VB6) were obtained in May 2019, November 2019, and September 2020 at the NASA IRTF using the SpeX instrument [14] in the low-resolution spectrographic mode (0.68–2.54 μm). Asteroid and standard star observations were interspersed within the same airmass range to allow modeling of atmospheric extinction. Data reduction and analyses were done using previously outlined procedures [2,6]. A final spectrum was produced for each asteroid and a meteorite analogue was evaluated for each asteroid based on spectral band parameters, slope, albedo, and calculated geochemistry.

Results: Five of the asteroids exhibited two absorption features in the near-infrared, and two were featureless. See Figures 1 and 2. The five that exhibited features have spectra consistent with the presence of mafic minerals. The measured band parameters were temperature corrected [15,16]. Using these band parameters, we calculated the mineral chemistry for each asteroid using equations from [15,17] to assist in determining a meteorite analogue. These values are reported in Tables 1 and 2.

The two featureless asteroids have low albedos and at least one of them resembles the carbonaceous chondrites. The asteroids 15458 (1998 YW9) and 20264 Chauhan are compositionally similar to ordinary chondrites. The asteroids 17473 Freddiemercury, 24097 (1998 VB6), 14747 (2541 P-L) most closely resemble HEDs in their composition.

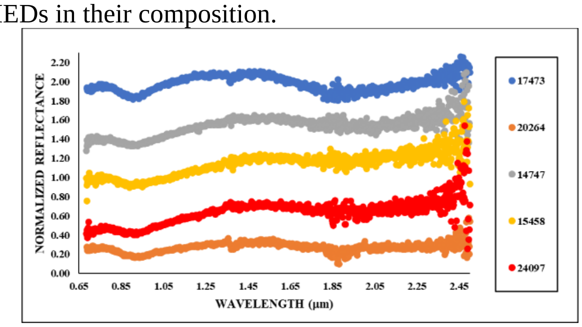

Fig. 1. Plot of Massalia asteroids exhibiting features, the above spectra were normalized to 1.5 μm and then offset for clarity. The asteroids shown above display absorption features associated with the mafic minerals pyroxene and olivine.

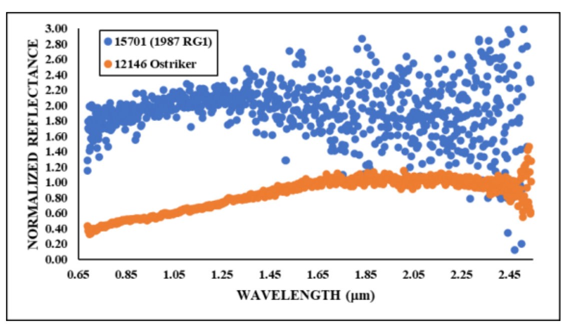

Fig. 2. A plot of two featureless asteroids located in the Massalia dynamical family. The spectra were normalized to 1.5 μm and then offset for clarity. As shown, 12146 Ostriker and 15701 (1987 RG1) lack absorption features and are slightly red-sloped.

Table 1. Target Band Parameters

Target	BI	BII	BAR
17473	0.92 ± 0.01	1.90 ± 0.04	3.31 ± 0.33
20264	0.94 ±0.01	1.89 ± 0.09	1.06 ± 0.56
15701	--	--	--
12146	--	--	--
15458	0.93 ± 0.01	1.92 ± 0.03	1.04 ± 0.16
24097	0.93 ± 0.01	1.99 ± 0.02	2.04 ± 0.81
14747	0.92 ± 0.01	2.02 ± 0.01	1.16 ± 0.24

Table 2. Asteroids and meteorite affinities.

Asteroid	Pyroxene Chemistry[a]	Meteorite Analogue
17473	$Fs_{29.39}Wo_{4.50}$	HED
20264	$Fa_{19.47}Fs_{16.93}$	H-chondrite
15701	--	CO3 chondrite
12146	--	Inconclusive
15458	$Fa_{16.93}Fs_{15.12}$	L-chondrite
24097	$Fs_{39.28}Wo_{8.36}$	HED
14747	$Fs_{34.51}Wo_{6.52}$	HED

[15]'s equations were used for HED-like meteorite analogues and [17]'s equations were used for ordinary chondrite-like meteorite analogues.

Asteroids, 12146 Ostriker and 15701 (1987 RG1) were featureless and had low albedos as can be seen in Table 3. Curve matching was used to suggest a meteorite analogue using data from RELAB at the Department of Planetary Geosciences at Brown University [18]. Results indicate 15701 (1987 RG1) most closely resembles the spectrum of a Cb-type asteroid [19] and that its meteorite analogue may be a CO3 chondrite. See Figure 3. Analysis of 12146 Ostriker has so far produced inconclusive results, and a clear meteorite analogue has not been identified.

Table 3. Asteroid albedos.

Asteroid	Albedo[a]
17473 Freddiemercury	0.313
20264 Chauhan	0.133
15701 (1987 RG1)	0.045
12146 Ostriker	0.058
14747 (2541 P-L)	0.312
24097 (1999 VB6)	0.300[b]
15458 (1998 YW9)	0.280

[a]*The albedos were derived from [20] and [21].*[b]*The albedo for 24097 is an estimation based on [22].*

The results of this paper indicated that the Massalia asteroid family at least contains ordinary chondrite-like asteroids, basaltic achondrite-like asteroids, and a possible carbonaceous chondrite-like asteroid.

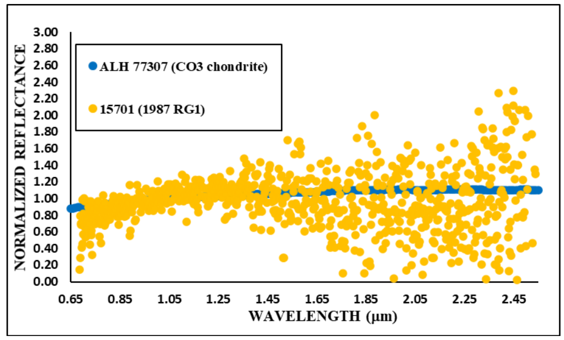

Fig. 3. The spectrum of asteroid 15701, although quite noisy, matches closely with that of CO3 chondrite ALH 77307 [23], in terms of slope and albedo, suggesting a carbonaceous chondritic composition. The spectra were normalized to 1.5 μm for clarity.

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