EVALUATING MASSALIA FAMILY ASTEROIDS AS THE SOURCE OF THE L-CHONDRITE METEORITES. C.A. Strom[1], S. K. Fieber-Beyer[1,2], M. J. Gaffey[1,2], [1]Department 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

Introduction: Over the past 50 years, a key objective of asteroid science has been to identify the source bodies of major meteorite types. Only a few meteorite parent bodies have been identified: the H-chondrites [1-2], HEDs [3], pallasites [4], and mesosiderites [5].

Of the major meteorite classes, a parent body has not been identified for the L-chondrite meteorites. Unique among these meteorites is evidence of a shock event dating to 470 Ma, indicating that the parent body suffered a catastrophic disruption [7-12]. This suggests that the source body of the L-chondrite meteorites may be an asteroid family. As such, the Massalia Asteroid Family has been posited as a source for the L-chondrite meteorites [13]. Our main objective is to test this hypothesis by examining Massalia Family members to determine their surface composition and ascertain if their surfaces have an L-chondrite-like composition.

Methods: Near-infrared (NIR) spectra were obtained remotely for the Massalia asteroids: 98146, 37118, (182) Elsa, (11519) Adler, (2946) Muchachos, (12414) Bure, and 34508 in April and July 2021. We used the SpeX instrument at the NASA IRTF on Mauna Kea in Hawai'i [14]. Observations were conducted over two nights in April 2021 and one night in July 2021, using the low resolution spectrographic mode (0.68-2.54 μm). Standard star and asteroid observations were interspersed within the same airmass in order to model atmospheric extinction. The data was calibrated, processed, and reduced using procedures outlined in [2,6]. An average nightly spectrum was created for each asteroid. For asteroids containing spectral absorption features diagnostic of the presence of olivine and pyroxene, the band parameters were calculated to determine the geochemistry of the asteroid and its likely meteorite analogue [15-17]. For asteroid spectra for which the band parameters could not be calculated, the spectra were compared to the spectra of known meteorites from the Brown University RELAB database to determine the most likely meteorite analogue [18].

Results: Of the 7 asteroids studied, five were found to have absorption features consistent with the mafic minerals olivine and pyroxene; two of these asteroids exhibited a single feature at about 0.9 μm (Band I). The band parameters, including the Band Area Ratio (BAR), for each asteroid are shown in Table 1.

Table 1. Target band parameters

Target	BI (mm)	BII (mm)	BAR
98146	0.96 ± 0.01	2.04 ± 0.03	0.07 ± 0.03
2946	--	--	--
182	0.93 ± 0.01	1.87 ± 0.01	1.88 ± 0.36
35408	0.95 ± 0.01	1.86 ± 0.06	1.7 ± 1.1
37118	0.92 ± 0.01	1.75 ± 0.06	0.76 ± 1.3
12414	0.94 ± 0.01	2.19 ± 0.02	0.07 ± 1.2
11519	1.00 ± 0.03	--	--

Of the 5 asteroids which had two absorption features, a meteorite analogue was only determined for one of them. The asteroid (182) Elsa was identified as having an HED-like surface. For the other 4 featured asteroids, a high level of noise and a very weak Band II feature made the uncertainty in the BAR calculation too high to accurately determine the most-likely meteorite analogue. We could only conclude that they are S-type asteroids. However, (12414) Bure was determined to be a possible Sq type asteroid based on the Bus-Demeo taxonomy [19]. The asteroids with two absorption features are shown in Fig. 1.

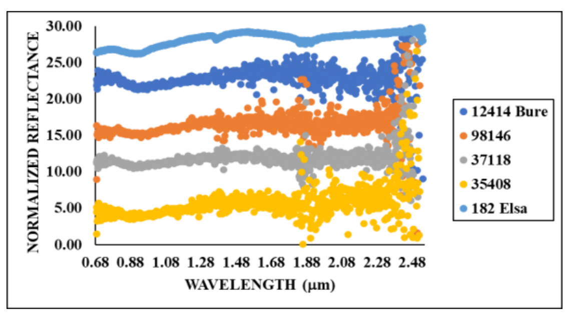

Fig. 1. Plot of the Massalia asteroids with diagnostic Band I and Band II features. Using the taxonomy described in [19], 98146, 37118, (182) Elsa, and 35408 were classified as S-type asteroids based on the mafic mineral features near 1 μm and 2 μm. Furthermore, (182) Elsa was also identified as having an HED-like surface. Also, (12414) Bure was identified as a possible Sq type asteroid [19]. The meteorite analogue identifications for the asteroids other than (182) Elsa were inconclusive because of

excessive noise and high uncertainties in their BAR values. The spectra are offset for clarity.

Two of the asteroids, (11519) Adler and (2946) Muchachos, lacked discernible Band II features, but showed a feature near 1 μm for (2946) Muchachos and at 1 μm for (11519) Adler. Curve matching and comparison with the Bus-Demeo taxonomic classes [19] suggest that (11519) Adler has a pallasite-like surface and that it is an Sa type asteroid. For (2946) Muchachos, the curve matching results suggest that it is an Sa type asteroid but the meteorite analogue results are inconclusive. The spectra for the two asteroids are shown in Fig. 2.

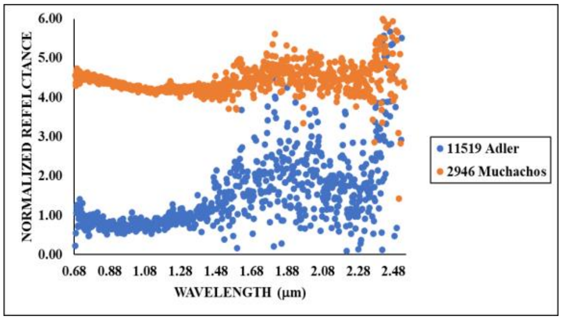

Fig. 2. The asteroids (11519) Adler and (2946) Muchachos have a strong feature at about 1 μm but lack a Band II feature. They were identified as Sa-type asteroids using [19]. The spectrum of (11519) Adler was matched with a pallasite meteorite using data from [18]. The search for the meteorite analogue for (2946) Muchachos was inconclusive. The spectra are intentionally offset for clarity.

The meteorite affinities, taxonomic classification, and geochemistry, where relevant, for each asteroid are shown in Table 2.

Table 2. Asteroids and meteorite affinities

Asteroid	Taxonomy[b]	Chemistry[a]	Meteorite Analogue
98146	S	--	Inconclusive
2946	Sa	--	Inconclusive
182	S	$Fs_{33.36}Wo_{6.06}$	HED
35408	S	$Fs_{44.4}Wo_{10.35}$*	HED*
37118	S	--	Inconclusive
12414	Sq	--	Inconclusive
11519	Sa	--	Pallasite[c]

**very uncertain.* [a]*[15]'s equations were used to calculate the geochemistry.* [b]*[19]'s taxonomy and software was used to determine the asteroid taxonomy for each meteorite.* [c]*The Brown University RELAB spectral catalogue [18] was used to determine the meteorite analogue for (11519) Adler.*

Summary: Of the objects studied, potential meteorite analogues were identified for (182) Elsa (HED) and (11519) Adler (pallasite).

Asteroids with HED-like spectra are probably differentiated bodies, or fragments of differentiated parent bodies similar to (4) Vesta [3]. Pallasite meteorites, containing a mixture of FeNi and olivine, represent the core mantle boundaries of differentiated parent bodies that were disrupted by subsequent collisions [20]. Thus (182) Elsa and (11519) Adler appear to represent a fragment of the crust and core mantle-boundary, respectively, of bodies that experienced enough internal heating to form a distinct core, mantle, and crust through differentiation.

Based on the Bus-Demeo taxonomy [19], four of the asteroids studied were simply identified as S-types, two were identified as Sa types, and one was identified as a possible Sq type. The tentative results of this study confirm that Massalia asteroids are mostly S-types, but the most common meteorite analogue is still yet to be determined by future studies.

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