IMPACT MELT ORIGN OF BAPTISTINA ASTEROID FAMILY: LESSONS FROM THE CHELYABINSK METEORITE FALL. V. Reddy[1], J. A. Sanchez[2], E. A. Cloutis[3], P. Mann[3], M. R. M. Izawa[3], L. Le Corre[1], M. Cuddy[3], M. J. Gaffey[4] and G. Fujihara[5], [1]Planetary Science Institute, Tucson, Arizona, [2]Max Planck Institute for Solar System Research, Germany, [3]University of Winnipeg, Manitoba, Canada, [4]University of North Dakota, Grand Forks, North Dakota, [5]Big Kahuna Meteorites, Hilo, Hawaii.

Introduction: On February 15, 2013, a 17-20 meter diameter asteroid entered the atmosphere over Chelyabinsk, Russia, and disintegrated in an airburst with an energy of ~500±100 kilotons of TNT [1]. Orbital parameters for the meteor calculated using video recordings of the bolide suggested a pre-impact orbit consistent with an inner main belt origin near the ν_6 resonance [2]. The orbit of Chelyabinsk bolide also shows similarity with a Q-type [3] near-Earth asteroid (86039) 1999 NC43 [2].

Q-type asteroids are thought to have surface composition similar to ordinary chondrite meteorites based on their nearly identical reflectance spectra [4]. Laboratory classification of recovered fragments by [5] shows that Chelyabinsk is an LL5 ordinary chondrite with olivine and pyroxene as major mineral phases. The meteorite included a dark-colored fine-grained impact melt component, which represents a significant portion (~1/3) of the meteorite apart from light-colored lithology typical of ordinary chondrites [5]. Previous work [6-9] has suggested dynamical and compositional links between LL chondrites and the Flora family.

Spectral and compositional properties of Chelyabinsk and (8) Flora, the largest member of the Flora family, were compared by [10] and a compositional relationship was established between the two. Baptistina asteroid family (BAF), which is dynamically intertwined with the Flora family, has been compositionally linked to the Floras [11, 12]. BAF members have spectral properties similar to LL chondrites and Floras, but with subdued absorption features and a bimodal albedo distribution in WISE data [13]. This led to some authors [14] to argue that the BAF is dominated by primitive taxonomic types despite their LL chondrite composition. Our premise for this study is to explain the observed subdued absorption bands and LL chondrite composition in the BAF based on our laboratory study of Chelyabinsk LL chondrite and impact melt mixtures.

Methodology: A series of 13 mixtures of two endmembers (impact melt and LL5 chondrite from Chelyabinsk) were made with the <45 μm grain size splits in succession by adding a pre-determined amount of sample to the previous mixture to minimize the amount of sample required. Reflectance spectra were acquired with an Analytical Spectral Devices FieldSpec Pro HR spectrometer over the range of 350 to 2500 nm in 1.4 nm steps, with a spectral resolution of 2 to 7 nm.

Analysis: Figure 1 shows the NIR spectra for intimate mixtures of Chelyabinsk LL5 chondrite (LL) and impact melt (IM) components. Increasing the fraction of the lower albedo impact melt (9.8% albedo) in the intimate mixture will cause a drop in reflectance (pure LL5 albedo 28%) throughout the entire spectrum, and a dramatic suppression of the absorption bands. Band I depth of the endmember impact melt is ~4%, compared to 18% for unaltered, and Band II depth is 2.5% for the impact melt and 6% for the unaltered LL5 material. Both lithologies have a red slope with increasing reflectance as wavelength increasing.

Taxonomy: The albedo and/or intensity of the absorption bands (if present) are parameters typically used for taxonomic classification [4]. The broad range of albedos exhibited by the Chelyabinsk samples demonstrate how objects that originated in the same parent body could be classified under different taxonomic types. Thus, in order to explain the primitive taxonomic classification of some BAF members with LL chondrite composition, we applied the Bus-DeMeo classification [4] to the NIR spectra of the intimate mixtures. It is important to point out that the Bus-DeMeo system was developed from the analysis of NIR spectra of asteroids, which generally exhibit weaker absorption bands than meteorite spectra. Therefore, caution must be taken when using this classification system with laboratory spectra of meteorite samples.

Spectra of the intimate mixtures were classified using the online Bus-DeMeo taxonomy calculator. We found that the sample corresponding to 100% impact melt is classified as either C-complex or Cb-type. For intimate mixtures with 50 % < IM ≤ 95 % samples are ambiguously classified as C/Ch/Xk/Xn-type. However, when intimate mixtures ≤ 50 % IM, absorption bands become deeper and the spectra are classified as Q-types.

From our study it is obvious that significant impact melt could led to some BAF members being classified as primitive asteroids although their band parameters and derived surface composition remain unaffected. As further evidence we compared spectra of LL chondrite and impact melt mixtures with nine BAF members (Figure 2). Based on the Band I depth comparison, the abundance of impact melt ranges from 10% to 100% for these BAF members. Suppression of absorption bands with increasing impact melt abundance is due to the presence of fine-grained opaques (dominantly iron and troilite) that also lower the albedo and redden the spectral slope. Our non-diagnostic mixing experiment suggests that impact melt could suppress the absorption bands in spectra of BAF members and account for the apparent differences with those of Floras. The presence of impact melt would also explain the bimodal albedo distribution observed by WISE [13] and why weakly featured BAF members could easily be misclassified as X/C taxonomic types [14].

Mineralogy: We used equations from [15] to derive olivine (fayalite) and pyroxene (ferrosilite) mol. % from Band I centers of BAF members' spectra. Several previous publications [11, 12] have noted a similarity in surface mineralogy of BAF members and Floras. This compositional link between the two families extends to smaller members of the BAF observed as part of this study. The average fayalite (Fa_{28}) and forsterite (Fs_{23}) values for BAF members matches exactly with that of Chelyabinsk (Fa_{28}, Fs_{23}) and is within the range of LL chondrites (Fa_{27-33}, Fs_{23-27}).

We plotted the Fa and Fs values of these BAF members in Figure 3 along with Flora, Baptistina, Itokawa and Chelyabinsk. The nine BAF members we observed plot precisely in the LL chondrite region forming a continuum that spans the entire compositional range for the LL chondrites. The results presented in this plot are a confirmation that impact melting has little or no effect on surface composition. Our results account for the apparent differences between the spectra of BAF and Flora family members even though their spectrally derived compositions appear to be similar to LL chondrites in both cases.

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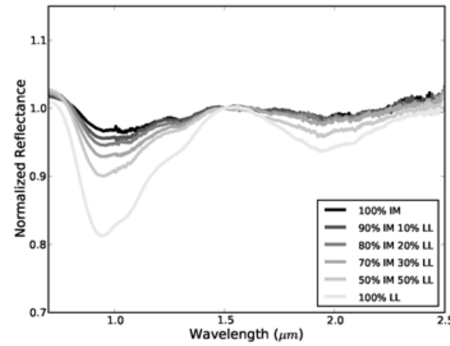

Figure 1. Continuum-removed spectra of mixtures of LL5 chondrite and impact melt lithologies. Some mixture bins were omitted for clarity.

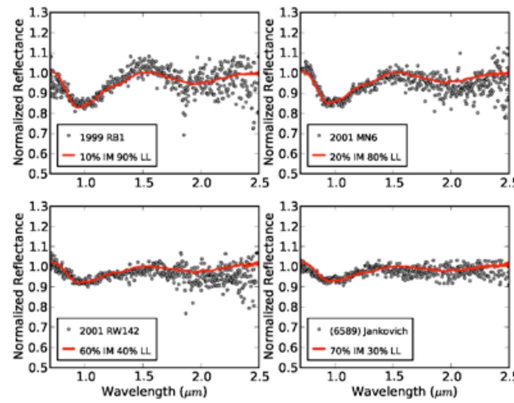

Figure 2. Plots showing spectral match for four of the nine BAF members using intimate mixtures of Chelyabinsk LL5 chondrite and impact melt.

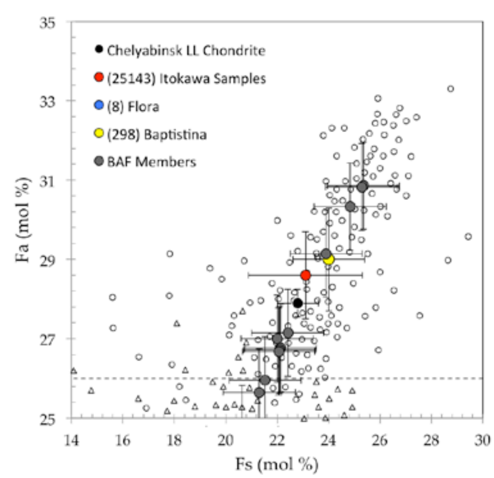

Figure 3. Plot showing fayalite and ferrosillite mol. % of BAF members along with Flora, Baptistina, Itokawa and Chelyabinsk [adapted from 16]. The nine BAF members we observed plot precisely on the LL chondrite region forming a continuum that spans the entire compositional range for LL chondrites