The Flyby Model of Chondrule Formation: an Investigation into the Viability of Granoblastic Olivine Aggregates as Type I Chondrule Precursor Material

Ian K. Bania
Department of Physics and Astronomy, Colgate University
Advisors: William Herbst, James P. Greenwood
Department of Astronomy and Department of Earth and Environmental Sciences, Wesleyan University

Introduction

Chondritic meteorites represent some of the oldest physical samples the scientific community currently has available to study, dating to just a few million years younger than the solar system. The $\sim .1mm$ spheres known as chondrules are composed predominantly of silicates and account for a significant volume of their host chondrites. Chondrites are unique from other meteorites in that they are undifferentiated–in principle this means they have maintained the same composition and structure since their formation.

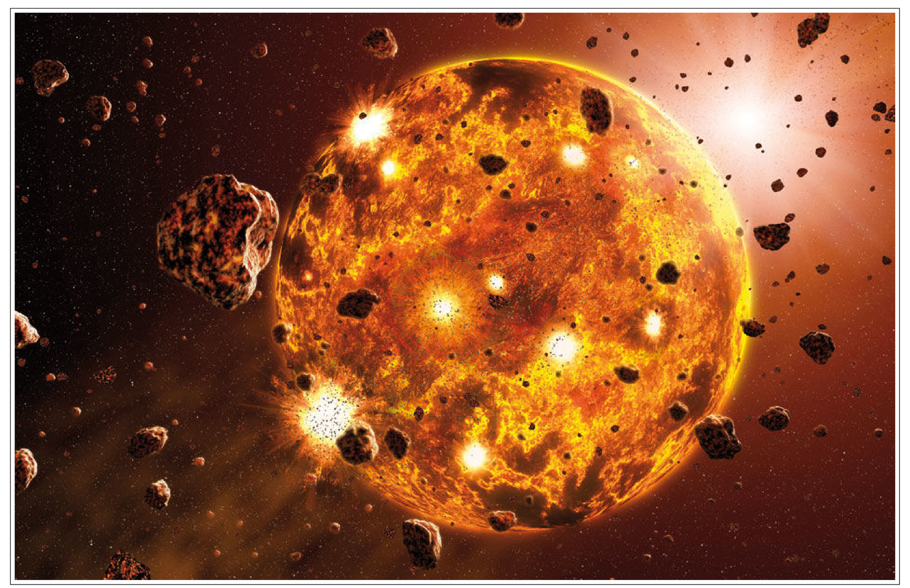

Figure 1: Artist's impression of a molten planetesimal surrounded by debris. [1].

One way chondrules are classified is by their iron oxide content, with FeO poor chondrules known as type I. Moreover type Ia chondrules are rich in Olivine, and type Ib in pyroxene. While 'nebular' models have fallen out of prevalence in favor of a 'planetary' ones, the question of chondrule formation is still a very open one. The **flyby model** proposes that chondrules are formed within small collections of pre-chondrule dust during close encounters with magmatically-active planetesimals. We attempt to show that during these close flybys, material is heated radiatively by exposure to liquid lakes of molten magma at the surface of radioactively heated planetesimals. Furthermore, I investigate granoblastic olivine aggregates' (**GOAs**) viability as type Ia chondrule precursor material within the heating and cooling constraints of the flyby model. **GOAs** are collections of olivine exhibiting anhedral, phaneritic and equigranular texture. In my experiments I use 100hr sintered olivine as an analogue for **GOAs** within precursor material.

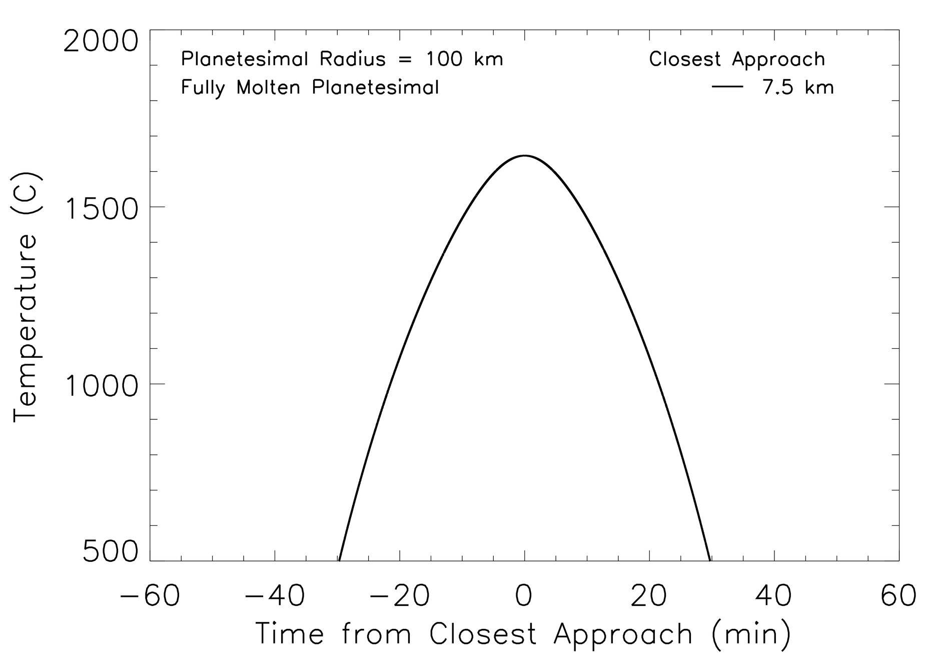

Figure 2: Plan E heating curve, used to simulate the 'flyby' of a molten planetesimal.

SEM Imaging

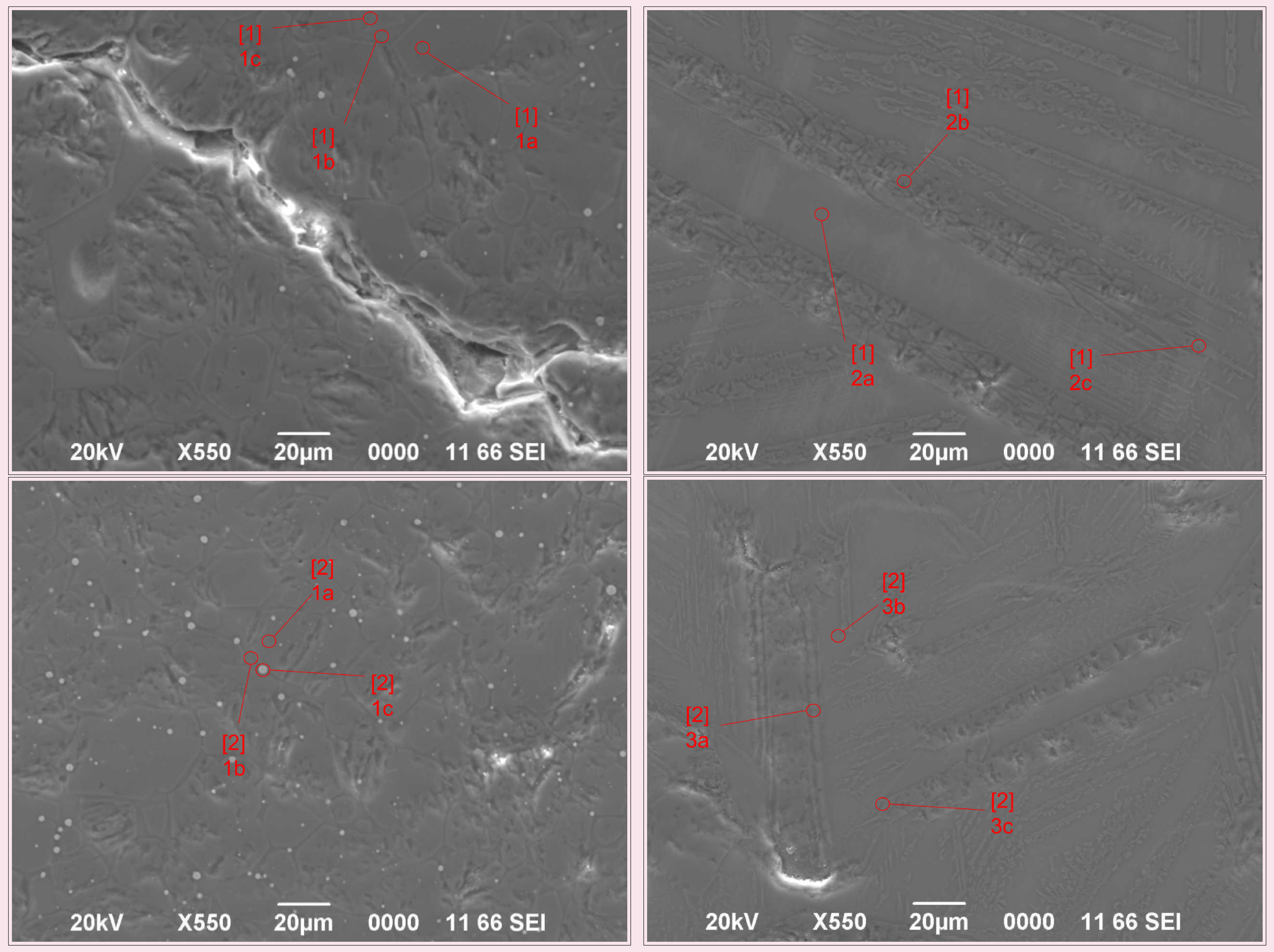

Figure 3: Backscattered electron imaging, each site with three points of elemental analysis. Top: sample[1], without iron. Bottom: sample[2], with iron.

Experimental Methodology

In order to simulate a $7.5km$ orbital encounter with a completely molten planetesimal of radius $100km$, surface temperature $2150K$, and density $3g \cdot cm^3$, I used a Deltech VT-31 tube furnace to heat two charges ([1] and [2]) contained in platinum tubes up to peak temperatures of $\sim 1650K$. These heating parameters are known as 'Plane E'. The identical samples were composed of a 1:1 combination of **San Carlos olivine** which had been ground to $< 43\mu m$, pressed into $\sim 6mm$ disks and sintered for 100 hours at $1350°C$ and then broken into pieces, and a 3:7 mix of **plagioclase** and **Bamble enstatite**, ground to $< 63\mu m$. For sample[2], %10 iron fillings were added by weight.

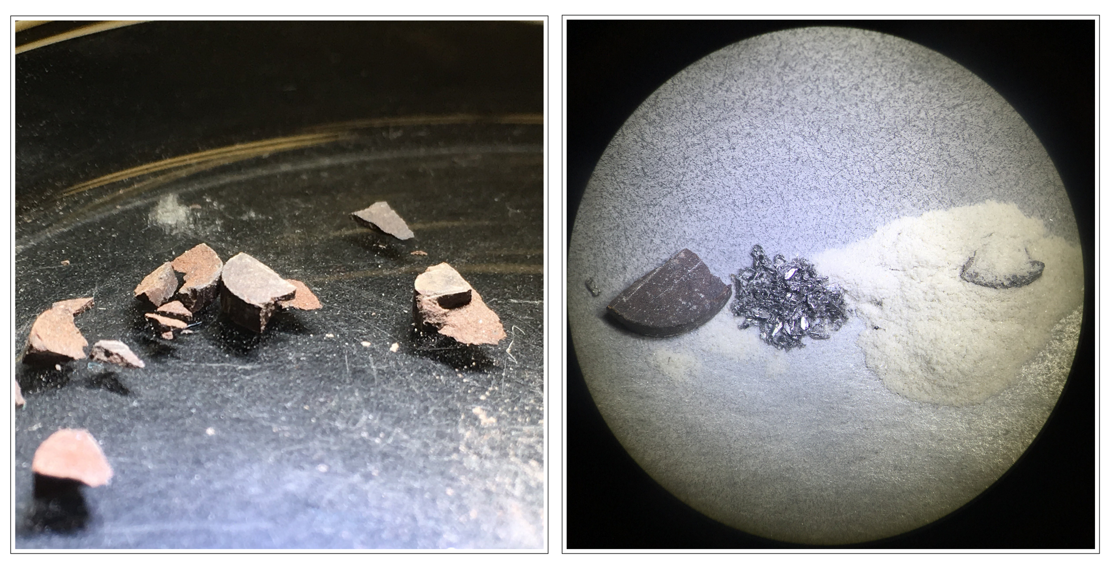

Figure 4: Left: San Carlos olivine, crushed after sintering at $1350°C$ for 100 hours. Right: 4x optical microscope image of the components of sample[2]: Ol., iron, Pl.+En. mix.

Results

Point	O	Mg	Si	Fe	Ni	Al	Ca	Sr
[1]1a	51.28	28.84	16.57	2.31	-	-	-	-
[1]1b	61.60	2.78	25.98	-	-	6.53	3.12	-
[1]1c	51.09	29.48	16.43	2.99	-	-	-	-
[1]2a	60.12	5.71	21.01	3.42	-	5.35	2.73	1.66
[1]2b	55.71	27.50	16.79	-	-	-	-	-
[1]2c	53.80	19.70	21.92	4.58	-	-	-	-
[2]1a	54.33	29.28	16.39	-	-	-	-	-
[2]1b	61.63	3.62	22.52	1.90	-	5.69	2.97	1.66
[2]1c	-	-	-	90.63	9.37	-	-	-
[2]3a	55.27	25.27	19.46	-	-	-	-	-
[2]3b	61.61	3.44	23.26	1.41	-	5.59	2.86	1.82
[2]3c	54.36	27.98	14.33	2.19	-	-	-	1.14

Table 1: Elemental compositions for point samples by atomic percent.

After heating, charges were thin sectioned, mounted polished, and analyzed using **backscattered electron imaging**. Within both samples, both composition and texture vary to the extreme based on location within the chondrule. Furthermore the sintered olivine did not fully melt and diffuse into the rest of the sample.

Discussion

These results show that with these heating parameters, **GOAs** are not a possible type Ia chondrule precursor within the **flyby model**. However, it is still possible that given longer heating and higher peak temperatures, **GOAs** could still fill this role. Within the **flyby model** it is possible to achieve this with closer encounters and larger planetesimal radii.

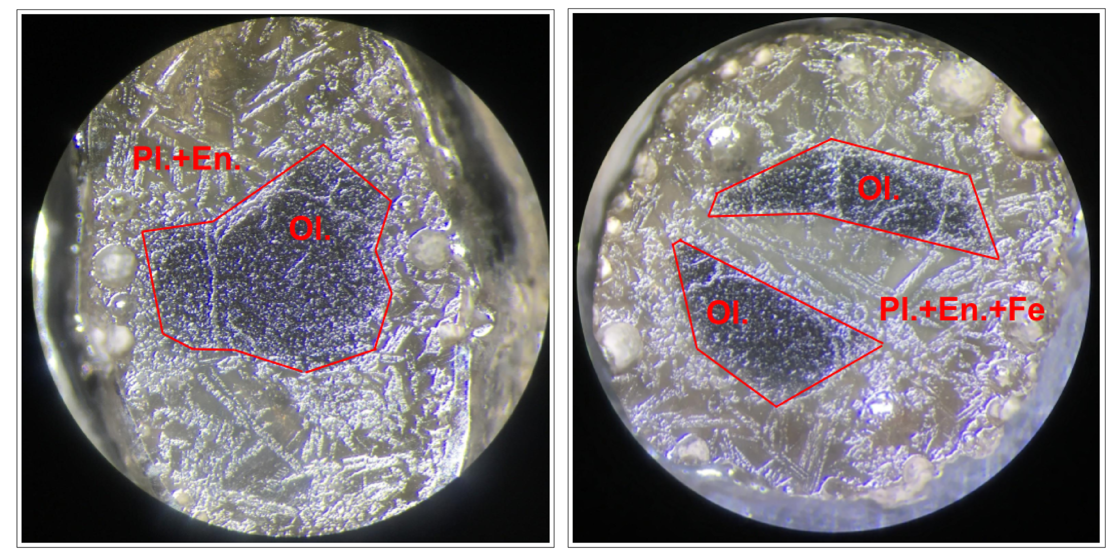

Figure 5: 4x optical microscope images of sample[1] (left), and sample[2] (right).

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Acknowledgements

Dr. Greenwood, Mr. Zareski and Dr. Herbst were all crucial for this project. I am very grateful of them for their invaluable direction and mentorship. Moreover I am very thankful towards the Keck Northeast Astronomy Consortium for providing me with this research opportunity and the accompanying funding. Finally, this work would not have been possible without the Emerging Worlds research grant from NASA.

Contact Information

- Observatory: http://observatory.colgate.edu/
- Web: http://www.colgate.edu/academics/departments-and-programs/physics-astronomy
- Email: ibania@colgate.edu