Using dust from asteroids as regolith microsamples

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Motivation

- More robust links need to be forged between meteorites and their parent bodies to understand the composition, diversity and distribution of the asteroids. A major link can be sample analysis of the parent body material and comparison with meteorite data (Table 1).
- Dust is present around all airless bodies, generated by micrometeorite impact into their airless surfaces, which in turn lofts regolith particles into a "cloud" around the body.
- The composition, flux, and size distribution of dust particles can provide insight into the geologic evolution of airless bodies. For example, the Cassini Cosmic Dust Analyzer detected salts and minerals emitted by plumes at Enceladus, evidence for a subsurface ocean with a silicate seafloor [Postberg et al. 2009, Hsu et al. 2015].
- Dust analysis instruments may enable future missions to obtain elemental, isotopic and mineralogical composition of regolith particles without returning the samples to terrestrial laboratories.

Model datasets

- We used point-counts of multiple meteorites and types as a proxy for regolith particles to construct a database of mineral abundance (silicates, Fe-Ni metal, oxides, sulfides, and others) and mineral composition (Mg#, An#) for the major meteorite groups (Fig 1).
- We used a dataset consisting of 1087 single-mineral particles in the Hayabusa sample (Table 2). Using all 1087 particles, Itokawa plots easliy into the ordinary chondrite group (Fig. 1), an association confirmed by laboratory-based analyses.
- We used a Monte Carlo model to understand whether analysis of smaller subsets of the 1087 Hayabusa particles would have yielded the link to ordinary chondrites with the same confidence.
  - We created 100 simulations of randomly selected sets of 20, 50, 100, 250, 500 and 750, 1000 particles and computed the mineral abundance that would be derived with a sample set of each size (Fig. 2)
  - The model sets have wider distributions with smaller set sizes, as expected, but the distributions decrease to about 10% (relative to the mean) around 100-250 particles.
  - None of the result sets have too high an abundance of FeNi metal (0.23% for Hayabusa), or too different a metal/sulfide ratio, to place the Itokawa composition into the H chondrite field.
- We also examined a set of 34 monomineralic particles from the Stardust mission in the same way. This limited dataset does not appear to link Wild 2 to any known meteorite group (Fig. 1). It may be that this sample size is too small to yield reliable statistics, or that the parent body is not represented on this figure. These samples are linked to IDPs by methods only available in the laboratory.

Results and recommendations

- **Sample return to Earth is not the only method for regolith particle analysis.**
- Major meteorite groups can be distinguished using uncomplicated indicators such as mineral abundance and Fe/Mg ratios in silicates, accomplishable by currently-available dust detector instruments.
- In general, a sample size of 100-250 monomineralic particles adequately establishes major groups.
- Firmer links may be made by
  - increasing the number of particles to improve counting statistics of minor phases
  - identifying diagnostic minerals, such as oldhamite in enstatite chondrites, or organics in carbonaceous chondrites
  - using contextual clues provided by other observations of the parent body, such as imaging and spectroscopy

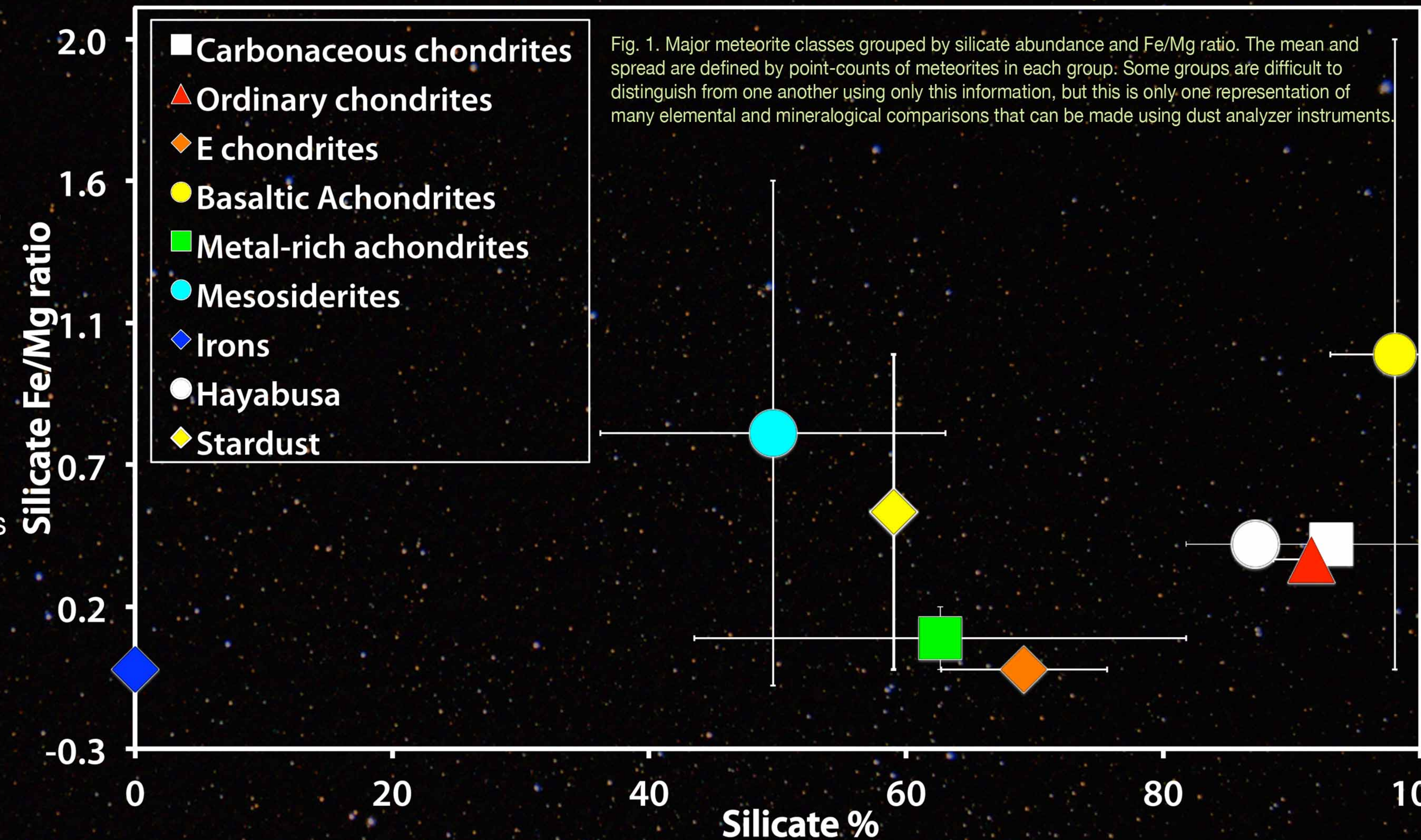

Fig. 1. Major meteorite classes grouped by silicate abundance and Fe/Mg ratio. The mean and spread are defined by point-counts of meteorites in each group. Some groups are difficult to distinguish from one another using only this information, but this is only one representation of many elemental and mineralogical comparisons that can be made using dust analyzer instruments.

	Class	Group	Asteroid match	% Silicate	Silicate Fe/Mg	FeNi metal	Sulfides	Oxides	Carbon	Hydrous
Chondrite	Enstatite	E	M	60-75	0	x	x			
	Ordinary	H, L, LL	S	85-95	0.3	x	x			
	C	many	C (D, B, F, G, Q)	80-100	0.4	x		x	x	x
	Rumuruti	R	none identified	90-95	0.7		x			
Achondrite	Evolved	HEDs	V	95-100	0.2-3.8			x		
		Aubrites	E	95-100	0		x			
		Angrites	none identified	95-98	0.1-1.0		x	x		
	Primitive	Acapulcoites & Lodranites	none identified	70-90	0.1	x	x		x	
		Brachinites	none identified	30-100	0.4		x	x		
		Ureilites	none identified	95-98	0.2-0.3	x	x		x	
		Winonaites & Silicate-bearing irons	(M)	10-75	0.05	x	x		x	
	Iron & stony-iron	Mesosiderites	(S)	35-65	0.1-1.4	x	x			
		Pallasites	A	55-75	.2	x	x			
		Irons	M	0	n/a	x	x		x	

Hayabusa, n=1087	%	Stardust, n=34	%
Fe-Ni metal	0.3	Fe-Ni metal	6
Sulfide	10	Sulfide	15
Oxides	1.2	Carbon	18
Phosphate	0.9	CAIs	3
Silicate	87	Silicate	59
Silicate Fe/Mg	0.4	Silicate Fe/Mg	0.1-24

Table 1 (left): Relevant features of meteorites linked to asteroid parent bodies.

Table 2 (right): Mineral characteristics of regolith particle datasets from the Hayabusa and Stardust missions.

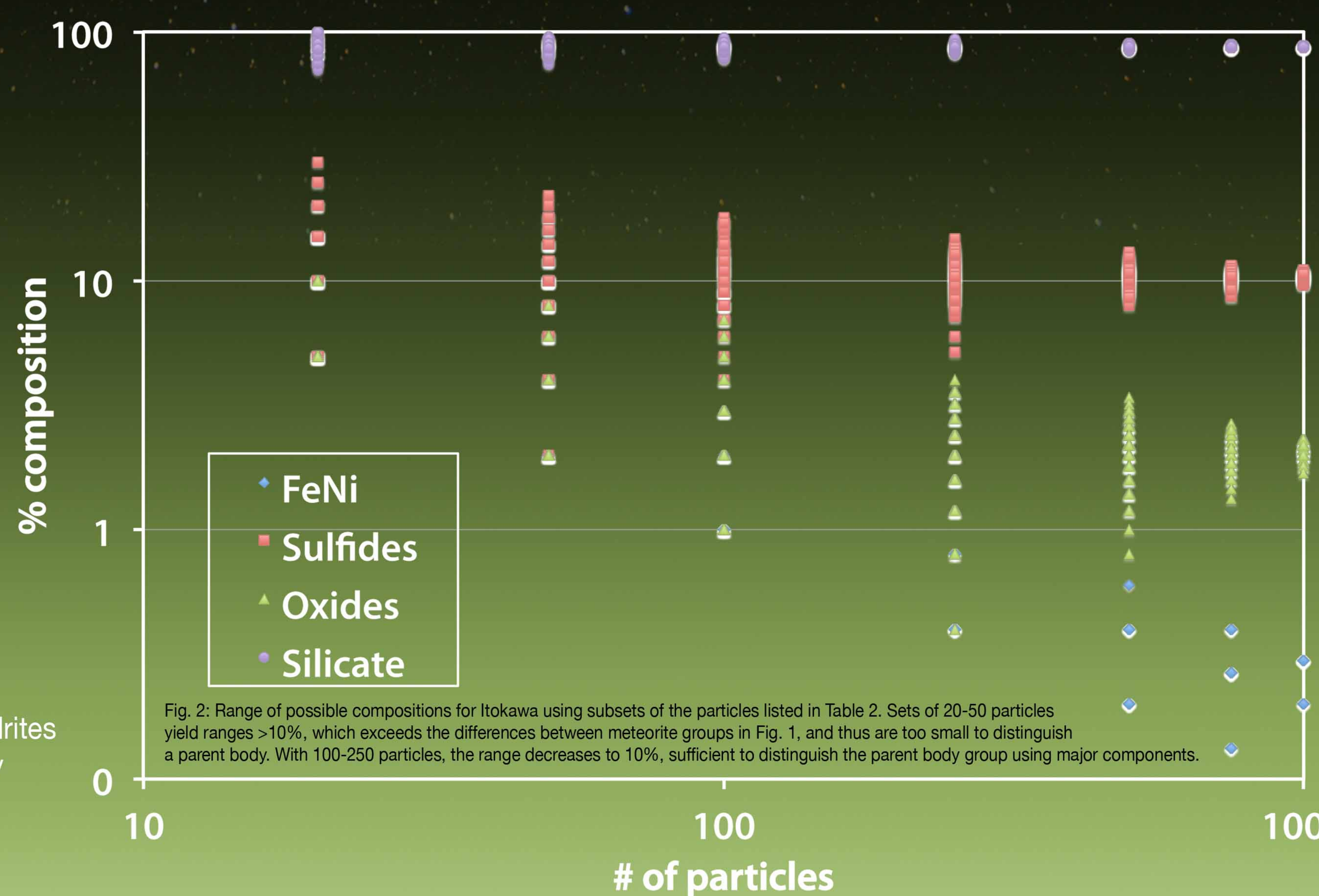

Fig. 2: Range of possible compositions for Itokawa using subsets of the particles listed in Table 2. Sets of 20-50 particles yield ranges >10%, which exceeds the differences between meteorite groups in Fig. 1, and thus are too small to distinguish a parent body. With 100-250 particles, the range decreases to 10%, sufficient to distinguish the parent body group using major components.