ZAGAMI: PRODUCT OF A TWO-STAGE MAGMATIC HISTORY T.J. McCoy[1], G.J. Taylor[1], K. Keil[1] and P.D.Noll, Jr.[2] [1] Planetary Geosci. Div., Dept. of Geology and Geophysics, SOEST, Univ. of Hawaii, Honolulu, HI 96822 [2] Inst. of Meteoritics, Dept. of Geology, Univ. of New Mexico, Albuquerque, NM 87131.

INTRODUCTION. As part of a consortium to study newly acquired pieces of Zagami, we have carried out petrologic studies of two samples which show marked variations in grain size. Our efforts focused on the magmatic history of Zagami and the cause of the grain size variation. The cause of this variation remains enigmatic, but must result from a complex interplay of processes. Numerous studies have characterized the properties of the shergottites (1-4) and favored one of two settings for their formation - either by slow cooling within a magma chamber or rapid cooling in a shallow intrusive or lava flow. We propose a model which combines these into a two-stage history in which the pyroxene's homogeneous Mg cores crystallize during slow cooling in a magma chamber and are subsequently entrained in a basaltic liquid erupted at the surface, where the remainder of the rock crystallized.

RESULTS. We will describe only those features of Zagami not noted by earlier workers, many of which were apparent to us because of the large amount of material available for study (Fig. 1). The most striking feature of these samples is the variation in average grain size, ranging between 0.24 for the fine-grained and 0.36 mm for the coarse-grained. This variation is similar to that between Shergotty and Zagami (2). In contrast to the strong preferred orientation in fine-grained Zagami and Shergotty, no preferred alignment exists in the coarser portion of Zagami. The fine-grained piece of Zagami is cut by shock-produced veins which are compositionally similar to the bulk rock and roughly follow the preferred orientation. Localized pockets of shock-melt exist in both the fine-grained and coarse-grained samples and seem to represent preferential melting of some phases. We have identified whitlockite in Zagami which is identical in composition and morphology to that in Shergotty (2).

DISCUSSION. A two-stage magmatic history for Zagami (and Shergotty) can explain many of the features present in these rocks. Here, we examine the details of each magmatic stage.

Magma Chamber. The homogeneous Mg cores described by previous studies (2) formed in a magma chamber by slow cooling or subsequent homogenization. We have mapped these cores from BSE images to determine their sizes, shapes, abundances and distributions. Only minor differences exist in the cores of the coarse- and fine-grained portions. The cores in the coarse-grained samples are slightly larger in long dimension (0.55mm) and slightly less abundant (14.4 vol.%) than cores in the fine-grained sample (0.41mm;18.8 vol.%). Distribution of cores is uniform throughout the samples and the shapes of the cores (laths, spheres) strongly controls the shapes of the final grains. We have calculated the settling distance of a Mg-core in a magma of known crystal content. At 1150°C, the homogeneous Mg cores would settle approximately 1 meter per year in a basaltic liquid with 20 vol.% crystals, resulting in only modest crystal concentrations. We are investigating the occurrence of amphibole-bearing melt inclusions in Zagami, which require formation at depth (>6 km) and should be present only in the Mg cores.

Lava Flow. The presence of Fe zonation in the rims of Zagami pyroxenes and the generally fine-grained texture of this rock argue for fairly rapid cooling. We have estimated the cooling rate of Zagami by two independent methods. Plagioclase (maskelynite) width is related to both the cooling rate and distance from the edge of a flow or intrusion (5,6). For Zagami, cooling at 0.1-1°C/hr is indicated. This suggests that Zagami crystallized 2-3 meters from the edge of a magma body at least 10 meters thick. The sharp contact between Mg-rich cores and Fe-rich rims requires rapid cooling to prevent homogenization. Cooling rates must have exceeded 0.1°C/hr, assuming that Fe-Mg diffusion in pyroxene is 1000 times slower than in olivine. These two independent methods point to cooling at rates of tenths of a degree per hour and cooling times on the order of weeks to months. These values are most readily explained by cooling in a moderatley thick lava flow. Fine lamellae in pyroxenes have been interpreted as indicative of slow cooling (3) or shock lamellae (7). We are currently studying these features. If these are fine exsolution lamellae, they are still consistent with cooling in a thick flow, which are common in the Tharsis region of Mars.

The composition of the liquid, calculated by mass balance, is basaltic (~51 wt% SiO_2) and rich in FeO (~18.5 wt%). In this lava flow, crystal settling would be small. A Mg core would settle 1-2 cm in a basaltic magma of 20% crystals while cooling from 1150°C to 1000°C at 0.5°C/hr. Thus, no diffentiation of core sizes could occur in the flow. The presence of two similar lithologies in sharp contact in the shergottite EETA 79001 indicates that this meteorite also formed as a series of flows, not by crystal accumulation. If settling played a major role, we would not find two lithologies formed by crystal accumulation in contact. Instead, a lithology with concentrated crystals would occur next to one depleted in crystals.

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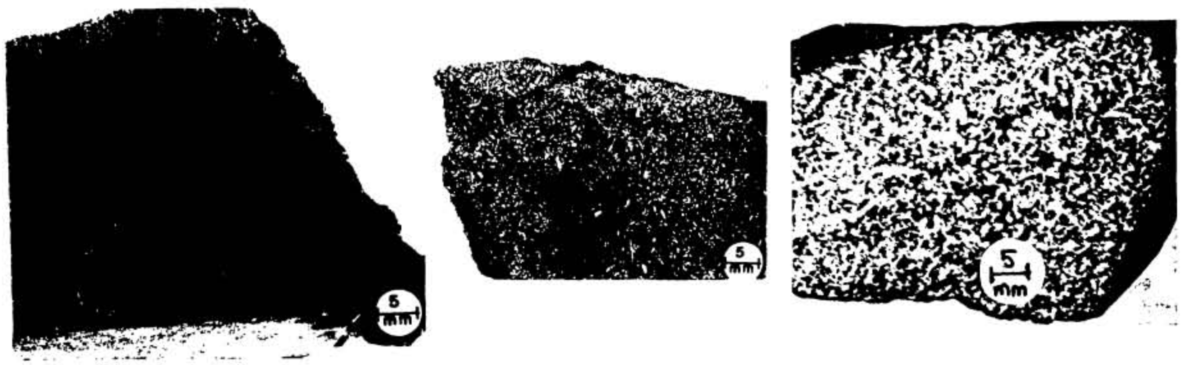
ZAGAMI — Fine — Coarse — SHERGOTTY



Zagami — Fine

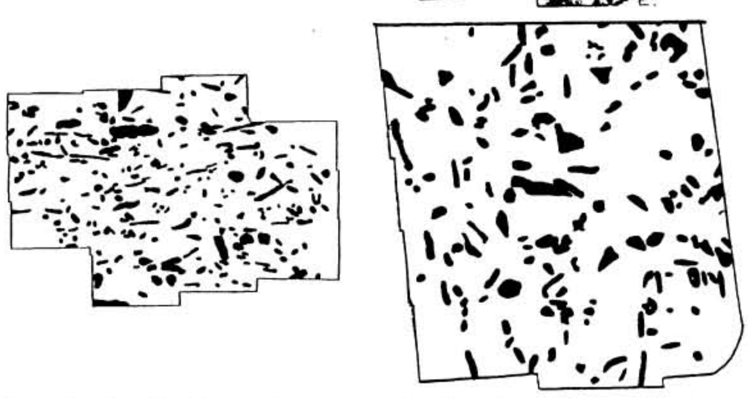
Bulk Rock		Mode	
SiO_2	50.76	Pyroxene	77.7
TiO_2	0.89	Maskelynite	17.6
Al_2O_3	6.69	Mesostasis	1.8
FeO^T	17.79	Oxides	1.5
MnO	0.53	Sulfides	0.6
MgO	9.70	Phosphates	0.5
CaO	11.53	Shock Veins	0.1
Na_2O	1.39		
K_2O	0.15	*Avg. Grain Size*	
P_2O_5	0.56	*0.24 mm*	

Zagami — Coarse

Bulk Rock		Mode	
SiO_2	51.21	Pyroxene	80.4
TiO_2	0.83	Maskelynite	10.3
Al_2O_3	6.19	Mesostasis	3.7
FeO^T	18.18	Oxides	2.6
MnO	0.55	Sulfides	0.6
MgO	10.36	Phosphates	1.3
CaO	10.66	Shock Veins	0.9
Na_2O	1.29		
K_2O	0.13	*Avg. Grain Size*	
P_2O_5	0.58	*0.36 mm*	

Shergotty

Bulk Rock		Mode	
SiO_2	49.50	Pyroxene	69.8
TiO_2	0.79	Maskelynite	23.3
Al_2O_3	7.18	Mesostasis	4.0
FeO^T	19.85	Oxides	2.3
MnO	0.53	Sulfides	Trace
MgO	9.15	Phosphates	Trace
CaO	9.69	Shock Veins	
Na_2O	1.35		
K_2O	0.17	*Avg. Grain Size*	
P_2O_5	0.71	*0.46 mm*	



Shergotty Data: Hand Sample and Thin Section Photos - Duke M.B. (1968) In *Shock Metamorphism of Natural Materials*, 613-621. Bulk Rock - Laul J.C., Smith M.R., Wanke H., Jagoutz E., Dreibus G., Palme H., Spettel B., Burghele A., Lipshutz M.E., and Verkouteren R.M. (1986) *GCA* **50**, 909-926. Mode and Grain Size - Stolper E.M. and McSween H.Y., Jr. (1979) *GCA* **43**, 1475-1498.

Figure 1. Data for fine- and coarse-grained portions of Zagami and comparison with literature data for Shergotty. Photos of hand-samples (real size) and thin sections (same scale) illustrate the range of grain sizes in Zagami and similarity between Zagami coarse material and Shergotty. Bottom diagrams are maps of homogeneous Mg cores for Zagami thin sections. The sizes and abundances of these cores are similar between coarse and fine material. These cores formed in a magma chamber at depth and were subsequently entrained in a basaltic lava flow which crystallized fairly rapidly.