STYLES OF ASTEROIDAL IGNEOUS PROCESSES: OBSERVATIONAL CONSTRAINTS FROM ROTATIONAL SPECTRAL INVESTIGATIONS. M.J. Gaffey, Geology Department, Rensselaer Polytechnic Institute, Troy, New York 12181

The presence of igneous assemblages in the asteroid belt is well established [1,2 and references therein]. Moreover, the putatively igneous asteroids (most members of taxonomic classes V,E,A,R,M, and S) are concentrated in the inner belt and show a strong decrease in their relative abundance with increasing heliocentric distance [2-5]. Although it is often useful to treat each type as a homogeneous group of materials with a single thermal and igneous history, recent analyses of spectral survey data has shown the existence of considerable variations in the degree of chemical modification (in both igneous and lower temperature aqueous alteration processes) on and within asteroidal parent bodies [6-9]. The overall pattern of decreasing peak post-accretionary temperature with increasing semimajor axis is maintained in these data sets and must reflect some early sun-centered process or conditions which varied with heliocentric distance. However, these detailed analysis indicate that the relationship is more complex than a simple monotonic function of semimajor axis. The detailed study of individual igneous asteroids, especially the anomalous or extreme members of these types, can provide additional powerful constraints of both the nature of this shortlived heat source and of the compositional gradients and inhomogeneities in the solar nebula.

The igneous S-asteroids exhibit considerable diversity in the mafic silicate assemblage (from dunite to basalt), mafic mineral composition, and metal abundance [8,9 and in preparation]. These differences appear to reflect variations both in the degree of melting and in the efficiency of magmatic segregation within individual parent bodies. Analysis of rotational spectral variations for individual asteroids can provide insight into the detailed history of the specific parent bodies of those asteroids. The initial results of such analysis on three key asteroids are outlined below.

<u>113 Amalthea</u> is an S-type asteroid with an IRAS diameter of 47.6±2.7km and an albedo of 0.27±0.03 [10,11]. It has a rotation period of 9.935 hours and a lightcurve amplitude of 0.19-0.26 magnitudes [12]. Spectrally it is very similar to a nearly monomineralic olivine assemblage (A-type) except for a slightly weaker absorption feature and a lower 2um reflectance. Amalthea was observed on two nights in February 1988 using the NASA Infrared Telescope Facility (IRTF) atop Mauna Kea to obtain CVF spectra (0.8-2.6um). Fifty-four individual observations were obtained throughout its rotational cycle. The spectrum indicates a nearly monomineralic olivine assemblage with a trace (≤5%) pyroxene component. The rotational spectral data of Amalthea indicate that the trace pyroxene component does not vary significantly across the surface. The relative IRAS emissivity of Amalthea is consistent with a metal free surface.

<u>446 Aeternitas</u> is an A-type asteroid with an IRAS diameter of 43±5km and an albedo of 0.35±0.08 [10,11]. The rotation period is not known. Eighteen observations of Aeternitas were obtained with the same IRTF system on two nights in December 1988. Although the relative rotational phase of these observations cannot yet be established, the significant systematic flux variations (0.3mag) seen in the data set indicates that a variety of rotational aspects were sampled. Olivine is the only mineral phase seen in the spectrum. There is no evidence of any pyroxene at any of the observed rotational aspects. The relative IRAS emissivity of Aeternitas is consistent with a metal free surface.

<u>349 Dembowska</u> is an R-type asteroid with an IRAS diameter of 143±3km and an albedo of 0.34±0.01 [10,11]. It has a rotational period of 4.701 hours and a lightcurve amplitude between 0.08 and 0.47 magnitudes depending upon the ecliptic longitude (projected pole orientation) of the observations [12]. Observations with a large light curve amplitude (0.34 mag) were obtained with the University of Hawaii 2.4m telescope in June 1980 (24 filters, 0.33-1.0um) and the IRTF in May 1990 (CVF, 0.8-2.6um). Observations with a small lightcurve amplitude (0.10 mag) were obtained with the UH 2.4m telescope in February 1979 (24 filters, 0.33-1.0um) and with the IRTF in June 1980 (CVF, 0.8-2.6um). Nearly complete rotational coverage was obtained for each aspect. The spectrum indicates an olivine-pyroxene assemblage with an olivine to pyroxene ratio of approximately 0.9. The olivine-pyroxene ratio varies substantially with rotational aspect.

Assuming a chondritic starting material, an igneous process would be required to produce the essentially pure high albedo olivine assemblages present on Amalthea and Aeternitas. This assemblage could be either the high temperature residue (olivine) left by the partial melting and essentially complete extraction of the pyroxene, feldspar, metal and sulfide components or it could be a cumulate layer produced by the settling and efficient segregation of olivine crystallizing out of a mafic melt. Given the low buoyancy forces in small planetesimals (on the order of a few percent or less of that in the Earth's mantle), efficient segregation of the basaltic partial liquid from the mantle of a parent planetesimal during low to moderate degrees of partial melting seems unlikely to produce such nearly pure olivine residual assemblages. The lack of any detectable compositional gradient across the layers of the parent bodies sampled by these two asteroids is also more easily reconciled with a magmatic differentiation process rather than a partial melt extraction. The surface assemblage of Amalthea and Aeternitas were derived from the mantles of parent planetesimals which were mostly or completely molten throughout their interior. Their internal temperatures must have been well above the orthopyroxene solidus and perhaps were above the olivine solidus. These peak temperatures are substantially higher than those inferred for many other igneous asteroids.

For a fully molten parent body of chondritic composition which underwent complete magmatic differentiation, the core would be overlain by a thick olivine mantle and an thinner basaltic crust. For the chondritic range of NiFe and FeS contents (5% - 35% wgt), the radius of the core ranges from 29% to 56% of the radius of the parent body. Based upon a modeled olivine mantle, Amalthea and Aeternitas set minimum sizes for their parent bodies of 140km to 260km depending upon the oxidation state of the initial assemblage.

The surface assemblage of Dembowska is enriched in pyroxene to some degree relative to a chondritic parent material. The rotational variations of Dembowska appear to be consistent with a range of mantle depths including a shallow zone enriched in basaltic partial melt extracted from a deeper mantle zone. The rotational variations exclude the surface exposure of a highly depleted olivine mantle similar to Amalthea or Aeternitas. Dembowska could include the NiFe-FeS core of an approximately 200km parent body, or it could be a mantle fragment of a larger ($\geq$500km) body. However, unless the Dembowska parent planetesimal was very large ($\geq$1500km), the initial analysis of the rotational spectral variations appear to exclude the possibility that it was a fully or extensively molten body. Thus Dembowska attained a peak temperature near the pyroxene solidus throughout its interior, a temperature substantially below that seen by either Amalthea or Aeternitas.

The variation in heating intensity between these three bodies is not a simple monotonic function of heliocentric distance, indicating that additional factors such as parent body composition or size must have played an important role in determining their susceptibility to the heat source.

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