NATURE AND ORIGINS OF THE OLIVINE-DOMINATED A- AND S(I)-TYPE ASTEROIDS;
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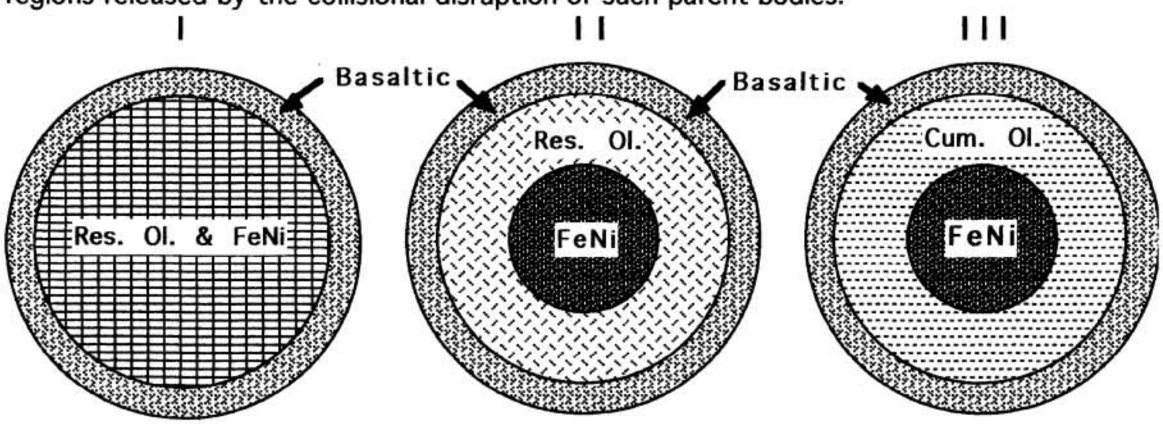
Olivine is the most abundant mineral which can be unambiguously identified on asteroid surfaces. Olivine is also the most abundant mineral in anhydrous silicate bodies of chondritic (or solar) composition. In undifferentiated asteroids and in chondritic meteorite parent bodies, this olivine is intimately mixed with a variety of other mineral species. However, the A-type asteroids and a significant portion of the S-type asteroids exhibit spectra indicating the presence of large concentrations of nearly pure olivine produced by igneous processes. Consideration of the nature of these igneous processes leads to constraints on the size of the parent planetesimals of these olivine-rich asteroids and on the identification of additional fragments of those specific disrupted parent bodies.

Olivine can be concentrated in three general ways by igneous processes depending on the peak temperature attained within a parent planetesimal. These include: i) extraction of a melt containing the basaltic components (pyroxene & feldspar) at low degrees of partial melting to leave a residual intimate mixture of olivine and metal-metal sulfides; ii) gravitational segregation of metal melt from the solid or partially solid olivine at high degrees of partial melting; and iii) gravitational segregation of dense, early crystallizing olivine to form an olivine cumulate layer in bodies which had undergone complete or nearly complete melting [1-3]. Meteorites such as brachinites, lodranites and (some) ureilites appear to have been produced by the first process [3,4,5]. Pallasites apparently represent samples of the olivine-metal boundary region in bodies produced by the second or third processes. Residual or cumulate olivine achondrites produced by the second or third processes have not been unambiguously recognized in meteorite collections.

Three general types of differentiated parent bodies (shown schematically on the figure below) include large olivine-dominated regions: I) a residual intimate olivine-metal mixture [ol/metal ~ 1-5] in the interior underlying the basaltic crust of bodies which underwent low degrees of partial melting; II) a residual olivine layer sandwiched between the metal core and basaltic crust of bodies which underwent high degrees of partial melting; and III) a cumulate olivine layer sandwiched between the metal core and basaltic crust of bodies which underwent complete or essentially complete melting and magmatic differentiation. For smaller bodies with abundant volatiles the basaltic component may have been expelled from the body by explosive volcanism [3,5,6]. Olivine-dominated asteroids represent samples of these olivine-rich regions released by the collisional disruption of such parent bodies.



Assuming efficient basaltic melt extraction [2], the relative dimensions of the olivine-metal volume (case I: 0.80 to 0.94 of the body radius) or olivine layer (cases II & III: 0.29 to 0.47 of the body radius) depends on the initial composition of the parent body (i.e., chondritic types H to CV/CO). The metal cores for cases II and III have fractional radii of 0.47 and 0.31 for H-type and CV/CO-type precursors, respectively.

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The A-type asteroids exhibit significantly stronger (~2x) olivine absorption features than the most olivine-rich S-asteroids (subtype S(I)) of comparable sizes [2]. It appears probable that the A-type assemblages represent fragments of case III parent bodies. The more strongly featured and higher albedo S(I)-objects (e.g., 113 Amalthea, 354 Eleonora) appear to represent fragments of case II parent objects, while the more weakly featured and lower albedo S(I)-object (e.g., 42 Isis) and associated objects (e.g., 9 Metis, 89 Julia) appear to sample case I parent planetesimals.

Based on the IRAS diameters of these olivine-dominated asteroids [7], the table below indicates the minimum diameter of their parent planetesimals assuming that they were derived from mantle layers in cases II and III and the maximum diameter of the parent planetesimals for objects which would still include the core of the parent body. For a case I parent object, the minimum diameter is indicated. In each case the diameters for H-type and for CV/CO-type parent compositions are indicated.

Parent Planetesimal Diameters as a Function of Parent Body Composition and Fragment Source

Object	Type	Case	Minimum Diameter if Mantle Fragment		Maximum Diameter if Core Included	
			H	CV/CO	H	CV/CO
289 Nenetta	A	III	285 km	175 km	90 km	135 km
446 Aeternitas	A	III	295 km	180 km	90 km	140 km
113 Amalthea	S(I)	II	330 km	205 km	100 km	155 km
354 Eleonora	S(I)	II	1120 km	690 km	345 km	520 km
42 Isis	S(I)	I	135 km	115 km	-----	-----
89 Julia	S(U)	I	200 km	170 km	-----	-----

Most are consistent with mantle fragments of 200 to 350 km parent planetesimals which fully melted (289, 446) or which extensively partially melted (113). 354 Eleonora probably still contains the core derived from a 350-520 km parent planetesimal.

Considerations of the relative survival probabilities of asteroidal bodies suggests that it is highly likely that the smaller case II and III objects (e.g., 298 Nenetta, 446 Aeternitas, 113 Amalthea) are not the largest remaining fragments of their respective parent bodies. Among the suite of fragments produced by the catastrophic disruption of a parent planetesimal, the larger and stronger (i.e., metal-rich) bodies have longer lifetimes against subsequent collisional destruction than smaller and weaker (i.e., silicate-rich) bodies. As noted above [2], the diameter of the cores ranges from 1.3 to 3.2 times the thickness of the overlying olivine-rich layer in cases II and III. The survival probability of such core objects (i.e., larger and metal-rich) is higher than that of the smaller, silicate-rich case II and III objects discussed above. Therefore it seems probable that each of these case II and III bodies (41-48 km) should have a large associated core fragment (an S- or M-type >55 - 155 km) located in a relatively nearby orbit. We are currently surveying the asteroid population near each of these case II and III olivine-rich asteroids to identify candidates for the associated cores.

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References: [1] Taylor G. J. (1992) *JGR (Planets)* **97**, 14717-14726. [2] Gaffey M. J. *et al.* (1993) *Icarus*, in press. [3] Taylor G. J. *et al.* (1993) *Meteoritics* **28**, 34-52. [4] Nehru C. E *et al.* (1992) *Meteoritics* **27**, 267 (abstract). [5] Warren P. H. and Kallemeyn G. W. (1992) *Icarus* **100**, 110-126. [6] Keil K. and Wilson L. (1993) *Earth Planet. Sci. Lett.* **117**, 111-124. [7] Tedesco E. F. (1989) In *Asteroids II* (eds. R. P. Binzel, T. Gehrels and M. S. Matthews), pp. 1090-1138. Univ. Arizona Press, Tucson.