

**THE OLIVINE ASTEROIDS: DISCOVERY, MINERALOGY, AND RELATIONSHIP TO METEORITES.**  
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**INTRODUCTION:** Telescopic observations have recently revealed the existence of a new class of asteroids whose surfaces show the spectral signature of abundant olivine. The mineralogy of a well-observed example (446 Aeternitas) is discussed and the implications for the origins of olivine-rich meteorites and the thermal evolution of asteroids outlined.

**DISCOVERY:** Veeder et al. (1,2) demonstrated by means of broadband (JHK filter) spectrophotometry that the asteroids classed as type "R" in the taxonomy of Bowell et al (3) actually comprised two classes with widely different infrared spectra, and introduced the designation type "A" for the smaller group. R. N. Clark pointed out during discussion of ref. 1 at the 1982 DPS-AAS meeting that the A-type objects lie in an area of the JHK plot which is occupied only by olivine-rich mixtures (4). Cruikshank and Hartmann (5,6) recently obtained spectrophotometry of 246 Aspordina and 289 Nenetta which revealed the distinctive deep multiple absorption bands of olivine, confirming this interpretation. At least 5 and possibly 13 (7) A-type asteroids are identifiable at present.

**NEW OBSERVATIONS:** We obtained high-resolution IR spectra of the A-type object 446 Aeternitas on 7 November 1983 with the NASA Infrared Telescope Facility on Mauna Kea, Hawaii. An average spectrum is shown in Fig. 1 as a ratio to the star 16 Cygni B which is spectrally similar to the sun. (Points plotted as crosses are existing photovisual data.) The individual spectra were taken over a period of about three hours during which the absolute brightness of the asteroid increased ~20% indicating significant rotation; however no detectable variations in mineralogy across the the surface of Aeternitas are apparent in our preliminary analysis.

**SURFACE MINERALOGY:** Our spectrum of Aeternitas clearly indicates that this asteroid's optically visible surface is predominantly olivine. Although a significant amount of plagioclase could be present without being evident in this spectral curve, only pyroxene and metal are directly indicated as accessory minerals. The weak possible 2-micron absorption band may indicate a minor component of pyroxene. Application of a newly developed calibration of the spectral properties of olivine-pyroxene mixtures (8) indicates an abundance of about 5% pyroxene. Uncertainty in the location of the continuum makes it impossible to rule out abundances between 0 and 10% of orthopyroxene or clinopyroxene. If small, distinct pyroxene-rich areas exist on Aeternitas the upper limit may be somewhat higher. The spectral curve is somewhat redder than would be expected for a pure mafic assemblage, indicating either A.) a fayalitic olivine, or B.) a metallic iron phase with exposed non-oxidised surfaces. The latter is more plausible. The surface of this asteroid is nearly monomineralic olivine with possible accessory pyroxene and metal. The similarity of broadband colors (2) indicates that similar mineral assemblages dominate the surfaces of the other A-type asteroids. Only 289 Nenetta appears slightly unusual, as both J-K color (1) and spectrophotometry (6) indicate a significantly deeper olivine band than in 246 and 446.

**ORIGIN OF OLIVINE-RICH ASTEROIDS:** The mineralogy inferred above indicates that the surfaces exposed to space today on the A objects were once in the interior, and that this region was subject to extreme magmatic differentiation. The apparent presence of metallic nickel-iron suggests that the current surface was originally the mantle-core transition region. These objects can be either differentiated planetesimals which have been eroded down symmetrically to a deep layer rich in cumulate olivine, or small fragments of a >50 km thick cumulate accumulation on a much larger parent body. The former interpretation appears most probable, and implies that some very small planetesimals (D < 100 km) were once almost completely melted. A search for mineralogical variations on the surfaces of these objects may allow a choice to be made between these alternate models. In either case, the A asteroids must derive from thermally evolved and magmatically differentiated parent planetesimals.

**RELATIONSHIP OF A-TYPE ASTEROIDS TO METEORITES:** Only two meteorite classes could plausibly be derived from the currently exposed surfaces of the A asteroids: pallasites (olivine crystals in a metal matrix) and olivine achondrites (cumulate olivine + accessory pyroxene and plagioclase). The presence of a metal phase supports an analogy with pallasites. No reflectance spectra of pallasites exist due to sample preparation difficulties. A lab spectrum does exist for the olivine achondrite Chassigny. However it has an anomalously young crystallization age and is therefore considered a member of the "SNC meteorites" for which an origin on Mars has been proposed (9). The discovery in Antarctica of a meteorite from the Moon has seemingly overcome the physical arguments

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against ejection of meteorites from Mars and greatly enhanced the credibility of a martian origin for the SNC meteorites. Thus Chassigny is of doubtful relevance to the A asteroids. The other olivine achondrite (Brachina) may be derived from a more pyroxene-rich and metal-poor layer of an A-type parent body.

**IMPLICATIONS FOR DELIVERY OF METEORITES TO THE EARTH:** The identification of the A-type objects as analogs of the olivine-rich meteorites is of high uniqueness due to the distinctive nature of the olivine spectral features, comparable in certainty to the identification of basaltic achondrites with Vesta. The existence of two reliable matches between two very different meteorite types and well-observed asteroids provides a clue as to the magnitude of possible bias factors in the relative abundance of meteorite types relative to the abundances of their parent bodies. There are about 40 observed basaltic achondrite falls known, but only one possible source body among the large, well observed asteroids. The dozen or so known A-type objects have produced at most 3 meteorite falls. Thus a bias factor of at least 150 exists between these two meteorite classes. Clearly the statistical distribution of meteorite types reaching the Earth has no relation to the abundances of mineralogically similar main belt asteroids.

**REFERENCES:** 1) Veeder et al., *Bull. AAS* 14, 719. 2) Veeder et al., *Icarus* 55, 177. 3) Bowell et al., *Icarus* 35, 313. 4) Clark, *Icarus* 49, 244. 5) Cruikshank and Hartmann, *Bull. AAS* 15, 825. 6) Cruikshank and Hartmann, *Science*, in press. 7) King et al., *Bull. AAS* 15, 825. 8) Cloutis et al., *Bull. AAS* 15, 826. 9) Wood and Ashwal, *PLPSC XIIB*, 1359.

