COMPOSITION OF THE D-TYPE ASTEROIDS DERIVED FROM INFRARED SPECTROPHOTOMETRY.
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INTRODUCTION: A class of asteroids (known as type D) characterized by low albedos and reflectivities which increase in a linear manner between 0.3 and 1.1 microns wavelength has been shown to be common in the outer portion of the asteroid belt and the Trojan clouds, apparently replacing the C-type common in the inner belt (1,2). No meteorites with these characteristics are known, but the visual spectral curves have been interpreted as indicating the presence of abundant organic compounds (3). New infrared telescopic observations demonstrate that these asteroids have IR spectra similar to that of the dark material on the Saturn satellite Iapetus. Laboratory experiments which reproduce the Iapetus material's spectrum suggest that both it and D-type asteroids are composed of undifferentiated "ultraprimitive" or "ultracarbonaceous" chondritic material with a large abundance of organic compounds. This material may be common in icy satellites.

OBSERVATIONS: We obtained a high-resolution IR spectrum of the D-type asteroid 849 Ara on 30 December 1983 with the NASA Infrared Telescope Facility on Mauna Kea, Hawaii. The facility InSb detector system was employed with a special circular variable filter designed for planetary surface spectrophotometry. A preliminary reduction of the data is shown as the lower spectrum in Fig. 1. The spectrum is plotted as a ratio to the solar-type star 16 Cygni B, and offset downward by 0.5 for clarity. It exhibits the typical D-type spectral slope in the .8-1.3 micron region with a gradual transition to a flat reflectivity near 2.0 microns. No absorption features are detectable.

INTERPRETATION: For comparison purposes two data sets are plotted in the figure above the Ara spectrum. The crosses are the average JHK broadband colors of 15 D-type asteroids (from ref. 4) converted to reflectance using the solar colors J-H = +0.30 and H-K = +0.05. [Note that our solar H-K is significantly different than the value of -0.05 often used (5), and produces reflectivities at 2.2 microns about 10% lower. This improved value may resolve some difficulties in interpretation of JHK colors of asteroids (6).] Error bars on the crosses represent the approximate range of reflectivities of the asteroids in the sample. Superimposed on the asteroid data is a reflectance curve of the dark material which covers the leading face of Iapetus. This curve was produced by means of a mixing model and is free of the water-ice component due to the "polar caps" which contaminates disk-averaged telescopic data for the Iapetus dark side (7). While the spectrum of Ara shares the general features of the "average D-type", its change in slope occurs at a significantly shorter wavelength. Thus this single IR spectrum may be somewhat atypical of the class. There is, however, a close correspondence between our recalibration of the JHK data and the spectral curve of the Iapetus dark material. This suggests that the minerals producing the D-type spectral curve are widespread in the solar system, extending from the main belt to at least Saturn, and that D-like material may be the elusive "non-ice component" in the surfaces of the large icy satellites. [Evidence that the Iapetus dark material is native and concentrated at the surface by an unusual regolith gardening process is reviewed in (8).] We have previously reported (7) attempts to simulate the Iapetus dark material with mixtures of hydrated silicates and organic compounds similar to those found in the the most primitive known meteorites. The best simulation of Iapetus (90% clay minerals + 10% organics) is also an excellent match to the average D-type JHK colors. Slightly different proportions of the same components can reproduce our spectrum of 849 Ara. The D-type asteroids apparently represent an extension of the sequence of known carbonaceous meteorites toward lower condensation temperatures and higher proportions of complex organics, consistent with their location at greater distances from the sun than C-type asteroids. Further spectroscopic studies should be able to resolve compositional differences within the D class. In particular, the large asymmetric bound-water band in the 3.0-3.8 micron region which is found in Iapetus (9) is probably present and should be searched for.

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