

**PROBABLE GEOLOGIC COMPOSITION, THERMAL HISTORY, AND METEORITE AFFINITIES FOR MAINBELT ASTEROID 349 DEMBOWSKA.** Paul A. Abell and Michael J. Gaffey, Planetary Sciences Laboratory, Department of Earth and Environmental Sciences, and New York Center for Studies on the Origins of Life, Science Center 1C 25, Rensselaer Polytechnic Institute, Troy, New York 12180-3590; e-mail: abellp@rpi.edu; gaffem@rpi.edu.

349 Dembowska has long been recognized by many investigators within the planetary science community as a unique object. This minor planet has a semi-major axis of 2.92 AU, an eccentricity of 0.05°, an inclination of 7.8° and a rotation period of 4.7 hr [1,2]. IRAS observations have determined a diameter of 140 km and an albedo of 0.38 for this asteroid [3]. 349 Dembowska has been classified as an R-type asteroid -- the only member of its class -- based on its spectral reflectance curve [4,5]. As this asteroid is a member of the mainbelt population, Dembowska represents an approximate *in situ* sample of the early solar system and may provide clues about the first stages of the solar system's formation and the later stages of the solar nebula's evolution. Previous researchers have concluded that this minor planet experienced some form of igneous processing and have suggested it may be a possible additional achondrite parent body [6]. However, the exact surface mineralogical composition and the degree of igneous processing of the original parent body of 349 Dembowska remain to be determined.

Previous spectroscopic observations of Dembowska demonstrated strong absorption features at 1 and 2 microns indicative of a mineral assemblage containing olivine and pyroxene [6,7]. Prior analyses showed these mineral species were present in approximately equal abundance, with the pyroxene component consisting primarily of a calcium-poor, low-iron ( $Fs_{16-32}$ ) orthopyroxene [6]. The relatively high IRAS albedo (0.38) of this minor planet suggests that its surface is devoid of absorbing phases such as dark metal oxides or other opaques thought to be present in the S- or M-type asteroids [8,9].

Interpretation of the significance of 349 Dembowska's spectral characteristics varies within the literature. Some investigators have proposed that the asteroid is a portion of a cumulate mantle from a fully differentiated body [6], but others have suggested that it may be a silicate residue left over from partial melting within a partially differentiated object [7,10]. This current study analyzes a large database of 0.33 to 2.5-micron reflectance spectra collected using the University of Hawai'i 88-inch telescope and the NASA Infrared Telescope Facility. Initial analysis of this data set demonstrated significant rotational spectral variations,

which can be used to test the igneous history of this body [11-13].

The current study of 349 Dembowska focuses on the reflectance spectra obtained at a sub-Earth latitude (SEL) of approximately -65° on the object, based on a previously derived pole position of 157° +30° N [14]. Analysis of this rotational data set indicates asteroid 349 has a surface material with an orthopyroxene to olivine ratio of approximately 45 to 55 with a variation of ~20% across its surface [15]. In addition, the orthopyroxene chemistry is determined to be approximately  $Fs_{25}$  and  $Wo_{10}$  which may be indicative of pigeonite [16].

Light curve information taken from this data set shows the presence of one distinct maximum and minimum per rotation for Dembowska at this observing geometry. Previous lightcurves at similar observing geometries (ecliptic longitudes ~150-160° and ~330-340°) also exhibit a single minimum and maximum per rotation and a small lightcurve amplitude of ~0.1 magnitudes [17,18]. Lightcurves at ecliptic longitudes near ~60-70° and ~230-240° (nearly equatorial viewing geometry) have a much larger amplitude (~0.4 magnitudes) and two distinct maxima and minima per rotation [19-22]. Due to the near-commensurability of the orbital periods of Dembowska and Earth ( $P_{349}/P_{Earth} = 5.002$ ), oppositions (and typically observations) occur in these four limited ranges of ecliptic longitude spaced ~90° apart.

The form of asteroidal lightcurves has been used as an indication of whether the lightcurve variation is due primarily to body shape or to albedo contrasts on the surface [23,24]. In the case of body shape, lightcurves exhibit two minima and two maxima per rotation and the lightcurve amplitude is a maximum for an equatorial viewing geometry and decreases to zero with a pole-on viewing geometry. This assumes, as is generally the case, that the rotation axis coincides with the shortest dimension of the body. On a spherical body, albedo variegation ranging from a spot on one hemisphere up to a hemispheric albedo asymmetry will produce a lightcurve with a single minimum and maximum per rotation.

As noted above, the lightcurve of Dembowska has a single maximum and minimum and a small amplitude with a high latitude viewing geometry, but a two

**ASTEROID 349 DEMBOWSKA:** Paul A. Abell and Michael J. Gaffey

maxima and minima lightcurve with a much larger amplitude at a nearly equatorial viewing geometry. Combined with the indications of rotational spectral variations, these data suggest that a significant albedo spot exists in the equatorial region north of latitude -25° (constrained by the requirement that it pass out of sight during part of the rotation as observed from a -65° latitude viewing geometry). At an equatorial viewing geometry, the body shape effects overwhelm the effects of the albedo unit and dominate the lightcurve. It is plausible that a significant portion of the observed compositional variation is due to a lithologic heterogeneity associated with the albedo unit region. There appears to be a small shoulder on the maximum in the IR portion of the spectrum which is probably due to an albedo spot on the surface.

Based on initial analyses of the observations from this study, several conclusions may be drawn. Asteroid 349 Dembowska is a heterogeneous body with changes in olivine and pyroxene abundance across its surface. The presence of the  $Wo_{10}$  component of the pyroxene demonstrates this minor planet experienced some form of igneous processing. However, the pyroxene chemistry and the pyroxene to olivine abundance ratio suggest only low degrees of partial melting without significant melt mobilization. If Dembowska did in fact experience minor partial melting, then the peak temperature of this body during the thermal processing event was approximately 1050° to 1200° C. Even though the chemistry of asteroid 349 Dembowska precludes a genetic association to the parent body of the Acapulcoites and Lodranites, it must have had a very similar thermal history. The presence of an albedo spot on the surface of this object could be due to a difference in surface mineralogy, or indicative of a large young (i.e. "fresh") impact crater, or both.

349 Dembowska has an extremely distinctive spectrum which has no known analog in the terrestrial meteorite collection. Given its location at 2.92 AU it is unlikely that any significant fraction of the ejecta from this object would be delivered into an Earth-crossing orbit. The 5:2 resonance which lies at ~2.8 AU is the outer boundary for efficient delivery of ejecta to the inner solar system, and thus any material located outside of this region is preferentially sent into Jupiter-crossing orbits [25,26]. Hence it is not surprising that we do not currently have samples of this object.

Further analysis of this data set is required to more rigorously constrain Dembowska's mineral abundance, chemistry, and surface heterogeneity. A second rotational data set with a SEL of roughly -14° is also available for study and will be used to additionally constrain the nature and origin of this object.

**ACKNOWLEDGMENTS:** Aspects of this work were supported by NSF Planetary Astronomy grant AST-9012180 and by NASA Exobiology Program grant NAG5-7598. Paul A. Abell and Michael J. Gaffey are visiting astronomers at the Infrared Telescope Facility which is operated by the University of Hawai'i under contract to the National Aeronautics and Space Administration.

**REFERENCES:** [1] Williams J.G. (1989) in Asteroids II, Univ. of Arizona Press pp. 1034-1072. [2] Lagerkvist C. I. *et al.* (1987) in Asteroid Photometric Catalogue, Consiglio Nazionale Delle Ricerche. [3] Tedesco E.F. *et al.* (1992) in IRAS Minor Planet Survey, Phillips Laboratory Technical Report No. PL-TR-92-2049. [4] Veeder G.J. *et al.* (1983) *Icarus* **55**, 177-180. [5] Tholen D.J. (1984) Ph.D. Thesis, Univ. of Arizona. [6] Feierberg M.A. *et al.* (1980) *Geo. et Cosmo. Acta* **44**, 513-524. [7] Gaffey M.J. *et al.* (1993) *Meteoritics* **28**, 161-187. [8] Gaffey M.J. (1986) *Icarus* **66**, 468-486. [9] Gaffey M.J. *et al.* (1993) *Icarus* **106**, 573-602. [10] Gaffey M.J. *et al.* (1989) in Asteroids II, Univ. of Arizona Press pp. 98-127. [11] Gaffey M.J. (1984) *Icarus* **60**, 83-114. [12] Gaffey M.J. (1997) *Icarus* **127**, 130-157. [13] Gaffey M.J. and S.L. Gilbert (1998) *Met. and Planet. Sci.* **33**, 1281-1295. [14] Magnusson P. (1989) in Asteroids II, Univ. of Arizona Press pp. 1180-1190. [15] Cloutis E.A. *et al.* (1986) *Journal of Geophys. Research* **91**, No. B11, 11641-11653. [16] Adams J.B. (1974) *Journal of Geophys. Research* **79**, No. 32, 4829-4836. [17] Weidenschilling S. J. *et al.* (1987) *Icarus* **70**, 191-245. [18] Di Martino M. *et al.* (1987) *Icarus* **69**, 338-353. [19] Chang Y. C. and C. Chang (1963) *Acta Astron. Sinica* **11**, 139-149. [20] Zappalà V. *et al.* (1979) *Astron. Astrophys. Suppl. Ser.* **35**, 312-321. [21] Haupt H. (1980) *Sitzungber. Math. Naturwiss. Kl. Osterr. Akad. Wiss. Abt. II* **189**, 429-436. [22] McCheyne R. S. *et al.* (1985) *Icarus* **61**, 443-460. [23] Dunlap J.L. (1972) M.S. Thesis, Univ. of Arizona. [24] Barucci M.A. *et al.* (1989) *Icarus* **78**, 311-322. [25] Gladman B. J. *et al.* (1997) *Science* **277**, 197-201. [26] Morbidelli A. and B. Gladman (1998) *Met. and Planet. Sci.* **33**, 999-1016.