

# THE EVOLUTION OF THE SURFACE OF 951 GASPRA: A PRE-GALILEO ESTIMATE. Noriyuki Namiki and Richard P. Binzel, Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139.

**Introduction.** In October, 1991, the *Galileo* spacecraft will carry out the first *in situ* measurement on an asteroid, 951 Gaspra. Because of the lack of atmosphere and negligible gravity, craters on such a small object are expected to show little modification subsequent to formation [1]. The size distribution of small objects in the asteroid belt may be simply interpreted from the cratering record on the asteroid in comparison with the complicated variations on larger planetary surfaces [2]. However, such an interpretation may not be so straightforward because characteristics of the surface will change as a result of numerous impacts during the life time of the asteroid. As the surface layer is ground by successive impacts, cratering processes will change corresponding to the decreasing yield strength relative to gravity [3]. With the help of recent progress in impact cratering studies [3-5], we model the size distribution of craters on the asteroid in combination with the evolution of the surface layer.

**Projectile Population.** The orbital distribution of projectiles is modeled on the basis of the elements of the first 4508 numbered asteroids. We exclude objects smaller than 30 km in order to avoid observational bias toward the inner belt and compute intrinsic collisional probabilities and relative encounter velocities according to *Wetherill's* formulae [6]. For Gaspra we compute an average intrinsic collisional probability of  $5.4 \times 10^{-18} \text{ km}^{-2} \text{ yr}^{-2}$  and a root mean square encounter velocity of 5.0 km/sec. We assume that these values describe the collisional parameters for projectiles smaller than 30 km.

We assume a power law distribution of projectiles,

$$N(d) = Cd^{-b} \quad (1)$$

where  $N(d)$  is the number of projectiles having diameter greater than  $d$ . Three types of projectile populations are assumed in this study. A least square fit to the observational data of Palomar-Leiden Survey [7] gives  $b = 2.517$  [8] (Population I). *Greenberg and Chapman* [9] assumed  $b = 2$  with a decrease by a factor of 10 over the range of  $10^{15}$  to  $2 \times 10^{12}$  g (Population II). A simply extrapolated size distribution from asteroids larger than 30 km gives  $b = 0.958$  (Population III).

**Cratering Model.** For a given diameter and relative encounter velocity, two sets of scaling laws can be applied depending on the strength and gravity of the target [3,4]. Initially the surface is expected to be intact and material strength dominates cratering processes ("strength regime"). After many impacts, however, the surface will be covered by weak ejecta material and the importance of gravity increases gradually ("gravity regime").

In the strength regime, a constant ratio between crater diameter and the projectile diameter is assumed,

$$D_s = 10d \quad (2)$$

where  $D_s$  is the crater diameter formed in the strength regime. The fraction of ejecta left on the surface is unknown. So we assume this fraction,  $f$ , to be 10 %, 1 % or 0.1 %. In the gravity regime, the efficiency of excavation depends on the gravity scaled size [4],

$$D_g \propto d^{0.833} \quad (3)$$

where  $D_g$  is the crater diameter formed in the gravity regime. The fraction of escaping ejecta is computed by a power law scaling [10],

$$V_e \propto D_g^{3.61} \quad (4)$$

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where  $V_e$  is the volume of ejecta whose velocity is larger than escape velocity.

A two layer model is assumed for the surface in this study. The upper weak layer consists of unconsolidated debris and the lower strong layer consists of intact rock which the base of any crater has not yet reached. If  $D_g/2$  is smaller than the thickness of the weak layer,  $h$ , we adopt equations (3) and (4). If  $D_g/2$  for a given impact is larger than  $h$ , the diameter is computed so that the partitioned energy in the upper weak layer and the lower strong layer is distributed by their respective scaling laws in proportion to the excavated volumes. At the end of each time step,  $h$  is computed by calculating the mass loss from the weak layer and mass added through penetration of the strong layer.

**Numerical Results.** The Figure shows the expected crater densities for a constant projectile flux corresponding to Population II and  $f$  of 10 %. Isochrons younger than 100 m.y. are proportional to the projectile size distribution because the weak layer is so thin that all craters form in the strength regime. After 1 b.y., the transition of cratering processes appears as a steeper slope in the size distribution for small craters ( $D \leq 8$  m). After 4 b.y., this transition occurs around  $D \approx 20$  m. However, craters smaller than 10 m show a gradual slope again because they reach the equilibrium crater density. Both transitions fall below the expected *Galileo* resolution of 50-100 m.

**Conclusions.** Current estimates of the projectile population [9] and our collisional probability calculation suggest that Gaspra's surface may not yet have an equilibrium distribution of craters. If the crater density on Gaspra's surface falls below equilibrium, the slope of the crater distribution will indicate the sub-km projectile size distribution within the asteroid belt. Assuming a constant flux, the age of the surface may also be determined. For equilibrium cratering, we may also place constraints on the projectile population [11].

**References.** [1] M. J. Cintala, J. W. Head, and L. Wilson, In *Asteroids*, 579, 1979; [2] Basaltic Volcanism Study Project, *Basaltic Volcanism on the Terrestrial Planets*, 1981; [3] H. J. Melosh, *Impact cratering*, 1989; [4] C. R. Chapman, and W. B. McKinnon, In *Satellites*, 492, 1986; [5] K. A. Holsapple, and R. M. Schmidt, *JGR*, 92, 6350, 1987; [6] G. W. Wetherill, *JGR*, 72, 2429, 1967; [7] C. J. van Houten, P. Herget, and B. G. Marsden, *Icarus*, 59, 1, 1984. [8] J. S. Dohnanyi, In *Physical studies of minor planets*, 263, 1971; [9] R. Greenberg, and C. R. Chapman, *Icarus*, 55, 455, 1983. [10] K. R. Housen, R. M. Schmidt, and K. A. Holsapple, *JGR*, 88, 2485, 1983. [11] N. Namiki and R. P. Binzel (in preparation)

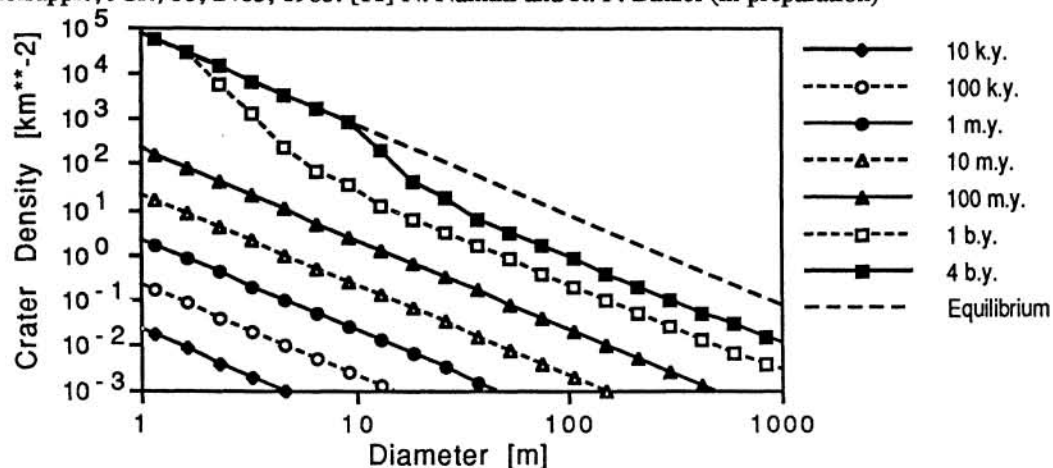


Figure. Expected isochrons for Population II and  $f$  of 10 %.