Deterministic Computer Simulations of Grazing Impacts on Planetary Surfaces

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ABSTRACT

Many bodies in the solar system have features which could conceivably have been formed by a grazing impact with a comet or asteroid. We present the results of deterministic computer simulations of various objects striking a terrestrial planet at a grazing angle. The system is modeled using a combination of the Material Point Method (MPM) and classical planetary dynamics. The impact exhibits three distinct regimes: (*i*) the initial stage where rapid ejecta leaves the planet in a nearly straight line, (*ii*) the intermediate stage where the ejecta begins to curve in towards the planet and the trench is being created on the surface and the (*iii*) the long term stage where the trench is created and any paths exhibited by the ejecta are stable capture orbits. In the case of Mars, we show that a grazing impact can not only dig a trench which has the same general morphology as *Valles Marineris* but also can create ejecta which orbits the planet at distances comparable to those for current Martian satellites.

I. BACKGROUND & INTRODUCTION

Valles Marineris is the deepest trench known to exist on a terrestrial body in the solar system. There is much curiosity as to how *Valles* was formed. Comparing the trench to a typical water-carved structure on Earth (Figure 1) reveals the lack of the tortuous network typical for rivers and tributaries. In addition, martian surface gravitational acceleration is about 1/3 that of the Earth on its surface and so it seems unlikely that water could have carved such a prominent structure on Mars. There is evidence that water or dry sand [1] ran down the sides of *Valles* at one point in time, but the erosion incurred from it seems clearly secondary and not related to the channel's creation [2].

Even though it is thought that *Valles* could be related to a fault in the martian crust [3], it could be that the fault was not active in the channel's formation. Could it be that a grazing impact created the trench?

It is possible that a grazing impact would leave evidence which is additional to an obvious impact site. If a grazing impact was indeed responsible for carving *Valles*, it is likely that some of the ejecta would have been moving fast enough to leave Mars altogether or, for the proper conditions, could have ended up in orbit about Mars. There are two natural satellites for Mars: Phobos and Deimos (Figure 2). They orbit Mars in planes fairly close the planet's equator, which is also close to where *Valles* is located. Moreover the two moons are not spherical in shape but show a history of trauma and collision. If *Valles* were cut by a

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