NUMERICAL SIMULATION OF RETROGRADE TIDAL CAPTURE OF A TRITON-LIKE PLANETOID BY A NEPTUNE-LIKE PLANET; Robert J. Malcuit, Dept. of Geology and Geog., Denison Univ., Granville, OH 43023; David M. Mehringer, Dept. of Astronomy and Astrophys., Univ. of Chicago, Chicago, IL 60637; and Ronald R. Winters, Dept. of Physics and Astron., Denison Univ., Granville, OH 43023.

Many planetary scientists agree that triton is a captured body mainly because of its retrograde orientation [1,2,3,4]. Suggested mechanisms are collisional capture [2] and capture by gas drag in a primitive planetary nebula [3]. In this paper we explore the possibility of retrograde capture due to radial tidal deformation of triton during a near collision encounter with Neptune. We have devised a three-body (sun, neptune-like planet, triton-like planetoid) computer program with an energy-dissipation subroutine that operates for distances within 20 R_n (neptune radii). The major variables are (1) the displacement Love number (h) for each body, (2) the specific energy dissipation factor (Q) for each body, (3) the position of the neptune-like planet relative to the sun at the beginning of the calculation (planet anomaly), and (4) the position of the planetoid relative to the planet at the beginning of the calculation (planetoid anomaly). We have determined by way of a series of neptocentric orbit calculations using the three-body program that the maximum apocenter for an orbit that is stable against solar gravitational perturbations is about 4300 R_n. This large planetoid orbit has a total energy of about -1.4×10^{34} ergs. Thus, under normal conditions, we would expect about that quantity of energy to be dissipated by some mechanism for stable capture. In our systematic examination of co-planar parameter space we can change (1) the eccentricity of neptune's orbit, (2) the eccentricity of the planetoid's orbit, (3) the pericenter radius of neptune's orbit, and (4) the pericenter radius of the planetoid's orbit. Using a zero eccentricity for both the planet and planetoid orbits, we have had no successful capture scenarios. All such initial values result in neptocentric orbital collision scenarios after a small number of orbits. However, when the eccentricity of the planetoid's orbit is increased to 1%, with a semimajor axis of 31.2 AU (slightly larger than neptune's orbit) and a pericenter radius of 180°, we find that the zone of successful (stable) capture is about 25° wide along neptune's orbit (from about neptune anomaly 291° to 315°; neptune anomaly is the position of the planet at the beginning of the calculation measured in a counterclockwise direction from an arbitrary starting point). All close encounters outside this anomaly zone that could possibly lead to capture eventually result in neptocentric orbital collision scenarios. Another notable trend within this favorable anomaly zone is that complex gravitational interactions between the three interaction bodies caused an increase in transit time for the planetoid moving from 10000 Rn to the pericenter point which results in a favorable orientation for a stable capture orbit.

The energy sink for all capture scenarios in our simulations is radial tidal dissipation within the triton-like planetoid using equations from [5,6]. The h of the neptune-like planet is held at zero because for pure tidal capture a gaseous planet would not be expected to dissipate much energy. The r_p is held constant at 1.10 R_n (1.055 R_n = grazing collision). We use a Q_t of 1 for the initial encounter and increase the Q_t to 10 for all subsequent encounters. We have found that the limiting case for stable capture under these conditions is to have an h_t about 0.15 for an encounter at 1.10 $R_n = r_p$. With this orientation about 0.76×10^{34} ergs are dissipated during the first encounter; thus the solar assistance for this particular orientation of the three-body system is about 50%.

From our preliminary work on a co-planar arrangement for a 1% planetoid eccentricity state, we can show that (1) there is a stable retrograde capture window about 25° wide along the orbit of neptune, (2) that with a Q of 1 and an r_p=1.10 R_n, it is necessary for a triton-like planetoid to have an h of 0.15 or higher to dissipate the energy for stable capture by purely tidal processes, and (3) that solar assistance for a marginal capture scenario can be near 50%.

We think that it may be possible to integrate features of the other two capture mechanisms (gas drag capture and collisional capture) with elements our version of three-body tidal capture. In our simulations, we call any close encounter within 1.055 R_n a collision. When dealing with gaseous planets, however, a pass of the planetoid through a planet's atmosphere could result in some energy dissipation by gas drag. This gas-drag energy dissipation could be an important energy sink during a close encounter (whether it is the first or the n^{th} encounter of an encounter sequence). Also, any collisional encounter with natural satellites of neptune, as suggested by [2], could account for a considerable quantity of orbital energy.

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Figure 1. (a) Diagram showing a retrograde non-capture encounter with no energy dissipation between an triton-like planetoid and a neptune-like planet (located at origin of plot) in a non-rotating frame of reference. Some values for this run are r_p=1.10 R_n, neptune anomaly=315°, planetoid anomaly=1.23°, initial neptune-planetoid distance=10000 R_n, orbital eccentricity and pericenter radius for the planetoid orbit are stated in the text. (b) Diagram showing the first three orbits of a stable retrograde capture scenario for a triton-like planetoid by a neptune-like planet. All orbital parameters are identical to those in (a). Body parameters for planetoid are h=0.2 and Q=1 for the initial encounter and is 10 for all subsequent encounters. Energy dissipation in the planetoid is 1.03 X 10^{34} ergs during the initial encounter and is negligible during the two subsequent pericenter passages.