NUMERICAL SIMULATION OF RETROGRADE GRAVITATIONAL CAPTURE OF A SATELLITE BY VENUS: IMPLICATIONS FOR THE THERMAL HISTORY OF THE PLANET; Robert J. Malcuit, Dept. of Geology and Geog., Ronald R. Winters, Dept. of Physics and Astron., Denison Univ., Granville, Ohio 43023

A three-body (sun, planet, planetoid), co-planar, numerical integration code with an energy dissipation subroutine has been developed to assess the gravitational capture potential of planet venus for lunar-like planetoids. Two stable retrograde capture zones have been identified and can be defined in terms of planet anomaly (position of the planet at the beginning of the simulation) and planetoid orbital eccentricity. One SRCZ (stable retrograde capture zone) extends continuously from planet anomaly 160° to 30° and the other extends continuously from 340° to 250°. Although the planetoid eccentricity varies from 0.40 to 1.25%, the width of the SRCZ's is consistent at about 0.25% of planetoid eccentricity. Other factors that control the feasibility of retrograde tidal capture are the deformation and energy absorption characteristics of the planetoid during close encounters. If a sizable planetoid (0.5 moon-mass or greater) was gravitationally captured in a retrograde direction by venus (with a primordial prograde rotation), the thermal and rotational history of the planet would be effected severely during both the capture episode and subsequent stages of post-capture orbital evolution.

Over two decades ago Singer [1] suggested such a retrograde capture scenario to explain the apparent extreme degassing of venus and the present slow retrograde rotation of the planet. From our calculations thus far we can put some limits on the maximum dimensions of a stable retrograde venocentric orbit. The orbits in Figure 1a are near this maximum dimension. Note that the orbits are noticeably non-keplerian. The two-body parameters for such an orbit are semimajor axis = 70 R_v and orbital eccentricity = 0.8596. Thus this largest possible capture orbit sets an upper limit on the retrograde angular momentum that can be inherited via the capture process. The primordial rotation rate for venus is more difficult to assess. Goldreich and Soter [2] suggest a rotation rate of 13.5 hr/day prograde based on the specific angular momentum vs. mass plot of MacDonald [3]. Dones and Tremaine [4] suggest that the rotation rate for a terrestrial planet can be any of a wide range of values if stochastic collisional processes featuring a variety of planetoid masses are involved in the planetary accretion process. There is, however, a fixed point for venusian rotation rate in the present very slow rotation rate of 243 earth days/rotation retrograde. Assuming (1) conservation of orbital and rotational angular momentum for a system of initial prograde rotation of the planet and retrograde orientation of the satellite and (2) the final rotation rate given above, a satellite of 1.00 M_m (moon-mass), 0.75 M_m, and 0.50 M_m would require a primordial rotation rate for venus of 7.5 hr/day, 10 hr/day and 15 hr/day, respectively. We have done capture simulations for these three satellite masses and have found that for an initial encounter distance of 1.39 R_v, the necessary displacement Love number for stable retrograde satellite capture when the planetoid has a Q (specific dissipation factor) of 1 for the first encounter and 10 for subsequent encounters is 0.22, 0.25, and 0.28 for 1.00, 0.75, and 0.50 moon-masses, respectively. Although the encountering planetoid must absorb well over 90% of the energy for its own capture, the planet will dissipate a significant quantity of energy during the initial stages of the orbit circularization era. For the 4-year scenario in Figure 1 a, about 7 x 10^{25} joules/year is absorbed by the planet.

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This quantity is about 3 orders of magnitude greater than the radiogenic heat production of early venus. Thus, even a 0.5 moon-mass planetoid can cause a major thermal episode in the early history of the planet. The other predictable major heating event would be associated with the final demise of the satellite. For a 0.5 moon-mass body in a circular orbit at 1.6 R_v (essentially the solid-body Roche limit for the satellite, the heat production in the planet with nominal values of h_v=0.70 and Q_v=100 is about 2.0 x 10^{22} joules/year, a value about 10x the estimated radioactive heat generation for venus about 1.0 Ga ago. We conclude that a model involving retrograde gravitational capture of a moon-like planetoid and subsequent orbital evolution is a candidate for explaining (1) the extreme degassing of the planet, (2) the slow retrograde rotation rate of the planet, and (3) the geologically recent destruction of the crust of the planet which apparently terminated in a resurfacing event about 0.5 to 0.3 Ga ago [5,6].

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Figure 1. Diagram of a stable retrograde capture scenario and associated rock tidal activity on venus. a. Plot of a numerical simulation of the first 35 orbits of a stable retrograde capture scenario (4 earth years; 6.48 venus years). Venus anomaly = 210° planetoid anomaly = 284.537°, initial distance of separation between venus and planetoid = 600 R_v; ecc. of venus orbit = 0, ecc. of planetoid orbit = 0.0070; h_v = 0.70, Q_v = 100, h_{pl} = 0.32, Q_{pl} = 1 for the initial encounter and 10 for all subsequent encounters, pericenter radius of pre-capture orbit of planetoid = 180°, planetoid mass = 0.5 moon-mass. b. Venus rock tidal diagram for the orbital scenario in a. Note that several perigee passages result in equilibrium rock tidal amplitudes over 8 km during the four-year-long scenario. Energy dissipated in the planet during this scenario = 7.27 x 10^{25} joules; energy dissipation in planetoid = 7.41 x 10^{27} joules.