TRITON'S CRATERING RECORD AND ITS TIME OF CAPTURE.

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Recent impact crater counts on the Voyager 2 high resolution images of Triton have resulted in a more accurate crater size/frequency distribution down to about 3 km diameter. These counts reveal a size/frequency distribution characterized by a differential -4 slope. This is consistent with the observation that there are no craters larger than 27 km diameter on the 20% of Triton viewed at resolutions capable of detecting them. A -4 slope is deficient in large craters and at the very low crater density on Triton no craters larger than about 30 km are expected on just 20% of the satellite.

The Triton size distribution is significantly different from the differential -3 slope of the fresh crater population on Miranda (Fig. 1), but both show leading/trailing asymmetries (1,2, 3). Since Miranda is in prograde orbit this crater population is probably due to objects in heliocentric orbit, i.e., comets. If this crater population is due to comets, then the significantly different crater population on Triton is probably due to some other population of impacting objects. The most likely origin of these objects is planetesimals in planetocentric orbits. Because Triton is in retrograde orbit, objects in prograde planetocentric orbits will also produce a leading/trailing asymmetry. If the Triton craters are largely the result of objects in planetocentric orbit, then where are the comet craters that should be there if they have a differential -3 distribution function as inferred from the Miranda fresh crater population? The most likely answer is that they are there, but at such a low density that they can not be distinguished from the planetocentric population. An upper bound on this density can be estimated by determining the density of a crater population with a differential -3 slope (the comet distribution inferred from Miranda) where no craters larger than 27 km would be expected on the 20% of Triton viewed by Voyager at resolutions sufficient to detect them. This density is at the density of the largest crater (27 km) shown in Fig. 1. At this density the number of craters in size bins greater than 27 km is less than 1 for a -3 distribution function. Fig. 2 shows the observed size distribution, the upper limit of the hypothetical comet crater size distribution, and the difference between the observed and the hypothetical comet crater populations. The "difference" curve is not appreciably different from the observed curve.

Shoemaker (1) estimates that at Triton the comet crater production rate for craters >10 km diameter is 8.4×10^{-15} km^{-2} yr^{-1}. If we assume that the "comet" curve shown in Fig. 2 represents the maximum number of comet craters that could be present on 20% of the surface, then the number of craters greater than 10 km diameter is less than half the number observed, and the maximum average surface age is about 600 million years. This age is not changed significantly by scenarios invoking an early massive atmosphere on Triton (10).

Because of its retrograde orbit and high inclination to Neptune's equatorial plane (21°), Triton is thought to have been captured by Neptune, possibly following a collision with a regular satellite(4). The collision-capture hypothesis is thought to be more plausible than others, e.g., gas drag (9), because (a) the Neptune satellite system is the only one in the outer Solar System that has just one major satellite, and it is in a retrograde and highly inclined orbit, (b) Nereid has an unusually large semimajor axis and eccentricity, and (c) all other minor regular satellites are interior to Triton. The capture process would probably produce a highly eccentric orbit that would evolve by tidal dissipation to its present near circular orbit. During the capture process it could have caused Nereid to acquire its peculiar orbit (4). The estimated time to evolve from an eccentric orbit to its present orbit is about 400 million years (4). As the orbit circularized, Triton would sweep up pre-existing satellites. During this time tidal dissipation would have heated Triton, leading to large scale melting. This may have resulted in the global volcanism and large scale resurfacing observed on Triton.

Triton's Time of Capture: Strom, R.G. and Croft, S.K.

In this scenario, the cratering record is largely the result of the final sweep up of objects in prograde planetocentric orbits after circularization of the orbit and cession of internal activity. Neried and the present satellites interior to the orbit of Triton may be all that remains of the satellites of Neptune prior to the capture event (4). Since all unambiguous impact craters are relatively fresh (there are no degraded or partially embayed craters) and the sweep up time for planetocentric objects is very rapid, the cession of widespread resurfacing must have been relatively abrupt. The maximum time at which Triton was captured is then the age of the surface estimated from inferences of the maximum density of comet impacts, plus the time to circularize Triton's orbit and cession of widespread volcanic activity. If all of the above reasoning is correct, then this capture event occurred roughly about 1 billion years ago with probably a large, but unknown, uncertainty.

The capture of Triton by collision or with a previously existing satellite of Neptune gas drag probably requires that it took place near the end of the accretion of Neptune in order for there to be a sufficient number of planetesimals or sufficiently high gas densities in the vicinity to make capture plausible (4). The accretion time scale for Neptune is highly uncertain, with numerical models suggesting formation times as short as 5×10^6-10^8 years (5,6) to many billion years (7,8). However, even those that indicate runaway accretion only accrete about 1/10 the mass of Neptune in 2×10^5 years (5). The rest takes much longer. If the capture event of Triton took place about 1 billion years ago, then it suggests that Neptune finished its accretion rather late in Solar System history.

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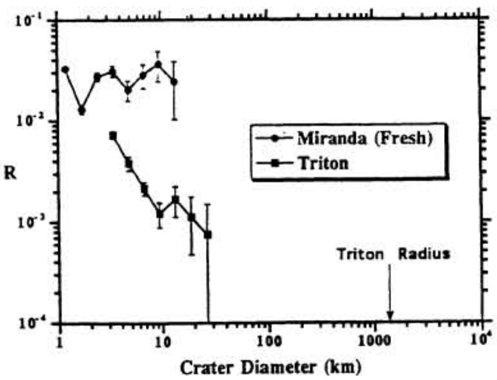

Fig. 1. "R" plot of the size distribution of the fresh crater population on Miranda and Triton.

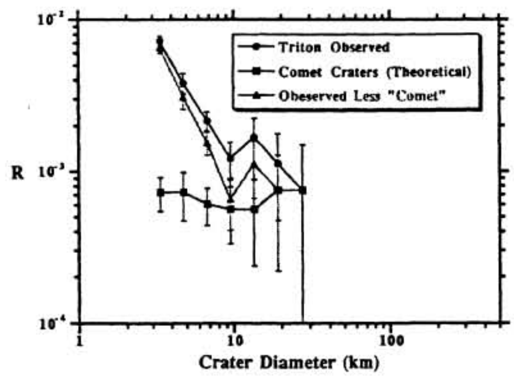

Fig. 2. "R" plot of the size distribution of Triton craters, the maximum hypothetical comet craters that could be present, and the difference between the hypothetical and observed curves.