INTERPRETATION OF GRAZING IMPACTS ON MARS BY THE AXIAL ROTATION THEORY

(Letter to the Editor)

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(Recieved 17 April, 1984)

Abstract. This paper calls attention to the fact that the distribution of grazing impacts on Mars, as described by Schultz and Lutz-Garihan (1982), agrees with the distribution predictable by the theory of planetary axial rotation based on the transmission of mass and angular momentum from a satellite system to its primary (Barricelli, 1972). A few additional implications of the theory are pointed out.

1. Introduction

In a recent paper, Schultz and Lutz-Garihan (1982) have presented evidence strongly suggesting that grazing impact craters on Mars (elongated craters with a distinctive pattern of ejecta deposits characteristic of a low angle impact) are mainly due to earlier Mars satellites whose orbits tidally decayed with time. The most recent grazing impact craters are near the Martian equator, and they are elongated in an East-West direction with a major axis parallel to the equator. Older Mars grazers appear to occur along great circles different from the equator, some of them (the oldest one) in a rough North-South direction. The picture suggests that the Martian equator may gradually have been changing with time.

The purpose of this paper is calling attention to the fact that the observed properties and distribution of Mars grazers is supporting evidence for the theory of planetary rotation (Barricelli, 1972) based on the transmission of mass and angular momentum from satellite system to planet. The theory is intended as an interpretation of planetary axial rotations and the prevailing approximate coincidence between planetary equators and the orbital planes of the nearest satellites.

Main features of the theory can be summarized as follows. After the orbits of the closest satellites have been focused into a common plane with a common direction of movement (Alfvén, 1969; Alfvén and Arrhenius, 1970; Trulsen, 1972a and 1972b; Barricelli and Aashamar, 1980; Barricelli, 1972), angular momentum will be transmitted by tidal effects from the closest satellites to the planet, unless the planet already has an axial rotation in the same plane and same direction as the satellites with a period not longer than the revolution period of the closest satellite. As a result, the orbit(s) of the closest satellite(s) will gradually decay with time, until the satellite(s) reaches the Roche limit. At this point the satellite(s) may disintegrate into a swarm of smaller objects possibly forming a kind of (Saturnian) ring around the planet. Gradually the smaller objects will mostly end up in a low-angle (possibly grazing) collision with the planet.

Earth, Moon, and Planets **31** (1984) 75–78. 0167-9295/84/0311-0075$00.60.

As a result, the planet will gain angular momentum and an axial rotation in the same direction as the closest satellites. The process may continue until one of the following two alternatives has been realized:

(1) All satellites with an orbital revolution period shorter than the planet's axial rotation period are eliminated.

(2) The planet has reached an axial rotation period shorter than the revolution period of a satellite at the Roche limit (Jupiter, Saturn, Uranus). Major satellites below the Roche limit cannot be formed, and satellites above the Roche limit will, on this assumption, have a revolution period longer than the planetary axial roation period and will, therefore, have an increasing (rather than a decreasing) mean distance from the planet (like our Moon).

Mars is an example of the first alternative if we disregard Phobos, whose orbital angular momentum will contribute only an insignificant increase of the axial rotation of Mars when it (or its fragments) will eventually reach the planetary surface.

2. Implied Evolution of Mars' Axial Rotation and Satellite System

After the orbits of Martian satellites had been focused into a common plane, the innermost (pre-phobian) satellite may have started disintegrating after reaching the Roche limit. The situation at this stage may have been roughly as follows. The outermost satellite was probably Deimos in an orbit possibly similar to its present orbit. Inside Deimos there may have been one or a few major pre-phobian satellites of which the most internal one was in the process of disintegrating at the Roche limit. According to Schultz and Lutz-Garihan "The estimated combined mass of grazing impactors would form a satellite of at least 225 km in diameter". In order to explain the present rotational angular momentum of Mars we must assume a total mass of pre-phobian satellite(s) much greater than that and probably approaching 0.44% of the mass of Mars (see Barricelli, 1972; Table VI). This is roughly 4% of the mass of our moon, and the diameter of a satellite with that mass would be nearly 1/3 of the diameter of our Moon, or roughly 1150 km, assuming a density comparable to that of our Moon; but most of this material was going to be disintegrated into small fragments at the Roche limit, producing craters with a diameter much smaller than 3 km, which is the lower limit of the crater diameters included in the Schultz and Lutz-Garihan study. Moreover, not all the impacts by Mars satellites would necessarily be recognized as grazers.

At this stage the equator of Mars was in a completely different plane than its present equator and its position was the one roughly indicated by the ancient impacts in the Schultz and Lutz-Garihan paper, Figures 6, 9a, 9b, 9c, and 9d (original equator).

The axial rotation period of Mars at this early stage (original axial rotation) must have been much slower than its present axial rotation, and the rotation period must have been substantially longer than 500 h. If the original axial rotation period had been comparable to the present one, the present position of the Martian northern pole would not be where it is now. It would, on the contrary, be located about midway between its present position and the original one.

As the pre-phobian satellite(s) disintegrated its (or their) mass and angular momentum was gradually transmitted to the planet bringing its equatorial plane to a position approaching the oribital plane of the pre-phobian satellite(s) supposedly approximated by the orbital planes of the present satellites Phobos and Deimos.

The last remnant of the pre-phobian satellites(s) is Phobos which is already close to the Roche limit and, no matter whether it does or does not avoid disintegration, will end up colliding with Mars.

3. The New Polar Wandering Theory

Schultz and Lutz-Garihan have proposed a different (geological) explanation for the changing position of the Martian equator and its North pole (polar wandering). Following suggestions by Murray and Malin (1973) and others, they ascribe the changes to migration of the crust with respect to the spin axis of Mars.

If this interpretation were correct, the original axial rotation period of Mars would have been comparable to the present one, and the polar wandering process may not necessarily have been associated with a substantial change in the axial rotation period.

We call attention to the fact that the distribution and orientations of grazing impact craters do not give much information about the axial rotation period. Only the past positions of the North pole and equator can roughly be inferred from this kind of data. The difference between the two polar wandering theories is not one which can be decided by the grazing impact distribution and their characteristics. The issue will have to be decided by other criteria. The main advantage of the satellite angular momentum (and mass) transmission theory is that it explains why the planetary equator nearly coincides with the orbital planes and the direction of rotation of the nearest satellites, an explanation which is common to most other planets as well (Barricelli, 1972). Moreover, it is a fact that impacts by satellites (grazing or non-grazing ones) transmit satellite angular momentum to the planet. One may argue about the amount of angular momentum transmitted this way, but one can not ignore it as if it did not exist. Any valid theory will have to take the angular momentum transmitted by satellite impacts into account.

Our theory ascribes the rotational angular momentum of Mars (as in most other planets) mainly to the transmission of satellite angular momentum by impacts and tidal effects. Other theories may include also other sources of angular momentum, but the exchange of angular momentum between planet and satellites cannot be ignored by any valid theory.

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