LONG-WAVELENGTH SHORELINE DEFORMATION ON MARS RELATED TO TRUE POLAR WANDER.

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Introduction: Geologic and topographic features near the margins of the northern plains of Mars have been interpreted as shorelines formed by ancient oceans [1,2]. The idea that large standing bodies of water once existed on Mars is consistent with evidence of long-lived fluvial processes early in Mars' history [3], evidence that large floods emptied into the northern plains [4], and measurements of surface composition that suggest aqueous alteration of minerals [5–7].

There are, however, problems with the ocean hypothesis. One of the most serious objections is that topographic profiles along the putative shorelines do not follow surfaces of equal gravitational potential, as the margins of a standing body of water should [8,9]. Long-wavelength (thousands of km) trends, with amplitudes of hundreds of meters, are especially apparent in the shoreline topography [9]. We investigate the possibility that these topographic trends are the result of deformation induced by true polar wander (TPW).

TPW-induced shoreline deformation: Changes in the orientation of a planet's rotation vector with respect to the planet's surface induce perturbations in the centrifugal potential, and these perturbations drive long-wavelength variations in the heights of both the solid surface and the gravitational potential that defines the sea surface [10]. If the planet has a lithosphere that behaves elastically on the timescale of the TPW, the solid surface and sea surface will deform by different amounts. Topographic features that followed sea level prior to a TPW event, such as shorelines, may no longer do so after the TPW event.

We use fluid Love number theory to calculate the deformation resulting from a reorientation of Mars' rotation vector. The spatial pattern of deformation is given by the difference between degree two, order zero spherical harmonics aligned with the initial and final rotation poles. The amplitude of the deformation depends on the net amount of TPW, the elastic thickness of the lithosphere, T_e, and the planet's internal density structure [11].

We compare the predicted deformation patterns with the topography of the two most prominent shorelines: Arabia (contact 1 of Parker et al. [1]), which coincides roughly with the dichotomy boundary and is inferred to be ≥ 4 Gyr old; and Deuteronilus (contact 2), which is inferred to be younger because it is encircled by the Arabia shoreline and is less degraded. We find that TPW-induced deformation of formerly equipotential surfaces can explain the long-wavelength topography of both shorelines. For T_e = 200 km, the present locations of the best-fit paleopoles are 40°N, 334°E for Arabia and 79°N, 337°E for Deuteronilus. These paleopoles lie within a few degrees of the same meridian, and suggest a polar wander path that is consistent with the relative ages of the shorelines: the north rotation pole was in Acidalia Planitia at the time the Arabia shoreline formed, and subsequently moved along a great circle toward the present north pole, with the younger Deuteronilus shoreline forming when the pole was 11° away from its present location. This TPW path is nearly orthogonal to the meridian that passes through the center of the Tharsis volcanic province (~250°E), which implies that Tharsis would have remained at the equator throughout the TPW event.

Nature of the driving load: TPW occurs in response to a change in the principal axes of the inertia tensor of a rotating planet. Two observations suggest that the mass redistribution associated with the formation of oceans in the northern lowlands could have driven the rotation pole to the locations inferred from the deformed shorelines. First, the center of mass of a northern ocean would lie approximately 180° in longitude away from the inferred paleopoles, and thus the positive mass anomaly associated with the ocean would drive the rotation pole from its present location toward the paleopoles. Second, the ratio of the ocean masses (the Arabia ocean would have been ~4.3 times larger) is comparable to the ratio of the inferred TPW angles (4.5). We are currently using the theory of Matsuyama et al. [12] to compare the polar wander that would have occurred in response to the ocean loads with the TPW path inferred from the shorelines.

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