ROTATIONAL STABILITY OF DYNAMIC PLANETS WITH LITHOSPHERES. I. Matsuyama, *Department of Astronomy & Astrophysics, University of Toronto, Toronto, Canada, M5S 3H8 (isamu@astro.utoronto.ca)*, J. X. Mitrovica, *Department of Physics, University of Toronto, Toronto, Canada, M5S 1A7*, J. T. Perron, M. Manga, M. A. Richards, *Department of Earth and Planetary Science, University of California, Berkeley, CA 94720-4767*.

The secular rotational stability of terrestrial planets subject to surface mass loading and internal convective dynamics is a long-standing problem in geophysics framed by a series of seminal studies [e.g., 1-3]. Gold [1], for example, discussed the stability of a hydrostatic planet subject to an anomalous (i.e., non-hydrostatic or imperfectly compensated) load. The uncompensated load would act to push the rotation pole away or, alternatively, would migrate toward the equator. In the short term, the hydrostatic bulge would act to stabilize the pole (i.e., retard polar motion). However, since the hydrostatic rotational bulge of the planet would, in time, relax to any new orientation of the rotation pole, all memory of this previous orientation would ultimately vanish. That is, a hydrostatic bulge provides no long-term rotational stability and the reorientation of the pole, or so-called true polar wander (TPW), would be governed solely by the location of the uncompensated surface mass load. In particular, a mass excess of any size (indeed, as small as Gold's beetle) would drive a TPW that would eventually reorient the load to the equator.

Gold's [1] arguments, while providing significant insight into the secular rotational stability of planets, involved an underlying inconsistency that was highlighted, and addressed, by Willemann [3]. Gold's [1] beetles would not be perfectly compensated because of the presence of a lithosphere with long term elastic strength. However, the development of a lithosphere would also ensure that the initial hydrostatic figure of the planet could not entirely relax to any new orientation associated with TPW. Simply put, one cannot have an uncompensated surface mass load and a completely relaxed hydrostatic bulge. All memory of the original rotation does not vanish, and the 'remnant of the rotational flattening' [3] will act to stabilize the rotation vector. Willemann [3] concluded that the final position of the rotation vector will depend on the initial position of the (assumed axi-symmetric disk) load and its uncompensated size relative relative to the rotational bulge. He furthermore concluded that the reorientation was independent of the thickness of the lithosphere.

In this paper we revisit the general problem addressed by Willemann [3]. In particular, the new analysis extends this work in three ways. First, our derivation avoids a series of assumptions made in the thin plate model of Willemann [3] and yields a prediction of TPW (driven by the axi-symmetric load) which is a function of the elastic thickness of the model lithosphere. Second, we consider the impact on the predicted polar motion of moderate asymmetries in the surface mass load and show that this impact can be profound. (Indeed, we demonstrate conditions under which inertial interchange true polar wander events - i.e., 90° shifts in the pole - will occur.) Finally, we complete our analysis by considering the influence on the rotational stability of internal convective dynamics. Although the nature of this contribution is largely unconstrained for planets other than the Earth, this does not diminish its potential relevance; indeed, it would be difficult to argue that the massive Tharsis rise on Mars, the subject of significant interest in the field of Martian rotation stability [e.g., 3,4], does not reflect the action of both external and internal processes. As a final comment, we note that our analysis suggests, in contrast to previous assertions, that a large TPW event driven by Tharsis growth cannot be ruled out - at least on the basis of our general consideration of rotational stability.

References: [1] Gold T. (1955) *Nature*, 175, 526. [2] Goldreich P. & Toomre A. (1969) *J. Geophys. Res.*, 74, 2555. [3] Willemann R. J. (1984) *Icarus*, 60, 701. [4] Bills, B. G., & James, T. S. (1999) *J. Geophys. Res.*, 104, 9081.