HOW VOLCANO-TECTONICALLY ACTIVE IS VENUS ANYWAY? P. J. McGovern, Lunar and Planetary Institute, USRA, 3600 Bay Area Blvd., Houston, TX 77058 (mcgovern@lpi.usra.edu).

Introduction.

Data collected during the initial reconnaissance of the inner solar system (through the mid-1990s) indicated ages for terrestrial planet surfaces (other than the plate tectonics-endowed Earth) of order 10^9 years, suggesting dead or at best dormant planets. For Venus in particular, a consensus emerged, based largely on the impact cratering record, that a somewhat rapid and quite vigorous era of volcano-tectonic (V-T) resurfacing was followed by an era of relatively low V-T activity of substantial duration. Under such a scenario, cratering-derived mean surface ages of as much as 750 Myr [1] pointed towards rather small present day V-T rates. However, data obtained during the last two decades, combined with careful re-analysis of previous datasets, point to substantial present-day activity at Venus. For example, Venus Express instruments have uncovered signatures of geologically recent [2] and even possibly active [3] volcanism on that planet. A re-examination of Magellan SAR images of dark-floored craters [4] suggested a mean surface age for Venus of around 150 Ma. This result was followed up by a re-calibration of the Venus impactor distribution curve giving a comparably young surface age [5].

These results justify a re-examination of tectonic and volcanic activity on Venus. Suggestions of substantial ongoing volcano-tectonic activity on a "one-plate planet" [6] provide strong motivation to return to Venus with modern remote sensing and in-situ monitoring technology, in order to listen for the vital signs of a planet heretofore left for dead.

Volcano-tectonic seismicity: Hawaii Baseline.

Large basaltic volcanic edifices formed at intraplate volcanic settings ("hotspots") on Earth are the best analogs for large volcanoes on Mars and Venus. At Hawaii, extensive instrumentation provides detailed records of seismic activity. A catalog of 7022 earthquakes spanning 45 years, with moment magnitudes M_0 ranging from 3.2. to 6.6 [7], can be used to derive the Gutenberg-Richter (G-R) frequency-magnitde relation for the Island of Hawaii, expressed as $\log(N) = a - bM_0$, where N is the number of earthquakes with magnitudes greater than or equal to M_0, and a and b are constants [8]. By this analysis, (Fig. 1), one earthquake with M_0 4.9 or greater can be expected every year. Under the assumption that the mechanisms of seismicity for edifice building are similar across the planets, we use the same b for all planets [9] and scale a according to estimates of magmatic volume flux rates dV/dt at the various planets. Over the 80 Myr history of the Hawaiian-Emperor volcanic chain, dV/dt is around 1.7 x 10^{-2} km^3/yr [11].

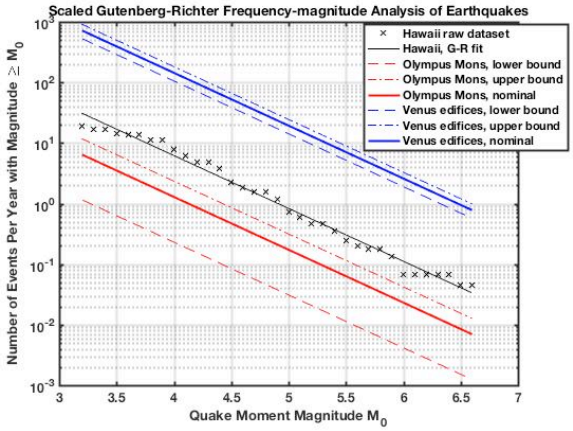

Figure 1. Frequency of seismic events with moment $\geq M_0$ as a function of M_0. Black 'x's show raw data for Hawaii [7], and the black line shows the best-fit G-R relation (a = 5.93 and b = 0.872), scaled to the duration of the seismic catalog to give rates. Red lines show nominal and bounding G-R relations for quakes at Olympus Mons, Mars; blue lines show them for volcanic edifices on Venus.

Extrapolation to Venus.

Findings of a young(er) Venus surface age [4,5] greatly enhance predicted rates of volcanism. Estimates of dV/dt associated with 145 large volcanoes on Venus [10], under the assumption of a surface age of 150 Ma [4,5], yields nominal dV/dt = 3.95 x 10^{-1} km^3/yr, more than an order of magnitude greater than the Hawaiian-Emperor flux and comparable to Earth's total intraplate volcanic flux [11]. Scaling the Hawaiian G-R relation to Venus edifices (alone) yields a prediction of at least one quake with $M_0 \geq 6.5$ per year.

Activity Levels: Not Dead Yet?

The findings for magmatic flux dV/dt and seismic activity suggest the obituaries for Venus that commonly appear in the literature are premature.

References: [1] McKinnon W. B., et al. (1997), in *Venus*, U. of Arizona Press, 1362 pp. [2] Stofan et al. (2016) *Icarus, 271*, 375-386. [3] Shalygin et al. (2015), *GRL, 42*, 4762-4769. [4] Herrick R. R. and Rumpf M. E. (2011) *J. Geophys. Res., 116,* doi:10.1029/ 2010JE003722. [5] Bottke W. F. et al. (2016) *LPS XLVII*, abstract 2036. [6] Head J. W. and Solomon S. C. (1981) Science, 213, 62-76. [7] The IRIS Earthquake Browser, http://ds.iris.edu/ieb. [8] Stein S. and Wysession M. (2003) An Introduction to Seismology, Earthquakes, and Earth Structure, Blackwell, 498 pp. [9] Phillips R. J. (1991) *LPI Tech. Rep. 91-02*, Apppendix B. [10] McGovern P. J. and Solomon S.C. (1997) *J. Geophys. Res., 102,* 16,303-16318. [11] Crisp J. A. (1984) *J. Volcanol. Geotherm. Res., 20*, 177-211.