FACTORS CONTROLLING VOLCANISM AND TECTONISM IN SOLAR SYSTEM SOLID BODIES

A. T. BASILEVSKY

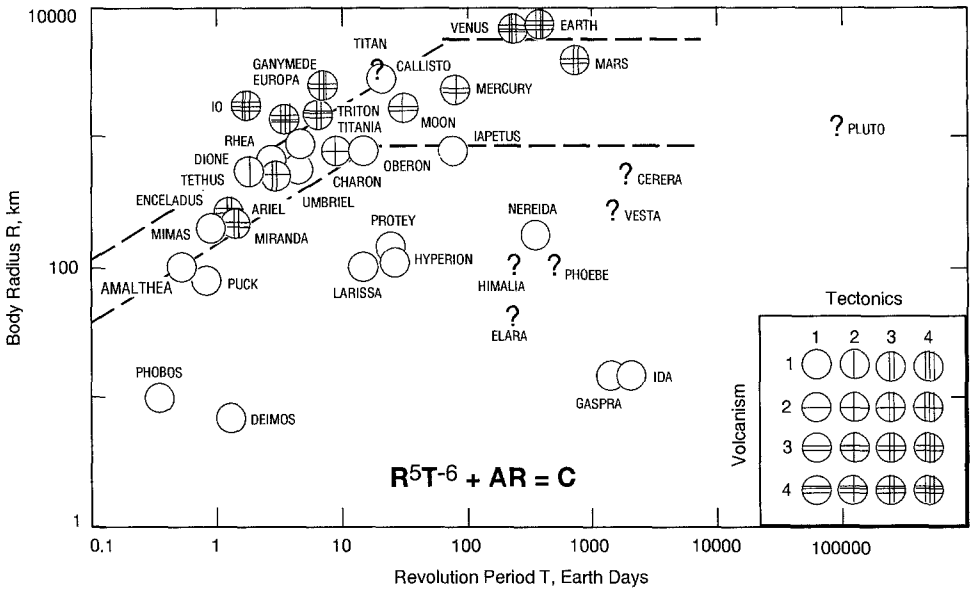
A Panel Discussion

Following the guidelines given by the leader of the panel discussion, Dr. Moustafa Chahine, your attention is directed to the attempt made by myself and Mikhail A. Kreslavsky, Kharkov Astronomical Observatory, Kharkov, Ukraine, to look for fundamental laws which control the formation and evolution of the solar system solid bodies. This work was published in a Russian journal [1], and thus is almost unknown abroad, although it has been translated into English [2]. We have attempted to find factors which control volcanism and tectonism on different solid bodies: terrestrial planets and their satellites, asteroids, and satellites of the giant planets. The terms "volcanism" and "tectonism" are used here in a broad sense. Volcanism includes eruptions of silicate melts on the terrestrial planets, sulphur on Io, and water-rich liquids on icy satellites of the giant planets. Tectonism is defined as the deformation of a body's outer layers, excluding those produced by meteoroid impacts. We used television images and radar images to classify the bodies into several categories depending on whether they have (1) only heavily cratered ancient surfaces, or whether the heavily cratered terrain on them was (2) slightly, (3) significantly, or (4) completely resurfaced by volcanism and tectonism. At the time of our study we had images of 28 solid bodies. Recent images of asteroids Gaspra and Ida obtained by the Galileo Spacecraft now extends that number to 30.

At the time of our analysis it was quite evident that the degree of post-heavy-bombardment (i.e., late) volcanic and tectonic resurfacing correlated with planet size. It is reasonable because the energy source both for volcanism and tectonism is the interior heat resulting from K, Th, and U radioactive decay, and from gravitational energy. In both cases the heat generation is proportional to the mass of the body (R3, where R is the body's radius) while heat is being lost through the body's surface area (R2). This results in proportionality of endogenic heat to the bodies' radii. It was also known that some satellites of the giant planets, despite their relatively small sizes, display volcanic and tectonic resurfacing which has evidently been driven by tidal heating. Tidal heating and several other factors depend on the radius (~R5) and its orbital period (T-6). This is why we created symbols showing degrees of late volcanic and tectonic activity on the accompanying diagram whose logarithmic axes are radius (R) and orbital period (T).

You will note on the diagram that symbols of the bodies with "significant," "moderate-to-weak," and "no" late endogenic activity are clustered into three fields.

Earth, Moon, and Planets **67**: 47–49, 1995.
© 1995 *Kluwer Academic Publishers. Printed in the Netherlands.*



The field boundaries are specified by the equation AR+R5T-6=C, where A and C are constants chosen so that the boundaries best separate the objects with different degrees of endogenic activity.

This approach is the first approximation in the analysis; nevertheless, it provides a possibility to find and examine deviations from this correlation, and to make predictions of the endogenic activity of objects for which high-resolution images are not yet available. The deviations from the correlation are represented by four bodies: Callisto, Mimas, Umbriel, and Triton. 26 of the 30 bodies are consistent with this correlation. The reader is referred to the referenced paper for an explanation of the deviations.

More interesting now are predictions of late endogenic activity based on the body sizes and orbital periods. From their position on the diagram (shown by question marks), it is evident that even the largest asteroids (Ceres and Vesta) should not have late volcanic and tectonic resurfacing, and even less chance for other asteroids and small and distant satellites of the giant planets. Titan, the largest Saturnian satellite, has a good chance for significant late volcanism and tectonism. In the Pluto/Charon system, Charon has a better chance for late endogenic resurfacing than Pluto. The crucial issue of these predictions is the dynamic history of the bodies, which could be both more and less violent than their current orbital parameters would imply.

So, in keeping with the discussion guidelines, I should say that the above consideration gives high priority to missions that explore Titan, Pluto/Charon, and the largest asteroids.

References

1. Basilevsky, A.T., and Kreslavsky, M.A., "Volcanism and Tectonics on Planets and Satellites of the Solar System: Dependence on Size and Orbital Period." Astronomicheskii Vestnik, v.26, N2, March-April 1992, 66-76 (in Russian).

2. English translation of the paper in: Solar System Research, Consultant's Bureau, New York, September, 1992, 183-190.