12.10 Fe/Silicate Fractionation and the Origin of Mercury.
S. J. WEIDENSCHILLING, Dept. of Terrestrial Magnetism, Carnegie Institution of Washington, D.C. 20015-Compared with the other terrestrial planets, Mercury has anomalously low mass and high Fe content. Equilibrium condensation and inhomogeneous accretional models are not compatible with these properties unless the thermal structure and history of the solar nebula meet very strigent conditions. Also, Mercury's predicted composition in those cases is not compatible with the presence of a currently molten core. It appears that most of the solid matter which originally condensed in Mercury's zone has been removed. The planet's composition may be explained if the removal process was only slightly more effective for silicates than for Fe. However, previously suggested fractionation mechanisms are inadequate or ad hoc. It is proposed that planetesimal orbits in the inner solar system decayed due to drag of nebular gas. This process is a natural consequence of the non-Keplerian rotation of a centrally condensed nebula. A simple quantitative model shows good agreement with the observed mass distribution of the terrestrial planets, and can also produce density fractionation of the required sense. Cosmogomical implications are discussed.

12.11 Secularly Unstable Maclaurin Spheroids and the Origin of the Moon.

J.A. O'KEEFE, Code 681, and E.C. SULLIVAN, Code 680.1, Goddard Space Flight Center, Greenbelt, MD 20771 (301-982-4445). O'Keefe and Urey (1977 Phil Trans 285, 569) brought forward geochemical evidence that the moon formed by fission. We here suggest that the earth formed initially in a configuration resembling a Maclaurin spheroid rotating with an angular velocity which approached the limit of dynamical stability. In the units of Chandrasekhar (Ellipsoidal Figures of Equilibrium, Yale Univ. Press 1969) the angular momentum was greater than 0.39, but less than the limit of dynamical stability near 0.51. Spheroids in this range decay via the Riemann ellipsoids toward unstable Jacobi ellipsoids. The decay rate is proportional to the viscosity; for viscosities appropriate to melted rock, the decay times are typically in the range of at least 1000 years. This allows time for the formation of the core (about 1 year according to Fish et al, 1960 Ap. J. 132, 243). Within the range cited, the decay process is terminated, not by arrival at the Jacobi ellipsoids, but by a 3rd harmonic instability, which is catastrophic and leads to fission. Thus the fission process does not require any special spin-up mechanism: it is the inevitable result of certain initial values of the angular momentum. Fission cannot take place until after the formation of the core, because core formation, by heating the earth, delays the decay of the Maclaurin spheroids. Fission is followed by severe tidal heating, which leads to a deep common atmosphere; this is lost to space, and repeatedly regenerated and lost; in this way most of the original mass of the moon and most of the angular momentum of the system is lost.

12.12 Nebular Condensation Models and the Place of Origin of the Moon. R. J. MALCUIT and R. R. WINTERS, Denison Univ. - The origin of the Moon remains an unsolved problem. Examination of nebular condensation models of Grossman (1972 G.C.Acta 36,597) and Lewis (1973 A.R. Phys. Chem. 24,339) suggests that a planetary body of lunar density could have formed either inside the orbit of Mercury or beyond the orbit of Mars. The presence of a significant quantity of Fe(≈16 wt.%) and abundant ferromagnesian minerals in mare rocks (and presumably in the outer portion of the Moon) argues against an origin inside the orbit of Mercury where only high temperature Ca-Al-Mg-Ti silicates would form. However, these same chemical constraints are consistent with an origin in a zone beyond Mars at about 1.7-2.0 AU. Assuming predominately homogeneous accretion, Lewis' model predicts an assemblage of Fe-rich serpentine, actinolite, alkali feldspar, and troilite. A combination of 40 vol.% Fe-rich serpentine (Fe/Fe+Mg=50%), 40 vol.% actinolite (Fe/Fe+Mg=50%), 15 vol.% alkali feldspar (Na/Na+K=50%), and 5 vol.% troilite yields a body whose uncompressed density is about 3.0 g/cm^3. However, dehydration of the outer 2/3 of the mass (the magma ocean of Wood, 1975 G.C.Acta Sup.6,1087) results in an uncompressed density of about 3.3 g/cm^3. In this model the inner 1/3 of the mass of the body is assumed to retain most of its original volatiles; thus, it would be somewhat less dense than the exterior, even after self-compression. This model of lunar zonation-composition agrees reasonably well with the major element chemistry of the outer zone of the Moon. But, it is not consistent with current estimates of the Fe (and Mg) content of the entire lunar body: Our model predicts about 20 wt.% Fe, Taylor (1975) and others estimate about 8 wt.% Fe. One explanation for this iron anomaly is that the additional iron mass is masked by the low density of a hydrous core. Our model is also consistent with the ≈0.4 = C/Ma^2 of the Moon.

12.13 A Former Major Planet of the Solar System.
T. C. VAN FLANDERN, U. S. Naval Observatory - Recent dynamical investigations by Ovenden (1972 Nature 239, 508) and Van Flandern (in press) have advanced the thesis that comets, asteroids and most meteorites are by-products of the break-up of a 90-Earth-mass planet orbiting 2.8 a.u. from the Sun until just 5x10^6 years ago. The break-up epoch is given by