THERMAL, STRESS AND MINERALOGICAL EVOLUTION OF SMALL PLANETARY OBJECTS. Andrew R. Lazarewicz and Michael J. Gaffey, Planetary Science Division, Hawaii Institute of Geophysics, 2525 Correa Rd., Honolulu, Hawaii 96822.

Unmelted C2-type Small Planetary Objects (SPOs) are being studied for their thermal, thermally-induced stress, and dehydration histories. These objects are assumed to contain the least altered material in the Solar System (1). We are focussing our attention primarily on the mechanisms (i.e. short (Al^{26}) and long (U^{238}, U^{235}, Th^{232}, K^{40}) lived radioisotope abundance, solar T-Tauri phase (2,3,4), dehydration) involved in the thermal evolution of SPOs, and not on models for specific objects. Our models show high sensitivity of the thermal profiles to relatively small changes (factor of 3-10) of the long-lived radioisotope abundance, and a sensitivity to solar T-Tauri heating for SPOs of approximately 250 km in radii. These heating mechanisms will increase the temperature of internal portions of the SPOs into the temperature regime (600-700°C) for dehydration of clay minerals (e.g. chlorite, serpentine). These dehydration reactions result in tectonic effects by two processes a) gas pressure increases, and b) rock shrinkage (assumed density increase from 2.5 to 3.3 cm/gm^3), in addition to the expected thermal expansion and/or contraction.

The dehydration of clay mineral species in the core of an SPO and the subsequent migration of the water vapor toward the surface will transport the vapor into regions within the SPO where pressure and temperature conditions make liquid water the stable phase. Such regions should be several tens of kilometers in thickness and extend to within a kilometer of the surface. The lower bound of the liquid water region is defined by the isotherm corresponding to the phase boundary between liquid and vapor water for the pressure at that isotherm depth (pressure is assumed to be equal to or less than the lithostatic pressure). The upper boundary of the liquid region is defined by the penetration of fractures from the surface, which give efficient access to the zero pressure environment.

Thus under nominal conditions (no short-lived radioisotopes, no T-Tauri heating, normal C2 abundance of long-lived radioisotopes) a C2 SPO the size of the largest asteroids (R=500km) should develop a three layer internal structure as a result of heating: a) a dehydrated core, b) a near surface shell some tens of kilometers in thickness in which liquid water has been an abundant phase, and c) a surface layer of essentially pristine (i.e. unaltered by thermal or aqueous processes) material. More active heating mechanisms will result in smaller SPOs being dehydrated, and less active heating mechanisms will result in larger SPOs being still hydrated. The dehydration mechanism will slow the change of temperature with time in the dehydrating layer, thus postponing or inhibiting melting in that region.

We model three distinct sizes of SPOs (100 km, 250 km, 500 km radius). Under nominal conditions, the 100 km SPO cools since its origin, thus remaining largely a pristine object. The 250 km SPO achieves core temperatures approaching the initiation of dehydration, and only needs a small additional heat source (e.g. slight increase in the long-lived radionuclide content, solar T-Tauri heating) to enter the dehydration temperature regime. The 500 km SPO approaches and may achieve melting temperatures in its core early in its history by heating due to long-lived radionuclides in chondritic abundance only. We suggest SPOs smaller than 250 km in radii should be still hydrated, unless they represent fragments of a parent body or have had enhanced heating mechanisms.

Cumulative surface radius chage based on thermally induced volumetric change alone (positive is expanding) is -360 meters for a 100 km SPO, -810 meters for a 250 km SPO, and -180 meters for a 500 km SPO (after an expansion phase showing a maximum radius change of +1.6 km). Typical thermally induced stress rates (5,6), due to thermal volumetric changes range from a few bars per 100 m.y. to 3 kbars per 100 m.y. Tangential stress rates show two nodes, relatively stable with respect to time and radius, at approximately 0.05R to 0.08R, and at approximately 0.65R to 0.80R, where R is the surface radius. These nodes may result in regions of less rock fracturing, thus possibly trapping deeper seated volatiles. The expected surface tectonic features include horsts, grabens, scarps, rifts, ridges and maar-type volcanic features. Such features are likely to leave observable evidence, even over geologically long periods of time (7,8,9). We also expect seismic activity on SPOs on a geologic time scale, extending into the present time for larger SPOs (>250 km radius). Although natural, internally generated seismic events are probably rare over an observable time scale, natural or artificial surface impacts may, through studies of seismic travel times, dispersion and normal modes, yield values for Q, elastic parameters and the volatile content of the SPO under study. We are in the process of deriving a rough classification of differing observable surface features and properties with different models, and ultimately plan to correlate observable surface features with the internal structure of SPOs.

This work has been supported by NASA contract NSG 7597.

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