ORBITAL EVOLUTION AND THE POSSIBILITY OF THERMAL DEHYDRATION OF ASTEROID 2008 EV5. L. Pohl and D. T. Britt University of Central Florida Department of Physics, 4111 Libra Dr, Orlando FL 32816, pohl@Knights.ucf.edu; Center of Lunar and Asteroid Surface Science, 12354 Research Pkwy Suite 214, Orlando FL 32826.

Introduction: Asteroid 2008 EV5 is currently the leading target of NASA Asteroid Redirect Mission (ARM) whose objective it to recover a multi-ton from the surface of an asteroid. Besides 2008 EV5 there are several other ARM candidates including 101955 Bennu or 25143 Itokawa. Potential parameters for asteroidal target selection include:

- Boulders: The presence of boulders is a major driver to allow boulder recovery. Radar imaging suggests that EV5 probably does have boulders.
- Volatiles: The presence of volatiles and other potential resources for use in ISRU hardware demonstrations. Key parameters include the amount of water and OH on the surface as well as the distribution with depth. Water and hydroxyl in hydrated minerals are usually bound in the crystal structure as a layer in phyllosilicates. Several important phyllosilicates can be identified in meteorite samples. These resources are largely confined to CI, C2, CM, and CR carbonaceous chondrites. Serpentine (usually found as Mg2Si2O5(OH)4) is abundant in CI and C2 meteorites and often found intimately mixed with Saponite (general formula (Ca0.5|Na)0.3|Mg[Fe2+]|3(Si|Al)4O10(OH)2·4H2O) [1]. Cronstedtite (Fe2+|Fe3+|SiO2(OH)4) is abundant in CM meteorites [2], making about 59% of Murchison meteorite [1], but its content in some CMs can be as low as 10% [3]. In the CR group, it is possible to find both samples abundant in phyllosilicates as well as samples with little phyllosilicate content [4].
- Physical Properties: The physical properties of the asteroid’s surface including the strength of the surface materials and their degree of weathering and alteration. Thermal shock, impacts, and micrometeorite bombardment may alter the strength and cohesion of the surface materials making it harder to grip and extract boulders from the asteroid’s surface.

These parameters are also important for other missions: OSIRIS-Rex to 101955 Bennu, Hayabusa 2 to 162173 Ryugu and in general for In Situ Resource Utilization (ISRU) missions.

For asteroids to preserve their volatile content, it is important to avoid extended stays in the proximity of the Sun. The longer and the closer the stay, the more volatiles are lost, both from the bound water/OH in phyllosilicates and from any ice trapped in the asteroid. Based on the orbital evolution of 2008 EV5 [6], we determine the probabilities of volatile depletion on the surface and estimate to what depth volatile depletion may have penetrated based.

Discussion: The time the asteroid spends within a given distance of the Sun (along with the size of the asteroid) determines how close its actual equilibrium temperature is to the proper equilibrium temperature (Actual: the temperature deep inside the asteroid where the thermal wave has negligible effect on short time scales characterized by orbital and rotation periods. Proper: a temperature deep inside the asteroid if the asteroid spent infinitely long at that distance). The distance from the Sun determines the proper equilibrium temperature itself as well as amplitudes of thermal waves.

It is usually possible to neglect lateral heat transfer and thus treat the heat transfer inside the asteroid as a one dimensional problem. If we limit ourselves to the most idealized case with zero inclination, circular orbital path, only rotational or only orbital motion, we can find that the temperature/depth profile is an exponential with some characteristic penetration depth of thermal waves (characterized by attenuation of the thermal wave amplitude on the surface by a factor of $e^{-1}$). This characteristic depth is dependent on the material characteristics of the asteroid and the period of motion. For rotational motion we call the depth the diurnal skin depth, for orbital motion, it is the seasonal skin depth. In a general case of orbital-rotational motion with arbitrary orbital and rotational geometry and non-circular orbit, the characteristic depth becomes affected by the geometry as well. The important material properties of an asteroid that significantly affect the temperature distribution inside the asteroid are thermal conductivity and capacity, and bulk density. All these parameters are closely linked to the porosity of the material.

The description of heat transfer in small sized boulders on the surface is a rather involved problem which requires taking into account a full heat transfer model (including lateral transfers and reflections and shading...
from asteroid surface as well as conductive heat transfer into the asteroid).

Heat increases the crystal lattice vibrations as well as amplitudes of atomic random motion. If the energy provided by the heat is big enough, bonds within the crystal structure can be broken. In the case of phyllosilicates this can result in the release of volatiles and complex transformation of the crystal structure. Also some minerals like kaolin can experience complete degradation of the crystal lattice and transformation to an amorphous material [5]. Any water ice would also need further heat to melt and/or vaporize.

The temperatures at which the loss of volatiles occurs are usually published as ranges rather than as exact values (this is something to be expected though, as the minerals themselves do not occur as pure but rather as solid solutions between certain end states with likely interstitial additions or other defects). Another aspect of most of the available data is that the dehydration temperatures are measured in atmospheric pressure or under very high pressures. For hydroxyl bound in Serpentine and Cronstedtite the dehydration temperatures range from ~500 °C to ~700 °C. Water as H₂O usually occurs in Saponite with dehydration temperature between ~100 °C and 200 °C. The dehydration of Serpentine proceeds as: Serpentine → Forsterite + Silica + Water, analogously, Cronstedtite dehydrates as: Cronstedtite → Fe³⁺, Si Spinel phase + Water → Hematite + Cristobalite.

Conclusions:

• Information about volatile survival on Near Earth Asteroids is vital for several upcoming missions and ISRU.
• Whether volatiles can be found on CI, C2, CM, and CR types of asteroids is determined by their orbital history and degree of thermal alteration.
• We will determine the probability of volatile survival on asteroid 2008 EV5.

References: