THE SPECIFIC HEAT OF REGOLITH MATERIAL. Jens Biele[1], Matthias Grott[2], Michael E. Zolensky[3], Artur Benisek[4], Edgar Dachs[4] , (1) DLR – German Aerospace Center, RB-MUSC, 51147 Cologne, Germany, Jens.Biele@dlr.de, (2) DLR – German Aerospace Center, Institute for Planetary Research, Berlin, Germany, matthias.grott@dlr.de, (3) NASA Johnson Space Center (Houston, United States), michael.e.zolensky@nasa.gov, (4) Materialforschung und Physik, Universität Salzburg, Austria, Artur.Benisek@sbg.ac.at, edgar.dachs@sbg.ac.at.

Introduction: Specific heat $c_P(T)$ is one of the parameters which determine a surface's temperature response to heating. Remote sensing in the mid-infrared is often used to estimate a parameter termed the thermal inertia of the surface material, which is defined as $\Gamma = \sqrt{\rho k(T) c_p(T)}$, where T is absolute temperature in K, k is thermal conductivity in W m^{-1} K^{-1}, ρ is bulk density in kg m^{-3}, and c_P is specific heat at constant pressure in units of J kg^{-1} K^{-1}. Knowledge or an estimate of $c_P(T)$ is required to extract information on, e.g., thermal conductivity k from the data, which in turn allows for an estimation of important surface properties like grain size [1-4] and porosity [5] . Furthermore, knowledge of thermophysical surface properties is essential to model the Yarkovsky [6-8] and YORP [8, 9] effects as well as the response of planetary surfaces to impact cratering.

Only a handful of meteorite heat capacities have been published, virtually all of them measured at temperatures at or above 300 K or at a ~175 K (Consolmagno et al., 2013). The only other extraterrestrial material with known c_P over a limited temperature range is lunar samples from the Apollo missions, and many studies have used these values as a "standard" $c_P(T)$ curve. Heat capacity, however, strongly depends not only on temperature but also on composition, thus the use of lunar data for, e.g., C- or M-class asteroids or objects containing frozen volatiles may give rise to large systematic errors. Missing $c_P(T)$ data for rocks (in general, "regolith material", any solid material found on the surface of solar system bodies) can be calculated from the contributions of the constituent minerals (and mineraloids, i.e. amorphous substances): linear mixing model, neglecting (except for olivine Fo-Fa) the non-ideal "excess heat capacity". Except at very low temperatures, the model specific heat is accurate to ~1% in general.

Review in progress: We report here on a comprehensive review we are undertaking at present. We review the available data on lunar samples and meteorites as well as the specific heat capacities of the most abundant endmember minerals (the most common and important mineral groups that occur in solar system materials and which are part of the c_P database) including iron-nickel metal. Furthermore, organic materials found in meteorites and the specific heat of frozen volatiles thought to exist on outer solar system bodies are considered. From these data, we built up a computerized database to calculate the specific heat of approximately 90 minerals and compounds for temperatures between absolute zero and close to melting (or decomposition) by use of tables and correlation equations apt for convenient but accurate interpolation. We alsoreview reference (mineralogical) compositions for common ordinary and carbonaceous chondritic meteorites as well as lunar surface material to prepare the construction of the reference specific heat models.

Results are, besides the c_P database, reference $c_P(T)$ for lunar regolith, common meteorite classes and some (mostly commercial) laboratory regolith simulants. Where lunar and meteorite data were available, we fit those to composition models, enabling meaningful extrapolation to very low and very high temperatures. The effect of metal (Fe-Ni) and organic material content will be discussed quantitatively. Finally, we will look at models for very cold, icy regolith, including an educated guess on the specific heat of the enigmatic tholins. Using the database, anyone can construct his/her own $c_P(T)$ curves from the mineralogical composition.

We present some exemplary results.

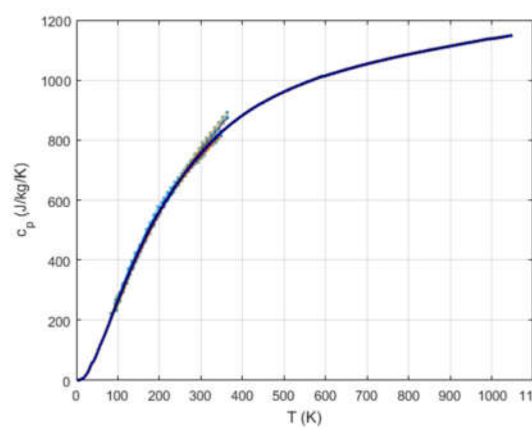

Fig. 1: New Lunar average $c_P(T)$. All raw data points with fitted and extrapolated cp (combination of lunar minerals)

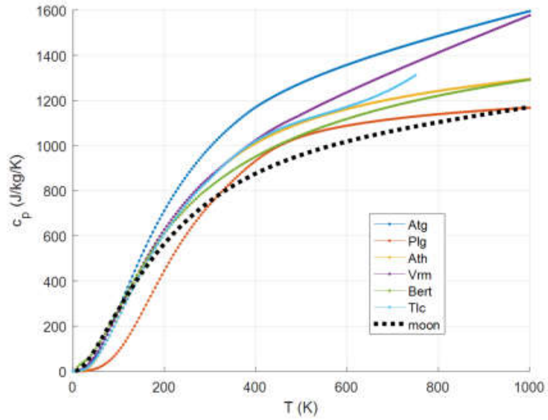

Fig. 2 $c_P(T)$ of phyllosilicates, compared to average lunar

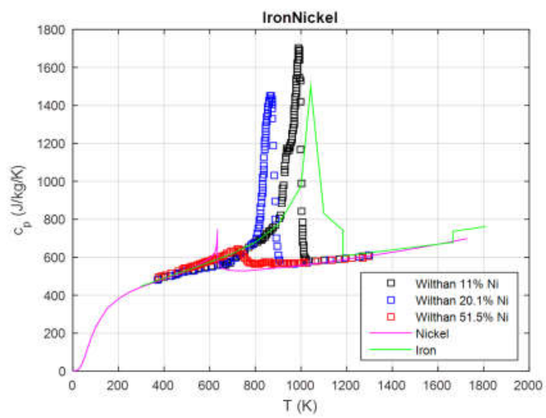

Fig. 3: $c_P(T)$ of Iron-Nickel

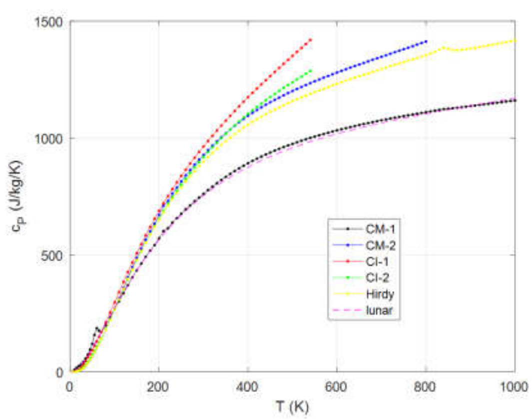

Fig. 4: Calculated $c_P(T)$ of analogue materials (DSI, "Hirdy"=U Tokyo UTPS)

Key points

- „Cologne c_P database" ~90 pure endmember minerals literature review, low-T (~5K) to melting point or decomposition, typically 1% accuracy
- c_P at low T: ices, tholin analogs, minerals.. (TNOs!)
- Inversion of lunar c_P data with raw data points shown and uncertainties of synthetic curve, convenient fit equation 5-1400K see [10]
- construct reasonable reference curves (or models) for the isobaric heat capacity c_p of small body surface material over a wide temperature range, typically (0) 10-1000K.
- Review paper in preparation
- We have a DSC (differential scanning calorimeter) in the laboratory, LN2 cooling, temperature range ca. 93-1023K, required sample mass 20-30 mg, realistic accuracy ~1%; plan is to measure $c_P(T)$ of our lab analogue materials and other interesting minerals, meteorites… ideas are welcome

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