"PRISTINE" MARTIAN CRATERS: PART 1 – CRITERIA AND CHARACTERISTICS. L. L. Tornabene[1], J. L. Piatek[2], N. G. Barlow[3], J. M. Boyce[4], P. J. Mouginis-Mark[4], G. R. Osinski[1,5], S. J. Robbins[6], [1]Centre for Planetary Science and Exploration, Dept. Earth Sciences, Univ. of Western Ontario, London, ON, N6A5B7, Canada, [2]Dept. of Geological Sciences, Central Connecticut State Univ., New Britain, CT, [3]Dept. Physics and Astronomy, Northern Arizona Univ., Flagstaff, AZ 86001, [4]Hawaii Institute of Geophysics and Planetology, University of Hawai'i, Honolulu, HI 96822, [5]Dept. Physics and Astronomy, University of Western Ontario, London, ON, N6A3K7, Canada, [6]Southwest Research Institute, Boulder, CO 80302; (livio@cpsx.uwo.ca)

Introduction: High-resolution meter-scale images of what are thought to be the youngest and best-preserved impact craters on Mars suggest that even the youngest craters on Mars [e.g., 1–4] show signs of modification by active geologic processes. As such, in order to constrain impact processes (e.g., ejecta properties and emplacement) and modification processes (i.e., various erosion and depositional processes), the visible and thermophysical characteristics of the most "pristine" craters on Mars must be constrained as a baseline. Indeed, various preservation/age terms (e.g., fresh, young, pristine, etc.) are used in the literature for Martian craters [e.g., 5–8] and often do not account for the fact that crater preservation and age may not be correlated. This is the case on a planet with active geologic processes, such as Mars, that exhibit both temporal and geographic variation in modification rates.

The objective of this study is to identify and characterize a set of physical properties associated with pristine Martian craters that will be utilized as a baseline for further studies. These craters will provide the best means to: 1) place further constraints on various aspects of the impact processes, and 2) examine how the physical properties of craters change as the crater and ejecta are modified over time, and as a function of target material and latitude (see companion abstract [9]). Here we define a "pristine" crater as a one that is both young (age) and appears morphologically "fresh" (i.e., the least-modified). In addition, we have begun to devise a crater classification scheme that couples both preservation and age of craters, which will prove useful for continued studies.

Background and Methods: In general, a synthesis of the cratering literature provides two main criteria for rapid identification of candidate youthful craters on a planetary body: 1) craters that possess a preserved ejecta ray pattern [e.g., 1, 10–11] or a well-contrasted thermophysical pattern [1, 3, 12] and 2) craters that preserve impact melt deposits [e.g., 3, 13–14]. We also include additional characteristics attributed to crater youthfulness such as: 1) crater morphometry (e.g., a high depth-to-Diameter (d/D) ratio suggestive of minimal post-impact degradation and infilling [e.g., 3, 5–8]), 2) very few overprinting craters, even at very small diameters (D<1 km) [e.g., 2], and 3) in lieu of a thermophysical crater ray pattern, a field of well-preserved secondary craters. All these characteristics have yet to be utilized together to identify a set of the most pristine craters on Mars.

Table 1 provides a summary of criteria for identifying pristine craters. Included in the table are a list of appropriate datasets for evaluating criteria (both preferred and secondary, when the preferred is not available), and associated limitations. The inclusion of data limitations is necessary as there is no single criterion that will be unique to all pristine craters on Mars due to the limitations listed in Table 1; for example, the thermophysical signature of rayed craters can be limited due to a lack of thermal inertia contrast with the underlying surface. Additionally, including these data restrictions/limitations will begin to make this system portable to other solar system bodies where less data are available. This synthesis approach will be implemented for the first time to find the most pristine craters on Mars.

For this study, we will limit our candidate craters based on latitude (<60°) as THEMIS coverage is poor above 60° latitude and uncertainties in quantitative thermal inertia increase with colder temperatures [15]. Craters <1 km in diameter will be avoided because they appear to lack discernible melt deposits [3], are not covered by the Barlow [5–6] and Robbins and Hynek [8] databases, and their features approach the spatial limitations of THEMIS data.

Pristine Crater Identification: We start by compiling a list of all known rayed craters on Mars and all craters with observed impact melt deposits (both pitted materials and lunar-like melt deposits – e.g., Pangboche Crater). Note that we distinguish rayed craters here from other ejecta patterns often mistaken as rays in a similar fashion to [16]. Next, we cross-referenceD and refined the list with as many of the criteria listed in Table 1 as possible. We then carefully assessed the occurrence and preservation state of the impact melt deposits of each these craters in HiRISE and CTX images while noting craters with the least overprinting impacts and those with preserved secondary fields. The preservation of impact melt deposits can be readily constrained as these deposits on the crater ejecta, relative to the crater floor, are more readily obscured by modification [3]. These additional assessments effectively refined the list of candidate craters.

Our working list was then next cross-referenced with the most current global databases of craters to constrain the best candidates for both the pristine and the modified classes. This includes Barlow [5–6] craters with a preservation class of 7.0 and Robbins and Hynek [8] craters of Class 4 preservation. Both Barlow [5–6] and Robbins and Hynek [8] include d/D of craters, which can be used as a tool to prioritize and further refine the best-candidate craters. Some care is needed, as these classes do not take account of pre-target slopes and topographic effects, which can exaggerate d/D ratios; however, [8] took into account local d/D instead of the global average. The refined working list is maintained as an ESRI shapefile database, which can be readily visualized and manipulated with other data sets in ArcGIS and JMARS [17]. We also separated out craters with the highest and lowest TES-derived Dust Cover Index (DCI) (i.e., low and high dust-cover, respectively; [18]). Dusty craters (DCI <0.950) will be put aside for later comparative analysis with respect to the non-dusty (DCI >0.950) pristine craters. Detailed analyses of pristine craters (rayed and non-rayed) will lead to the recognition and characterization of consistent morphologies and thermophysical properties associated with pristine deposits, which can then be used as a baseline for examining crater modification (see companion abstract [9]). For example, a dusty crater can be compared with these baseline morphologic and thermophysical properties, which can then be used to model the amount of dust deposition on the crater. Together, the results of these analyses will provide constraints for both impact processes and a variety of subsequent crater modification processes, both of which are relevant to understanding the evolution of the Martian surface and past climate (e.g., times of higher rates of erosion and deposition).

Initial results: We have begun to identify candidate pristine craters, which we will present at the LPSC in March [see also 9].

Summary and Conclusions: By using a synthesis approach that combines observations from both visible and thermal datasets, we are identifying examples of the youngest and best-preserved craters on Mars (i.e., “pristine”). These craters will provide a critical baseline for understanding the impact process and utilizing craters as a gauge for understanding the evolution of the Martian surface and past climates on Mars.

References: [1] Tornabene et al. (2006), *JGR* 111. [2] Hartmann et al. (2010), *Icarus* 208. [3] Tornabene et al. (2012), *Icarus* 220, 348–368. [4] Piatek et al. (2014) *LPSC 45*, abstract #2813. [5] Barlow (2004) *GRL*, 31, L05703. [6] Barlow (2006) *LPSC 37*, abstract #1337. [7] Boyce and Garbeil (2007), *GRL* 34. [8] Robbins and Hynek (2012), *JGR* 117. [9] Piatek et al. (2015) *this conference*. [10] Hawke et al. (2004), *Icarus* 170, 1-16. [11] McEwen et al. (2005), *JGR* 112. [12] Williams and Malin (2008) [13] Hawke and Head (1977), *in Impact and Explosion Cratering* (Roddy et al., eds.), 815-841. [14] Osinski et al. (2011), *EPSL* 310, 167–181. [15] Christensen et al. (2013) [16] Chuang et al. (2015) *this conference*. [17] Gorelick et al. (2003), *LPSC 34*, abstract #2057. [18] Ruff and Christensen (2002), *JGR*.

Table 1. Criteria for finding the best-preserved “pristine” Martian craters

Criterion	Assessment Difficulty	Preferred Data (Secondary)	Range	Limitations
Thermal Secondary Crater Rays	Easy	THEMIS day & night thermal infrared images	Below 60° latitude, range of good thermophysical data	Excludes craters at higher latitude (>±60°), craters well outside of Thermophysical Unit C (moderate TI, albedo and dust cover)
Pitted-Impact Deposits	Easy to Moderate	HiRISE (MOC & CTX)	Between 30-60° latitude,(Fig, 2, Tornabene et al., 2012)	Excludes high latitude (>±60°) craters
Depth-Diameter (d/D) Ratio	Moderate	MOLA PEDR (HiRISE CTX & HRSC stereo image derived DTMs)	MOLA PEDR coverage poorer at equator with respect to the poles	MOLA coverage limitations; craters below ~15 km are often poorly resolved; d/D may be exaggerated by pre-existing topographic effects
Preserved Secondary Crater Field	Moderate to Difficult	CTX (HiRISE, MOC & THEMIS VIS)	N/A	Small secondaries require higher-resolution datasets (e.g. HiRISE), which have less surface coverage
Low Size-Frequency Distribution (SFD) of Overprinting Impacts	Difficult	CTX or HiRISE	N/A	Time consuming to count small overprinting craters to derive a modeled age based on isochrons.