UTILITY OF REMOTE SENSING, ROBOTIC PRECURSOR DATA AND A FOCUSED SCIENCE HYPOTHESIS FOR A FOLLOW-ON HUMAN EXPLORATION LUNAR ANALOGUE MISSION AT THE MISTASTIN LAKE (KAMESTASTIN) IMPACT STRUCTURE. L. L. Tornabene[1], G. R. Osinski[1], M. M. Mader[1], A. Chanou[1], R. Francis[1], B. L. Jolliff[2], C. Marion[1], E. McCullough[1], A. Pickersgill[1], H. Sapers[1], K. Souders[3], P. Sylvester[3], K. Young[4], M. Zanetti[2] and the KRASH team[5], [1]Centre for Planetary Science and Exploration, Depts. Earth Sciences/Physics and Astronomy, University of Western Ontario, London, ON, Canada, [2]Dept. Earth & Planetary Sciences, Washington University, MO, USA, [3]Department of Earth Sciences, Memorial University of Newfoundland, St. John's, Canada, [4]School of Earth and Space Exploration, Arizona State University, AZ, USA, (ltornabe@uwo.com). [5]KRASH Operations and Science Team (see [1]).

Introduction: In order to prepare and test protocols for future lunar sample return missions, our Canadian-based international team carried out two lunar analogue missions funded by the Canadian Space Agency [1,2]. The first deployment took place over three weeks in 2010. It involved the collection of precursor data including robotic ground-based imaging (color panoramas), and airborne-based "descent-style" imaging of proposed landing sites [3]. This was followed by two separate human sortie missions in Aug.-Sept. 2011 to sites visited in 2010 [1,2].

Here we draw specifically from remote sensing data and precursor data from the 2010 deployment to formulate and address a focused testable hypothesis, which was applied to the second week of the 2011 follow-on human lunar analogue mission. We show the utility of using multiple datasets spanning three basic scales to formulate our hypothesis and also to plan traverses and follow-up observations from the field to test this hypothesis. The simulation was carried out without *a priori* knowledge of the field site.

Background: The ~36 Ma Mistastin Lake (Kamestastin) impact structure, in northern Labrador, Canada (55°53'N; 63°18'W), was chosen as a Lunar analogue field site because it is a complex crater formed in feldspathic rocks similar in composition to the lunar highlands [2]. This site includes both an anorthositic target and preserved ejecta deposits (including impact melt and breccias) [4,5]. The original crater has been differentially eroded; however, a subdued rim (diameter ~ 28 km) [4], terraces bounded by listric faults, and a distinct central uplift are still observed (Fig. 1). The inner portion of the structure is covered by the lake and the surrounding area is locally covered by soil/glacial deposits and vegetation.

The overarching objectives for this analogue mission were to: 1) determine impact chronology (sample and date impact melt), 2) characterize shock processes, 3) characterize impact ejecta, and 4) indentify potential mineral resources [1, 2]. Due to the 2-week duration of the mission, our science planning group ("Science"), based at Mission Control (MC), decided that a focused, testable hypothesis would be the most effective use of our time, address most of the above mission objectives, and perhaps improve our simulation by providing a realistic testable science goal.

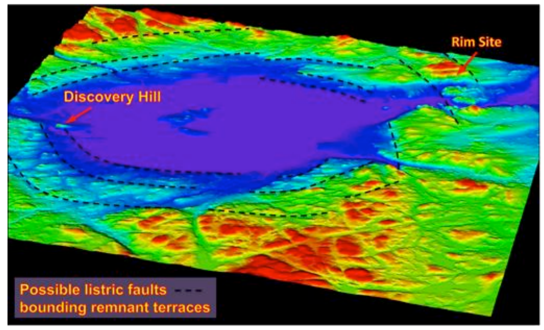
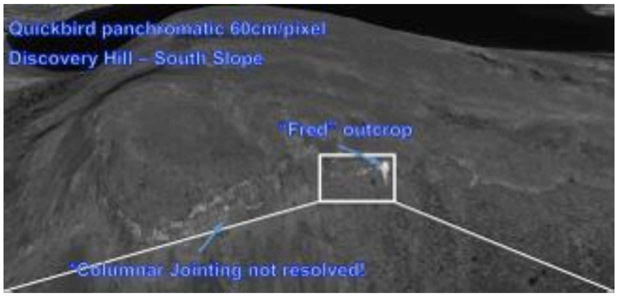


Fig. 1: A colorized shaded relief model of the Mistastin Lake impact structure showing the locations of week 1 (Rim) and week 2 (DH) sites. Possible listric faults, defining the terrace region, are outlined in black dashed lines.

Remote sensing of Discovery Hill (DH)*:* In-depth analysis of remote sensing and the 2010 precursor data show the presence of a local topographic high by the western lake shore, Discovery Hill "DH" (Fig. 1). Conventional band ratio techniques [6] for 30-m Landsat ETM+ were combined with a single channel (IR) 15-m ASTER grayscale image (to enhance resolution) to assess the location of fresh outcrops with low vegetation at Kamestastin. DH was recognized in this data product as distinctive and was interpreted to be fresh, relatively unaltered (ferrous-bearing) outcrops [see 7]. High-resolution panchromatic (60-cm) and color-infrared (2.4-m) Quickbird (QB) images were used to further investigate the characteristics of DH. These images show that DH is capped by massive, almost vertical outcrop of a dark-toned material that appears to exhibit multiple vertical fractures or joints (Fig. 2). A closer examination of these materials in the highest-resolution 2010 precursor images indicates that these features are consistent with columnar joints [e.g., 8]. Given the geologic context, we interpreted the "cap" unit to be an impact melt rock deposit.

Because impact melt rocks can address all of the aforementioned mission objectives, an investigation by the "astronauts" of this outcrop was given the highest priority. Also, "Science" devised a basic hypothesis to test, which involves the origin and provenance of the possible impact melt rock unit. Is the DH cap unit impact melt rock? If so, is it a portion of the coherent melt sheet of the crater-fill deposits, or a remnant of a terrace melt pond similar to those commonly observed in and around lunar craters (Fig. 3) [e.g., 9,10]?



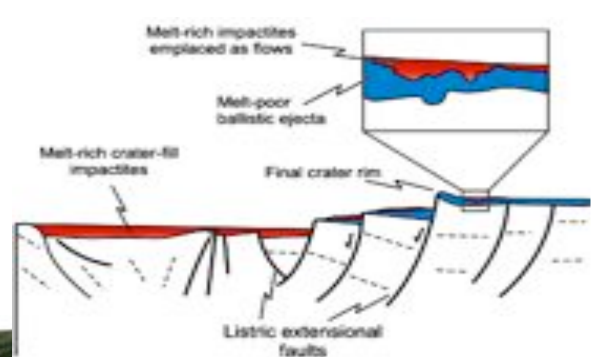


Fig. 2: A 3D perspective of the QB panchromatic image compared with 2010 precursor image of the southern slope of DH. A light-toned outcrop (Frederiction or "Fred") appears to unconformably underlie the impact melt and is resolved at both scales. (Top) The melt unit of DH (left) exhibits barely discernable columnar jointing which is better resolved by the precursor image (Bottom).

In addition to the cap unit at DH, a distinctive light-toned outcrop, Fredericton or "Fred", was identified as a key unit that was interpreted to be conformable with the cap unit. Therefore, this contact was considered to be key towards understanding the provenance and setting of this particular impact melt body (Table 1).

In summary, our goal was to characterize and determine the provenance of the unit via detailed field investigations by the "astronauts" and through use of the suite of instruments available to them [see 11-13] combined with the interpretations of the remote sensing and precursor data. The "astronauts" were supplied with annotated images (e.g., Fig 2.) and detailed observations from MC to guide their exploration of DH (Table 1).

Key points: We emphasize here how the remote sensing and precursor data were particularly useful in addressing our focused scientific hypothesis: 1) the Fred outcrop did indeed turn out to be a key observation that would not have been easily discovered in the field without the aid of remote sensing; due to the small areal occurrence and steep slopes the "astronauts" would have completely missed this outcrop without the aid of MC. 2) A focused science hypothesis greatly enhanced scientific return, use of the daily-downloaded data products returned to MC, and field team productivity (especially in terms of focusing the use of instruments and the "astronauts" time to address the overarching mission objectives. Results from the field regarding this focused hypothesis are detailed in [13].

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Table 1: Summary of evidence to look for in the field in support of impact melt provenance.

	Hypothesis 1 (melt = crater floor melt sheet)	Hypothesis 2 (melt = terraced rim unit)
Stratigraphy – unit(s) underlying melt	Potentially: - Melt in **contact** with target material that has been brecciated (i.e., both allochthonous and autochthonous breccias, monomict or polymict). - **Shock level** of underlying unit: highly variable but up to a few GPa (shatter cones possible)	Potentially: - Melt overlying breccia (e.g. ballistic ejecta). Breccia may be polymict in nature (many different types of rock fragments). - Shock level of underlying unit: generally unshocked (no visible evidence in field)
Structural features within underlying material	Material is heavily faulted and fractured. Irregular & random orientation of faults and fractures common.	Material may be relatively unfractured. Faults on an outcrop scale may be parallel to regional impact faults (e.g. listric faults defining terraces).
Contact relationship (between melt and underlying unit)	Basal contact of melt and underlying material would likely be chaotic, irregular.	Possibly sharp contact between melt and underlying unit.