Uniquely Multidisciplinary Investigations at Amundsen Crater for Artemis III

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Geologic Background: Amundsen Crater is the most morphologically fresh complex crater within 6˚ of the lunar south pole. At 100 km in diameter, it features terraced walls, boulder falls, a mare-covered floor, broad & accessible PSRs, and a central peak complex exposing outcrops of exhumed lithologies originating from depth. Within 6˚ of the pole, Amundsen Crater uniquely enables the study of complex crater geology and formation with large and highly accessible PSRs to study and utilize lunar polar volatiles [Lemelin et al., 2014]. Amundsen's central peak is anorthositic with a lower mafic content than the surrounding crater floor (e.g., [Lemelin et al., 2017; Blalock et al., 2020]. The central peak experiences ~11 days of illumination per lunation [Mazarico et al., 2011]. Its summit is nearly flat for hundreds of meters—making it amenable to landing on—and its flanks have slopes shallower than 25˚, amenable to traversability. While parts of the floor experience only 6 days near-continuous sunlight, this would be long enough for a sortie mission such as Artemis III. While we focus on the science of impact cratering, PSR volatiles, and adjacent topics (e.g., regolith properties and volatile abundance/transport), we couch this in terms of realistic scenarios for Artemis III: we assume an Apollo 14-like, on-foot mobility ConOp in which the Artemis III crew embark on two or three, ~5 hour-long EVAs. Notably, we highlight the science that Amundsen can teach us even if it is more than can be accomplished in just the Artemis III mission. We consider science objectives (see table) the crew can perform as well the unique measurements from long-lived instruments that would telemeter data to Earth long after the conclusion of Artemis III. Science objectives are community goals from "The Scientific Context for Exploration of the Moon" ("SCEM report") [NRC, 2007], the Lunar Exploration Roadmap (LER) [LEAG, 2016], and the 2013-2022 Decadal Survey [VV, 2011].

Discussion of Science Objectives: 1) Geologic field maps create the context for which all other geologic observations are based. Observations and ground-based data of, e.g., geomorphic and compositional unit contacts, faults, outcrops, boulder trails, wrinkle ridges, ejecta, etc., will ground-truth remote sensing geologic maps and inform sampling locations. 2) Different depths of the Amundsen melt sheet deposit may be exposed along the height of the central peaks, which is likely partially mass wasted along the base, and the base of the central peaks is thus a grab bag of mixed lithologies. While constraining precise provenance may not be possible of rocklets and fines therein, the degree of homogeneity or heterogeneity of mineralogies should provide some constraints on the degree of Amundsen's melt sheet differentiation. 3) Amundsen hosts one of the largest and most accessible PSRs at which remote sensing datasets are ambiguous as to the presence of water ice at the uppermost surface (Brown et al., 2019 and references therein), undergirding the need for ground truth. Recent work also suggests micrometeoroid impacts and other active processes may liberate water and other volatiles at PSRs [Farrell et al., 2019]. 4) The degree of natural and human-caused seismic activity—and associated risk for surface activities [LER 2016]—can be estimated with one seismometer, but subsurface 3D tomography requires at least three.

Table 1. Artemis III science measurements/actions (highlighted) tied with science objectives (left) and tie-in to community documents (right; not exhaustive); abbreviations defined in text. Notably, SCEM 4 refers to volatiles, SCEM 6 refers to the cratering process, and SCEM 7 refers to regolith properties. LER Sci and VV priorities have similar scope.

Science Objective	Science Measurements/Actions	Community Tie-In
1. Create geologic **field maps** and interpret cross sections of traversed regions.	1. Crew record verbal **geologic** descriptions, multispectral photos, and video acquired during Amundsen Crater traverses.	SCEM 6a,c,d; 7|LER Sci-A-3,5,7,8
2. Constrain degree of **melt sheet differentiation** and unit **emplacement ages.**	2a. Return rock samples from **exposed outcrops** in, e.g., central peaks, floor, & wall rock.	SCEM 6a,c,d; 7|VV p.11|VV p.26
	2b. Return **regolith samples** from Amundsen floor, PSRs (cryosampling), base of and transect up central peaks/walls/hills.	SCEM 4a-e; 6a,c,d; 7|VV p.26
3. Measure temporal & spatial changes in **volatile species** & abundance.	3a. Deploy **long-lived mass spectrometers** in and/or out of PSRs.	SCEM 4a-e; 7|LER Sci-A-3,5, 7,8
	3b. Deploy long-lived **Lyman-alpha telescopic camera** on peak flanks to image UV reflectance changes in adjacent PSRs.	
4. Assess current seismic activity; subsurface seismic tomography.	4. Deploy **long-lived local seismic network** (n >= 3) on Amundsen's floor.	LER Sci-A-5| VV p.15, 35

References: Blalock, J. J., et al. (2020). LPI Cont., 2241, Abstract #5112. **Brown**, H. M., et al. (2019), LPI Cont. 2132, Abstract #1054. **Farrell**, W. M., et al. (2019), GRL, 46(15), 8680-8688. **Lemelin**, M. et al (2014) Planetary and Space Science, 101, 149-161. **Lemelin**, M. et al. (2017) 48th LPSC, Abstract #2479. **LER** - Opening the Gateway to the Solar System. https://www.lpi.usra.edu/leag/roadmap/. **NRC**, 2007. The Scientific Context for Exploration of the Moon, The National Academies Press, Washington, D.C., National Academy of Sciences. **VV** (2011), 2013-2022 Decadal survey.