PREFACE

Much has happened in the world in the 17 years since the first New Views of the Moon (NVM) was published as volume 60 of the Mineralogical Society of America Reviews in Mineralogy and Geochemistry series. The original New Views of the Moon (published in 2006) was motivated by new results that came from two new missions to the Moon, Clementine (1994) and Lunar Prospector (1998), along with some 30 years of sample analyses and recognition of lunar meteorites. Since then, there have been over fifteen new missions to the Moon and counting! These new missions have provided a wealth of new information, mostly orbital, but culminating in a new look at Apollo samples 50 years after they were collected, and the release of previously unexamined Apollo samples (noting that a new generation of lunar scientists participated in this initiative), as well as a new robotic sample return mission from one of the Moon's youngest volcanic terrains as part of the highly successful Chang'e-5 mission.

An exciting new era of lunar exploration has begun, including the promise of resuming human lunar exploration, exploring the lunar Poles, and missions to many other high-priority science targets. It is fitting, therefore, to now summarize the current state of knowledge to the degree possible at a time when advancements in knowledge of the Moon are proceeding at a breakneck pace. Therefore, during this period of unprecedented lunar exploration activity, and as we continue to rebound from a global pandemic, we now happily announce this New Views of the Moon 2 (hereafter, NVM-2) volume summarizing the advances in lunar science and exploration since 2006. The Steering Committee is eternally grateful to all contributors and especially the chapter leads, and to Professor Makiko Ohtake (University of Aizu, Japan) and Dr. David Blewett (Johns Hopkins University Applied Physics Laboratory, U.S.A.) for organizing the New Views of the Moon 2 Electronic Annex. We deeply appreciate the hard work and dedication of everyone involved in the production of this volume, especially Rachel Russell and Ian Swainson at the Mineralogical Society of America.

Three amazingly successful workshops allowed diverse input to be obtained from a global lunar science and exploration community. Together they allowed the formation of nineteen-chapter teams to create NVM-2.

- The official kick-off for this initiative was a workshop at the Lunar & Planetary Institute in Houston, Texas 24-26 May 2016 (https://www.hou.usra.edu/meetings/newviews2016/) with Clive Neal, Steve Mackwell, Chip Shearer, Brad Jolliff, Lisa Gaddis, Sam Lawrence, and Sarah Valencia as the Science Organizing Committee. Owing to the interest in the Moon since 2000, it was recognized that this initiative should be an international effort, which resulted in subsequent workshops in Europe and Asia.
- New Views of the Moon 2 Europe followed in 2017 and was held on 4–5 May at the University of Münster in Münster, Germany (https://www.hou.usra.edu/meetings/newviews2017/), which also included Harry Hiesinger and Carolyn van der Bogart in the organizing committee with those from the first workshop.
- The third workshop, New Views of the Moon 2 Asia (https://www.hou.usra.edu/meetings/newviews2018/), was held 18–20 April 2018 in Japan at the University of Aizu Aizuwakamatsu City in the Fukushima prefecture. The organizing committee included those from the first workshop, and also Makiko Ohtake, Yoshiaki Ishihara, Hiroyuki Sato, Junichi Haruyama, Hirohide Demura, Naru Hirata, Yusuke Nakauchi, and Yoshiko Ogawa.

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In total, these workshops vividly demonstrated why this initiative was needed as they highlighted the tremendous advances in lunar science and exploration since 2006. These advances have been documented in the nineteen chapters that form NVM-2:

- There have been a large number of missions to the Moon since 2000, and new ones are occurring so frequently we cannot give a specific number here! Gaddis et al. (2023, this volume) present an overview of historic and recent lunar missions, including a snapshot of the rapidly changing international lunar exploration plans and missions.
- New models of lunar origin have been developed on the basis of new data and modeling concepts (see Canup et al. 2023, this volume).
- Our understanding of the lunar magma ocean has been refined and challenged over the last 20 years and developments are summarized in Gaffney et al. (2023, this volume). Likewise, our understanding of post-magma ocean volcanism (e.g., cryptomare, irregular mare patches, and mare volcanism <3 billion years old) is summarized by Shearer et al. (2023, this volume).
- Much has been learned about the primary and secondary lunar crust through lunar missions this century, including the recognition of new rock types and endogenous alteration of the crust, which is summarized by Elardo et al. (2023, this volume).
- The structure and evolution of the lunar interior have been examined through new data (e.g., the GRAIL mission) and a re-examination of previous data (e.g., the Apollo lunar seismic data). Andrews-Hanna et al. (2023, this volume) have integrated the new observations with previous ideas to reveal a new view of the lunar interior. The recognition of an inner solid and an outer liquid core has to be reconciled with the idea that the Moon may have had a global magnetic field generated by an internal dynamo, a concept that was not apparent in the writing of the original New Views of the Moon. New evidence for this global lunar dynamo is expertly synthesized by Wieczorek et al. (2023, this volume).
- The lunar surface has been exposed to extra-lunar impacts since formation. New Views of the Moon 2 devoted three chapters to impacts: the impact process (see Osinski et al. 2023, this volume), impact history (see Cohen et al. 2023, this volume), and crater chronology (see Hiesinger et al. 2023, this volume).
- Many new lunar samples have been found as lunar meteorites during the first quarter of this century. These continue to give us new understanding of our Moon that include new insights into crustal lithologies and several low-Ti mare basalts that represent younger volcanic events than the samples returned by the Apollo and Luna missions (see Joy et al. 2023, this volume).
- In the last 13 years, there have been over a half-dozen spacecraft sent to the Moon dedicated, wholly or in part, to the study of the neutral, ionized, and particulate atmosphere at the Moon. Syntheses of these new data regarding dust, atmosphere/exosphere, and plasma can be found in Farrell et al. (2023, this volume).
- Our understanding of the space weathering processes that occur on airless bodies have seen tremendous advances (see Denevi et al. 2023, this volume). These advances have resulted from new spacecraft observations of the Moon, and detailed analyses of lunar samples, for example, about rates of formation of weathering products, the composition and oxidation state of those products, and the effects of individual micrometeoroid impact events.
- New data from the Moon this century have emphasized the surface processes that have occurred and continue to occur. These missions obtained a wealth of data that have significantly changed our understanding of active processes, volatiles and the properties of the regolith. In particular, higher resolution data have permitted examination of processes

and characteristics at smaller spatial scales than was previously possible. Plescia et al. (2023, this volume) synthesize these new data to give a detailed understanding of the complexity of lunar surface processes.

- It is now known that the Moon has a complex water cycle both on the surface and in the interior. Lunar Prospector showed that at least some of the permanently shadowed craters contained water, but since that mission new data indicate a diurnal surface water cycle extending beyond the lunar poles and that neutron suppression zones, consistent with buried water ice, are present in and around some permanently shadowed craters (see Hurley et al. 2023, this volume). New analytical techniques are available to investigate the lunar samples for volatiles and begin to understand the volatile content of the mantle, which has led to a re-evaluation of the lunar magma ocean model and volatile processes in the proto-lunar disk (see McCubbin et al. 2023, this volume).
- The recognition of more rifts and thrust faults has been made possible by missions since 2006 (primarily through the Lunar Reconnaissance Orbiter Narrow Angle Camera), such that a lunar tectonic cycle has been recognized. The young thrust faults and young small-scale graben detected in LRO-NAC images offer insights into the origin of current lunar near-surface stresses (see Nahm, Watters et al. 2023, this volume).
- Lunar science has also revealed important aspects of the Moon that could enable sustainable human lunar exploration, potential human lunar permanence, and possibly a vibrant cislunar economy. These are collectively brought together under lunar resources (see Crawford et al. 2023, this volume), providing a summary of our current understanding of lunar resources and also discussion of the next steps in lunar resource characterization and use.
- Several chapters refer to an Electronic Annex, which contains high resolution images of important figures. This is being housed at the University of Aizu in Aizuwakamatsu, Fukushima Prefecture, Japan. The "EA" images called out in NVM-2 can be found using the following URL: https://apenninus.u-aizu.ac.jp/NVM2-EA.html. A big thank you to Makiko Ohtake (University of Aizu) and Dave Blewett (Johns Hopkins University Applied Physics Laboratory) who made the Electronic Annex a reality.
- Finally, you will notice that several chapters have updates because the leads finished their chapters early in the process. These updates include significant developments in that particular subject between chapter completion and publication.

As New Views of the Moon 2 is published, it helps to frame our knowledge and expectations for an exciting future of lunar science and exploration and the new discoveries to be made. Having humans return to the Moon now seems more likely than it ever has since the last humans left the Moon on 14 December 1972. The current United States Space Policy calls for human permanence on the Moon, and the Artemis Accords currently have 28 countries as signatories. China is proposing an International Lunar Research Station that currently has 4 signatories and is negotiating with more than 10 others. In the next decade close to 100 lunar missions have been proposed. Will we soon be looking back on Earth from a new home in space? What data will these missions return and what will we learn about the Moon and its environment? One thing is clear: Our Moon is a stunning world full of wonder and opportunity for science, exploration, and commerce. We look forward as one community with hope and optimism to seeing the amazing new discoveries from a new generation of lunar missions, and documenting them in a future New Views of the Moon 3.

The Science Organizing Committee:

Clive R. Neal, Lisa R. Gaddis, Bradley L. Jolliff, Samuel J. Lawrence, Stephen J. Mackwell, Charles K. Shearer, Sarah N. Valencia

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DEDICATION

New Views of the Moon-2 is dedicated to the life, career, and memory of all lunatics who have passed since the original New Views of the Moon was completed in 2005 and published in 2006. We build on their legacy.

Malcom J. "Mac" Rutherford	1939–2023	Elmar Jessberger	1943–2017
Robert O. Pepin	1933–2023	Lawrence A. Taylor	1938–2017
Jack L. Warren	1941–2023	Andrei Valerievich Ivanov	1937–2016
Klaus Keil	1934–2022	Edgar Mitchell	1930–2016
James A. McDivitt	1929–2022	Gerald Wasserburg	1927–2016
Charles Prewitt	1933–2022	Ewen Whitaker	1922–2016
Leon Silver	1925–2022	Arlin Crotts	1958–2015
William Stoney	1925–2022	Bernard Ray Hawke	1946–2015
Michael Collins	1930–2021	Heinrich Wänke	1928–2015
Gunter Lugmair	1940–2021	Noel Hinners	1925–2014
Stuart Ross Taylor	1925–2021	Gerhard Neukum	1944–2014
George Carruthers	1939–2020	Colin Pillinger	1943–2014
Jay Melosh	1947–2020	Gordon Swann	1931–2014
Brian O'Brien	1934–2020	Peter Eberhardt	1931–2013
James Papike	1937–2020	David McKay	1936–2013
Roger Philips	1940–2020	Michael Wargo	1952–2013
Al Worden	1932–2020	Neil Armstrong	1930–2012
Joshua L. Bandfield	1974–2019	James Arnold	1923–2012
Robin Brett	1935–2019	John William Dietrich	1925–2012
James Carter	1937–2019	John Guest	1938–2012
David Criswell	1941–2019	John McCauley	1932–2012
Ahmed El Goresy	1934–2019	Michael Drake	1946–2011
Alan Bean	1923–2018	Ronald Greeley	1939–2011
Christine Floss	1961–2018	Paul Lowman	1931–2011
Erik Hauri	1966–2018	William Muehlberger	1923–2011
John Longhi	1946–2018	Ralph Baldwin	1912–2010
Ursula Marvin	1921–2018	Audouin Charles Dollfus	1925–2010
Ian Stewart McCallum	1937–2018	Eric Essene	1948–2009
George McGill	1931–2018	Brian Mason	1917–2009
Verne Oberbeck	1936–2018	Edward Chao	1920–2008
Paul Spudis	1952–2018	John Lindsay	1941–2008
John Westfall	1938–2018	Gordon McKay	1946–2008
John Young	1930–2018	Robert Seamans, Jr.	1919–2008
Eugene Cernan	1934–2017	Wolf von Engelhardt	1910–2008
Robert Clayton	1930–2017	George Wetherill	1925–2006
Dick Gordon	1929–2017	Larry Haskin	1934–2005

FROM THE SERIES EDITOR

High-resolution images and sizeable datasets are associated with four of the chapters in this volume: Chapters 1, 4, 6, 11, and 17. These files are stored in an Electronic Annex at the University of Aizu, Japan, at https://apenninus.u-aizu.ac.jp/NVM2-EA.html, which can be accessed by the QR code below. The references to these tables and figures are referred to by the prefix "EA". Many thanks go to Professor Makiko Ohtake (University of Aizu, Japan) and Dr. David Blewett (Johns Hopkins University Applied Physics Laboratory, U.S.A.) for organizing the New Views of the Moon 2 Electronic Annex.