The Far Side of the Moon

Charles J. Byrne

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A Photographic Guide

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Image Again
Middletown, NJ
USA

ISBN-13: 978-0-387-73205-3 e-ISBN-13: 978-0-387-73206-0

Library of Congress Control Number: 2007932624

Printed on acid-free paper.

9 8 7 6 5 4 3 2 1

springer.com

Preface

The nature of the far side of the Moon has always been a mystery. Throughout human history, the far side of the Moon has been so near, its presence so obvious, and yet so hidden. It was only in the decade of the 1960s that we have been able to observe it, as opposed to inferring its existence. I have been fortunate to live during the period when the far side became visible and has been extensively examined by means that were not even known 50 years ago. During this time, we have learned much but of course we have asked new questions about secrets still hidden on the Moon. Some of these secrets will be revealed in the course of future exploration and robotic spacecraft missions. This book is about what we now know of the far side of the Moon, about what the current questions are, and about some possible answers.

It is a companion book to *The Lunar Orbiter Photographic Atlas of the Near Side of the Moon*, my first book (Byrne, 2005), also published by Springer in 2005. Together, these books cover the entire Moon in photographs taken by the robotic spacecraft that have done much of their work behind the Moon, out of communication with Earth for half of their orbital periods.

The photographs of the near side book were taken by a single mission of the Lunar Orbiter project, Lunar Orbiter 4 that was flown in 1967. This book is primarily composed of photographs from each of the Lunar Orbiter missions of the National Aeronautics and Space Administration (NASA) and from the Clementine mission of the Naval Research Laboratory (NRL). In addition, it contains images from the Russian Luna 3 and Zond 3, NASA's Apollo 16, and Japan's Nozomi.

The Clementine mission provided a comprehensive survey of altitude, albedo (intrinsic brightness), and multispectral data in 1994. Lunar Prospector provided gamma ray spectroscopy in 1998. The data from these spacecraft have added insight into the mineral composition of the lunar surface (supported by ground truth from analysis of lunar rocks and soil returned by Apollo and Luna missions). Clementine imagery is used extensively in this book where it is superior in topographic resolution or uniformity of coverage.

The reason for using photos from so many missions is that there has not been a single mission to systematically take pictures to show the topography of the far side of the Moon. Yet it has been possible to provide complete coverage of the far side by assembling photos from many sources.

Many years ago, I had the pleasure of working on the Lunar Orbiter project, representing the Apollo program in its search for safe and interesting landing sites. I worked for Bellcomm, a contractor to NASA headquarters. The Lunar Orbiter project was amazingly successful for the time, providing extensive new images in five out of five missions. This performance is a credit to Boeing, the prime contractor and manufacturer of the spacecraft, to Eastman Kodak, who made the camera system, and to the project management team at NASA's Langley Research Center, directed by Lee Scherer of NASA headquarters. The Langley team, who included Cliff Nelson, Israel Taback, and Norm Craybill, later managed the Viking project, which sent the first lander to Mars.

The limited scanning technology of the time resulted in artifacts in the images that distract a viewer. There are bright lines running across the mosaics between framelets and brightness variations from the spacecraft's scanner that appear as streaks within the framelets. Lunar scientists have become used to these artifacts, but they detract from the value to students and casual observers.

Since the first photos were received, I have wanted to clean up the scanning artifacts. Advances in the art of computation and the capacity of modern computers has enabled processing of the photos to remove nearly all of the scanning artifacts, resulting in clear images that are much easier to view.

Drawing on an understanding of the nature of the artifacts, I have written a software program that measures and compensates for the systematic artifacts and designed a filter that further reduces them, with minimal impact on the images of the Moon. This process is described in Appendix A.

It was with great satisfaction that, with the publication of this book, I have completed the publication of a comprehensive set of cleaned photographs from the Lunar Orbiter project. The photos are those that were selected by D. E. Bowker and J. K. Hughes for their book *Lunar Orbiter Photographic Atlas of the Moon* (Bowker, 1971). All of the far side photographs of Lunar Orbiter and the other photographs in the book are in the online extra material (extras.springer.com). Online extra material with the near side photographs was provided with my near side book.

While preparing these two books, I attended a series of yearly meetings of the Lunar and Planetary Science Conference (LPSC), sponsored by the Lunar and Planetary Institute, a NASA contractor. In the course of these meetings, where lunar and planetary scientists report on their current work, I became interested in the differences between the near and far sides of the Moon, and the attempts to explain that difference. Consequently, while preparing for this book on the far side, I took some time off to see if I could contribute to this question. It turned out that my background in communication research, specifically the art of finding signals in noise, led to a new hypothesis, with supporting quantitative evidence. I took the approach that a giant basin on the near side would be a signal, a pattern of elevation data, and that the subsequent history of bombardment of the Moon would be noise, random perturbations of the signal. Just as noise adds to a signal in communications, the principle of superposition establishes that the characteristic form of an impact adds to the form of an earlier basin, especially one of a much larger scale.

Accordingly, I modeled the elevation signal that would be produced by a giant basin, and varied the characteristics of such a basin, much like tuning a radio, until the maximum signal-to-noise ratio was found. Then the Near Side Megabasin revealed itself. This resulted in the parameters of the Near Side Megabasin that I reported to LPSC 2006 (Byrne, 2006). The method of this analysis is described in Chap. 13.

It remained to explain the crustal thickness data, which was qualitatively in agreement with the Near Side Megabasin, but in quantitative disagreement with the parameters I had first estimated (Byrne, 2006) by nearly an order of magnitude. Fortunately, I was able to contact H. Hikida and M. A. Wieczorek, who are actively studying the crustal thickness problem (Hikida, 2007), and they generously shared their new data. This reinforced the qualitative agreement with the ejecta that would be generated by the Near Side Megabasin, but also reiterated the quantitative disagreement.

The point that I had missed in 2006 was that the Moon was soft and easily deformed in the early times when the megabasins were formed. This has long been known (Lemoine, 1997) but not by me. The great weight of the ejecta on the far side would have caused it to sink, retaining its shape, but not its scale. This phenomenon is known as isostatic compensation. Given the accepted densities of the mantle and crust, isostatic compensation would cause the ejecta of the Near Side Megabasin to sink into the mantle, leaving only one-sixth of the initial depth of the deposit, accounting for the quantitative discrepancy.

The implication of the crustal thickness data is that both the cavity of the Near Side Megabasin and its ejecta would have been six times deeper at the time of its formation, before isostatic compensation, than the current topography would require.

This new modification to the Near Side Megabasin hypothesis is in quantitative agreement with all the relevant data that I have been able to review, and it answers many questions about the topography and crustal thickness of the Moon. I hope that it will be a lasting contribution to the understanding of the Moon, and that it will stimulate further questions and topics of research.

Several sources contributed to the digital imagery in this book. Lunar Orbiter photography has been archived as hard copy photographs, each about 60 cm (about 2 ft) wide, at each NASA Regional Planetary Image Facility, including one at LPI in Houston, Texas. LPI has digitized this important archival source and published the images in the Digital Lunar Orbiter Photographic Atlas of the Moon on the LPI Web site (http://www.lpi.usra.edu). Further, the LPI staff has added annotations to the photos, outlining nearly all of the named features.

A team led by Jeff Gillis carried out this important work (Gillis, 2002); Jeff was supported by Washington University at St. Louis and is currently with the University of Hawaii. LPI technical and administrative support was provided by Michael S. O'Dell, Debra Rueb, Mary Ann Hager, and James A. Cowan with assistance from Sandra Cherry, Mary Cloud, Renee Dotson, Kin Leung, Jackie Lyon, Mary Noel, Barbara Parnell, and Heather Scott. The selection of photos that were made available on the LPI Digital Archive is that selected for *Lunar Orbiter Photographic Atlas of the Moon* by Bowker and Hughes (Bowker, 1971).

NASA, NRL, the Russian space agency, and the Japan Aerospace Exploration Agency (JAXA) have made public the base data for the photos in this book. Processed images were downloaded from web sites at NRL, the United States Geological Survey (USGS), and the Jet Propulsion Laboratory (JPL). Ricardo Nunes and Phil Stookes have contributed mosaics.

Photos with annotated overlays identify the major features within each of the photos. These overlays were extracted digitally from those published by LPI, but I made additions, especially for the Clementine images, in the style established by LPI.

The names of features, both by LPI and myself, are aligned with the list approved by the International Astronomical Union (IAU), as maintained by Jennifer Blue of the USGS Astrogeology Branch. Notes with each photo point out salient aspects of the features. These notes, as well as those for my near side book, have been reviewed by Don Wilhelms, USGS retired, the author of my primary reference, who has taught me a great deal about lunar geology. The assignments of geological age to many far side features are derived from his book, which has contributions by John McClauley and Newell Trask (Wilhelms 1987). A reference that I used heavily in the preparation of this book is *The Clementine Atlas of the Moon* by Ben Bussey and Paul Spudis (Bussey, 2004). The dimensions of features (except for basins) are taken from this book, which in turn is based on the IAU catalog at USGS. Of course, I am personally responsible for any errors in this final book.

The combination of cleaned photos, labeled features, and notes are intended to serve as powerful aids to learning the geography of the Moon as well as valuable reference material.

My love and gratitude go to my wife Mary, who read and re-read the early drafts of this book and made many helpful comments.

Throughout the project of cleaning the photos and writing this book helpful suggestions and comments were made by Tammy Becker, Jeff Gillis, Mary Ann Hager, Ray Hawke, Paul Spudis, Ian Garrick-Bethell, Mark Robinson, Peter Schultz, Ewen Whitaker, and Don Wilhelms.

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The original version of this book was revised. The correction is available at https://doi.org/10.1007/978-0-387-73206-0_14