
EX LUNA, SCIENTIA

Ex Luna, Scientia

Toby R. Smith

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The current version can always be found at *http://exlunascientia.org*

This book was created using the ConTEXt typesetting package (http://www.pragma-ade.nl/) and a set of macros based on Andy Thomas' sidenote package (https://github.com/andythomas/TeX-sidenotes). Typeset in DejaVu, 10/13 pt.

Contents

1 Forward

This book started as a series of notes for a general, survey-level university class I teach on the Apollo lunar missions at the University of Washington in Seattle. While the literature covering the Apollo missions is shelf-saggingly massive, I have never found a text that covers the material I want to teach, at the appropriate level. So I wrote this book, focusing on just one aspect of the Apollo missions –the one aspect I do not think gets enough attention: the story that the *samples* collected on the surface tell us about the Moon.

The main protagonists in this story are the samples returned from the lunar surface. These fantastically complicated characters get little respect outside of the technical literature, which is unfortunate, since I believe their story is every bit as interesting, and far older, than any other story in the Apollo program. There is no way I could do justice to all of the samples collected by Apollo in so short a book, so I am only going to tell the story of *one* sample from each mission. I chose these samples to fit my story, not because they are the most important, or the most representative, or even the most well-known sample from each mission.

The fact that I am only covering one sample from each mission means that I am only going to discuss the part of each mission that directly concerns that one sample. In most cases this means that we will be looking at only a few minutes of work on the lunar surface for each mission.

The dialogue between the astronauts and Mission Control back on Earth plays an important part in this story. The dialogue of the astronauts on the lunar surface will be set off like this:

> 109:24:13 CDR: I'm going to step off the LM now.
>
> 109:24:48 CDR: That's one small step for man; one giant leap for mankind.

The time stamp in front of each line is the Mission Elapsed Time (MET), or the time since lift-off from the Earth. The speaker is identified by their role on the mission. CDR is the mission Commander, leader of the mission and first one on the surface of the Moon. LMP is the Lunar Module Pilot, the other astronaut on the surface. CMP is the Command Module Pilot, the astronaut keeping station in lunar orbit. CAPCOM is

the Capsule Communicator, an astronaut on Earth in Mission Control who is usually the only one in direct contact with the astronauts on the mission. In this example, the commander of Apollo 11, Neil Armstrong, speaks his famous lines 109 hours, 24 minutes, and 48 seconds after the lift-off of Apollo 11.

I should say a few words about the names, or rather, *numbers*, of my main characters. All of the Apollo samples were assigned a five-digit number by the Lunar Sample Preliminary Examination Team (LSPET). This number is called the *generic sample number*.

For the first four missions (Apollo 11, 12, 14, and 15), the first two digits identify the mission[1], and the final three digits identify the specific sample. For example, `12033` is sample `033` from Apollo 12.

[1] The digits 10 are used to identify the samples from Apollo 11

For Apollo 16 and 17, the initial `1` is dropped and the second digit refers to the specific location (called a station) where the sample was collected[2]. For example `72535` is sample `535` collected by Apollo 17 at collection site `2`.

[2] Actually, the last three digits of the sample number from Apollo 16 and 17 contain information about the type and size of the sample. For a complete explanation of the sample numbers, see page 10 of Heiken et al. (1991)

Sources

This book is entirely based on the work of others. I have tried my best to be complete and up-to-date in referencing all of my sources. Any omissions are unintentional and completely my fault. There are a few sources that I used extensively throughout this book. Really, without these, this book would not exist:

- Don E. Wilhelms, *To a Rocky Moon — A Geologist's History of Lunar Exploration*. [http://www.lpi.usra.edu/publications/books/rockyMoon/] This is the story of the scientific exploration of the Moon by one of the scientists deeply involved with the Apollo project. What could be better? My class on the Apollo missions is based largely on this book. Wilhelms' book is now available for free online, so there is no excuse not to read it.

- *Apollo Lunar Surface Journal*. Edited by Eric M. Jones and Ken Glover. [http://www.hq.nasa.gov/office/pao/History/alsj] This is an amazing online resource. It offers the complete documentation of the surface activities of the Apollo missions. Not only does it bring together a massive volume of the Apollo literature and images in one place, but the editors have added extensive commentary by themselves and by ten of the twelve moon-walking Apollo astronauts.

Images

I am continually astounded by the fact that nearly every image taken by the Apollo program is available in high-resolution online. I could not imagine trying to put this book together in the pre-Internet age. The main online archives I used for this book were:

- *Apollo Lunar Surface Journal* (see above). The most complete source for images taken by the astronauts on the surface of the Moon.
- *Lunar Sample Atlas*. Lunar and Planetary Institute. [http://www.lpi.usra.edu/lunar/samples/atlas/] My source for all of the images of the samples in the Lunar Receiving Laboratory.
- *USGS Geologic Atlas of the Moon*. U.S. Geological Survey. [http://www.lpi.usra.edu/resources/mapcatalog/usgs/] My source for the geological maps.
- *Lunar Reconnaissance Orbiter Camera*. Arizona State University. [http://www.lroc.asu.edu/images/index.php/] A high-resolution mapping camera currently in orbit around the Moon. This is my main source for the large-scale images of the Moon and the high-resolution images of the Apollo landing sites. The exploration of the Moon did not end with Apollo.

Toby Smith, Seattle - January 2014

2 Introduction

On Display

On September 17, 1969, the first public display of a rock returned from the Moon took place at the Smithsonian Institution in Washington, D.C. The excitement of seeing this Moon rock must have been tempered by the realization that the rock itself was an aesthetic disappointment. Nothing glowing. No colors, no shiny crystals. An official at the time described it as "Not dark or light grey, just grey grey."[3] A month later, another lunar sample went on display at the American Museum of Natural History in New York City and 42,195 people filed past it on its first day of display.[4] "It looks like a piece of something you could pick up in Central Park"[5] was a typical reaction to the rock's appearance.

[3] New York Times (1969a)

[4] New York Times (1969b)

[5] Greenhouse (1969)

Adding to the underwhelming appearance of the rock was the fact that these samples were far from the first extraterrestrial rocks that had been seen by the public. Meteorites have been falling to the Earth for the last 4.6 billion years. Both the Smithsonian and the American Museum of Natural History house world-class meteorite collections, each containing hundreds of samples from worlds much farther away than the Moon. Many of these meteorites are also far more visually striking than the lunar samples. However, those particular samples brought back to the Earth by the crew of Apollo 11 have one very important characteristic that *all* the meteorites lacked: **context**. We know *where* these rocks came from; we know their relation to a specific place on the Moon. These rocks tell a *story*. A story about a specific place on the Moon at a specific time. A story that led to a fundamental new understanding of the worlds in our solar system.

2,415 samples were returned from the Moon by six Apollo missions. This book is the story of just six of those 2,415 samples — one from each mission. The story they tell covers 4.6 billion years of history. It covers a time that is all but lost to us on the Earth, due to the ever-changing nature of the Earth's crust. Most importantly, it is a history that is shared by the worlds around us — Mercury, Venus, Earth, and Mars — and,

with some important caveats, shared by all of the worlds in our solar system.

Book Title

Seven Apollo missions were sent to land on the Moon, six landed, and one came back home safely without landing. The story of Apollo 13 is now so famous, via books and movies, that it need not be repeated here. The loss of the Apollo 13 lunar landing meant, among many other far more important things, that the best mission patch of the Apollo program did not land on the Moon (Figure 2.1). I have always considered the Apollo 13 patch the cream of the Apollo emblems for two reasons. The first reason is for what the patch *does not* say. Like the Apollo 11 patch, the Apollo 13 patch lacks the names of the three astronauts, a wonderfully ego-free gesture that illustrates that the Apollo programs were always about more than just the astronauts. Michael Collins, the Command Module Pilot of Apollo 11, put it perfectly in his book *Carrying the Fire*[6], still my favorite book written by an astronaut:

> "We wanted to keep our three names off it because we wanted the design to be representative of *everyone* who had worked toward a lunar landing, and there were thousands who could take a proprietary interest in it, and yet who would never see their names woven into the fabric of the patch."

[6] Collins (1974), p.332

Figure 2.1: The mission patch of Apollo 13 (NASA S69-60662)

The second reason for the awesomeness of the Apollo 13 patch is for what is *does* say. On the left side of the patch is the Latin phrase *Ex Luna, Scientia*, meaning "From the Moon, Knowledge." There is no better three-word summary of the scientific results of the Apollo missions.

My Goals

The story that the lunar samples tell us, is a story teased out by countless scientists in labs all over the world.[7] It is a story that is still being written over forty years after the first Moon landing. And it is a story that will continue to be revised, and possibly completely rewritten, by a generation of scientists who were not yet born during the Moon landings; new techniques continue to dig new stories out of the samples. This book will only touch on an infinitesimal fraction of the scientific work done on the Moon rocks; my main goal is that the book will give readers some small idea of how the story of the history of the Moon was put together.

[7] For a nice summary of the scientific teams involved in the initial investigation of the Apollo samples, see Chapter 1 of *Lunar Science: A Post-Apollo View* (Taylor, 1975).

I do have another goal for this work, and that is to bring a little bit of interest back to the lunar samples, at least for my students who are forced to read this book. Barely four years after the end of the Apollo mission, the luster of the Moon rocks had already dulled:

> "They were rock celebrities five years ago. People traveled hundreds of miles to see them. Politicians cozied up to be photographed beside them. Volumes were written about them. They were studied, oohed, analyzed and aahed. But as usual, Americans proved fickle ... everybody knows they're around but nobody cares.[8]"

I witness this attitude towards the Moon rocks every time I visit my favorite local museum. The Museum of Flight[9] in Seattle, Washington, has a fantastic collection of Apollo mission artifacts, including a Moon rock (Figure 2.2). The sample `12047` is a piece of volcanic basalt picked up by the Apollo 12 astronauts near the end of their mission. The sample is tucked away in a wall display near the entrance to the hall containing a life-sized model of the ascent stage of the lunar module. As I watch people walk into the room, I notice that the Moon rock display gets barely more than a very occasional, cursory glance. Since I cannot stand by the sample, carnival-barker-style, all of the time, writing this book will have to do.

Location, Location, Location

The samples collected by the six Apollo missions come from a very small subset of the total surface area of the Moon.

How the actual landing sites of the Apollo missions were selected is a very rich and colorful story full of clashing interests and egos.[10]

The Moon is big, but for a variety of reasons the area of the Moon accessible to the Apollo missions was very small. All six missions landed in the center of the near side of the Moon, all within 20 degrees of the lunar equator (Figure 2.3). Yet, as we will see, from this restricted area comes a surprisingly diverse collection of samples. While the samples themselves may be monochromatic, the story they tell is not.

[8] Sterba (1976)

Figure 2.2: Lunar sample `12047,6` on display at the Museum of Flight, Seattle, Washington [NASA S92-44066].

[9] http://www.museumofflight.org/

[10] By far the best accounts of the Apollo landing sites selection process can be found in Don Wilhelms' book *To a Rocky Moon* (Wilhelms, 1993).

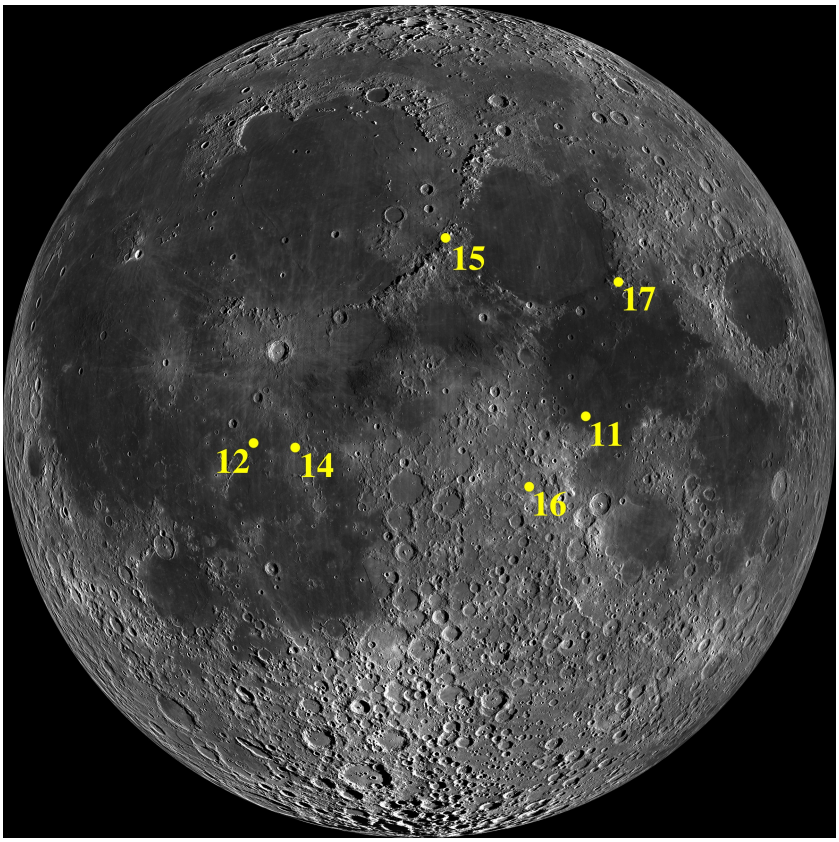

Figure 2.3: The landing sites of the six Apollo lunar missions. The base image is from the Lunar Reconnaissance Orbiter Wide Angle Camera (LROC WAC) mosaic of the lunar near side [NASA/GSFC/Arizona State University].