In our human history, we have perceived the Moon in different ways. Early astronomers saw the Moon as a sphere, the only object in the sky except the sun that was clearly not a point. Different cultures identified the patterns of light and dark in diverse ways, such as a man in the Moon and a rabbit. Now, we call the dark areas maria, comparing them to Earth’s seas. Shortly after the invention of telescopes, Galileo Galilei and others turned them to the Moon and saw that it was not a perfect sphere but was heavily cratered.

With or without instruments, we here on Earth see only the near side of the Moon: the far side is known to us only by the few astronauts who have orbited around it and the many unmanned space missions that have been sent around it. This is typical of a moon of a large planet because the gravity field of the planet dissipates any initial relative rotational moment of the moon by inducing a tidal effect. As a result, the Moon is locked so that its rotational period is equal to its 28 days period of revolution around Earth.

As spacecraft viewed the far side of the Moon, we learned that it looks very different from the near side; there is almost no pattern of dark smooth areas against lighter heavily cratered highlands. Later, manned and unmanned missions (for example, Apollo, Clementine, Chang-E, Kaguya, and Lunar Reconnaissance Orbiter) carried altimeters that defined the surface shape of the Moon.

Now we have Digital Elevation Maps (DEM)s for the topography of the whole Moon, defining its surface shape precisely. Most of the far side is covered by a bulge rising 6 km high, while the Man in the Moon area on the near side is about 2 km low and mostly level. The surface topography is only part of the description of the shape of the Moon. Tracking of spacecraft has produced a progressively refined measurement of the gravity field of the Moon that, in combination with topography, provides extensive information about the subsurface density structure, including the shape of the boundary between crust and mantle. The thickness of the crust is up to 26 km thicker on the far side than on the near side.

With the detailed DEMs, we can model the larger impact features one by one, and build a library of such features. As we near completion of the set of models, a comparison with the DEM of the measured topography reveals omissions and imperfections in the library of models, revealing new impact features and a few features that have other causes. The set of modeled features described here reduces
the differences between the comprehensive model and the measured topography to such an extent that the residual error is free of obvious features larger than about 200 km, a small fraction of the 8,696 km circumference of the Moon.

Samples returned to Earth by Apollo missions, supplemented by remote sensing instruments of increasing sophistication, give us insights into variations in composition and ages of some of the features, inferred from the ages of the soil and rocks exposed on the surface. Detailed descriptions of such mineralogy are not presented here but the results of analysis are used to support the sequence and age estimates of modeled features.

In this book, an algorithmic model of hypervelocity impact features is developed, based on extensions to the Maxwell-Z model for the ejection of material from an apparent crater. An extension permitting extrapolation of the model to impact features of arbitrarily large sizes is presented. A single algorithmic model serves for all impact features with the primary parameters being center coordinates, apparent diameter, apparent depth, and depth of level fill (if present).

In 2007, I found a major feature that is needed to explain the first-order asymmetry between the lunar near side and far side. I called it the Near Side Megabasin. This feature, similar to familiar impact basins but much larger, explains the topography and crustal thickness of the near side and (with its ejecta) the bulge on the far side. There is a long history of related proposals by J. Wood, P. Cadogan, E. Whittaker and others, but no previous explanation has stood up to quantitative comparison between theory and observations. The Near Side Megabasin was proposed on the basis of Clementine data and it fits new data from later missions, as well as new understanding of large impact basins, even better.

With the new data, the model of the Near Side Megabasin allowed derivation of an improved model of the South Pole-Aitken Basin (also an early megabasin) and the Chaplygin-Mende’shtam Basin, another previously unknown early megabasin. Next, a topographic model composed of these giant features and models of other basins and large features was constructed. Comparison of the composite model with the observed topography resulted in the discovery of several new features first reported here.

The set of modeled features are placed in time sequence by geologic period to produce a history of the Moon from when its crust first solidified until today. The larger pattern of this history follows the traditional stratigraphic periods established by Gene Shoemaker and modified by Don Wilhelms.

The lunar history in this book incorporates new observations and new understanding of giant impact features, of the era when the planets were forming. The early megabasins are proposed to have been caused by some of the last planetesimals that were completing the accretion of Earth. For each such event on the Moon, there were about 17 such impacts on Earth during the Hadean period, before the origin of life.

The lunar Late Heavy Bombardment (LHB), a period of a high rate of lunar impact events in the Nectarian, and Lower Imbrian periods, was proposed by F. Tera and others in 1974, based on the concentration of ages of Apollo samples. The lunar LHB is now understood to be directly related to a new model of the
evolution of the outer solar system, developed by astronomers at Nice, France and subsequently extended to the inner solar system. In the history of Earth, the time of the LHB occurred during the Early Archean period, shortly before or while primitive life was evolving. The extended Nice Model also identifies the probable source of most of the impacting asteroids after the LHB and the subsequent decline in size and rate of impacts.
The Moon's Near Side Megabasin and Far Side Bulge
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