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Introduction

Why Observe the Moon?

The best answer that anyone interested in lunar studies could give to the question posed by the title of this Introduction is: 'because I love doing it'. Here is the mark of the true amateur for whom this book is primarily written; this is someone who pursues a hobby or field of study for the sheer love of it, without any thought for material gain or notability. The amateur may, however, be sometimes incidentally rewarded by knowing that he has contributed to knowledge or advancement of his field of study as a result of his activities and researches.

Even if the work of the amateur does not contribute to knowledge or result in advancement of a field of study, this does not mean that he is wasting his time. There is much of individual educational value to be obtained from the pursuit of any branch of natural science; the mind is thereby broadened and deepened and first-hand study has an enlightening effect that is difficult to define and is definitely not attained from book study alone, important though this is. All this is a healthy antidote to the prevailing materialistic tenor of the times in which we live. Although much lip service is paid to the development and dignity of the individual, he is all too often overlooked in this technological age.

We live in times in which scientific pursuits, if they are not to be considered a waste of time, are expected to yield new knowledge or to answer hitherto unanswered questions. This is a pity because the pursuit of a scientific hobby, such as lunar observation and study for its own sake, has considerable aesthetic and other benefits to the individual as just mentioned. This is often overlooked in this present age of 'big science' with its characteristic unrelieved insistence on 'hard' data, results and publication output. The old-fashioned natural philosopher who did not care whether his work was published or not had a fund of true education, mental poise and inner contentment all too rarely found in the modern, often harassed, practitioners of 'big science'.

To come home after a tiring day at one's workplace and to view the silvery crescent of a three-day-old Moon on a cool clear spring evening with a small telescope is a most pleasant and relaxing exercise. If it lifts us out of ourselves and the workday world for only a few minutes it can only have a refreshing and exhilarating effect on our bodies and minds.

Even then, however much the amateur may enjoy the study of the Moon for its sake, there will nearly always come a time when desire to discover something new and to make a contribution to knowledge makes itself felt. At first sight there does not seem to be much hope for this today in amateur lunar observing; ever since the publication of the close-up photographs of the lunar surface obtained with the cameras aboard the lunar probes and Orbiter craft and the production of the USAF Moon maps, there has arisen not surprisingly the conviction among amateur astronomers that Earth-based lunar observation is no longer capable of yielding scientific data of permanent value. This is not the first time in the history of lunar studies that a major advance has, oddly, discouraged amateur lunar observers and made their efforts seem futile; there have been two others.

First, there was the publication in 1837 of Beer and Mädler's map of the Moon and their accompanying book. Mädler's reputation in astronomical circles was such that the map and the book were considered to be the last word on lunar matters and therefore made it unlikely that further telescopic study of the Moon would yield anything new. This feeling was reinforced by Mädler's assertion that the Moon was a dead and therefore unchanging world. This had a deadening effect on lunar studies for many years. Then, in 1866, J. Schmidt announced the 'disappearance' of the lunar crater Linné, which is discussed in detail in Chapter 6. This episode and the discovery of discrepancies between Beer and Mädler's map and charts drawn by later observers using larger telescopes made it appear that the Moon might not be a changeless world after all. The result was that telescopic observation of the Moon received a strong stimulus and lunar research was vigorously pursued in the ensuing years.

Second, there was the publication many years later of the photographs of the Moon's surface made with the 100-inch reflecting telescope at the Mount Wilson Observatory. It seemed pointless for observers using much smaller telescopes to attempt to contribute to knowledge of the Moon when such photographs became available, so that amateur lunar observers again felt discouraged. I experienced this feeling myself when I first became interested in the Moon as a schoolboy in England. The astronomy books of those days were illustrated with the Mount Wilson and other large observatory photographs in the sections dealing with the Moon. I quite naturally thought that studying the Moon with much smaller instruments could never be anything more than a relaxing and educational pastime. For the next several years I almost abandoned astronomy as I was engrossed with my academic studies at university for my B.Sc. & Ph.D. degrees in biology and biochemistry. One day, I came across a copy of Wilkins and Moore's book *The Moon*, then only recently published. In it I was amazed to see illustrations so refreshingly different from the lunar photographs that were repeated in every book on astronomy I had known as a boy. Here, instead, were drawings and charts of lunar formations I had hardly heard of made with much smaller telescopes as well as drawings, not just photographs, of lunar formations made with the great 33-inch refractor of the Meudon Observatory, a telescope I never even knew existed until then. Afterwards I found other books filled with drawings of lunar surface features made by amateurs working with moderate telescopes. I quickly realised that a whole world of discovery was open to anyone with even a modest telescope who chose to study the Moon. Wilkins and Moore's book brought me back to astronomy and rekindled my boyhood passion for the Moon, which has continued to this day. To these authors I am eternally grateful.

However, as is now well known, visual observers using moderate telescopes can perceive delicate lunar surface detail in moments of excellent seeing that do not appear in photographs taken with even the largest telescopes. Further, the photographs do not show every lunar feature under all possible illumination and libration conditions so that not long afterwards, amateur lunar observation got going again. Observers used the photographs to prepare accurate outlines of lunar formations on which they would insert details seen in their visual observations that were not visible in the photographs.

Nowadays, as already mentioned, many lunar enthusiasts once more feel that it is futile to pursue cartographic observation of the Moon because of the availability of the close-up photographs of the lunar surface obtained by circumlunar orbiting space craft. Professional astronomers have now turned their attention to the Moon and have constructed accurately detailed maps of almost the entire lunar surface using the close-up photographs as a basis but, as with the Mount Wilson pictures, these modern photographs still do not show every lunar feature under every possible illumination angle and libration state and no further lunar missions are planned for the foreseeable future.

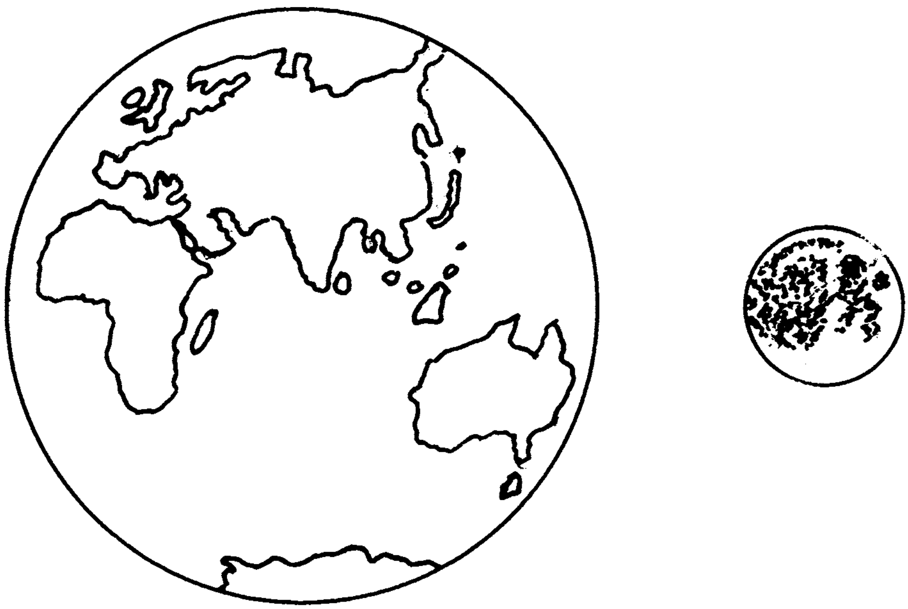
The emphasis of amateur lunar observation has now largely, but not entirely, shifted away from purely cartographic work to other areas, as described in Chapter 7. It is to be hoped that Earth-based telescopic study of the Moon will again be vigorously pursued in the coming years; there are many signs that a resurgence is already well under way.

1

Our Moon

The Moon is our Earth's nearest celestial neighbour and its only natural satellite. It is a spherical world about 2160 miles in diameter. The Earth's equatorial diameter is a little less than 8000 miles so the Moon's diameter is between one-quarter and one-third that of the Earth's (Fig 1.1). The Earth's equatorial diameter is specified here because it is somewhat greater than the diameter as measured through the poles–the polar diameter. The reason for this is that beneath the relatively thin solid crust the interior of the Earth is fluid and the Earth's axial rotation–one complete revolution taking

Fig. 1.1 Comparative sizes of the Earth and Moon



about 23 hours and 56 minutes–is fast enough to generate sufficient centrifugal force to cause a slight outward bulging at the equator. The Earth is therefore a spheroid rather than a sphere, the equatorial diameter being 7927 miles and the polar diameter 7900 miles, a difference of 27 miles.

The Moon is situated at a distance from the Earth of about a quarter of a million miles and moves around it in an approximately circular orbit. One complete circuit around the Earth takes somewhat less than one calendar month.

The Earth–Moon system

The Earth is one of a system of nine worlds, or planets as they are called, all moving in nearly circular and roughly concentric orbits around the Sun. The Sun's family of planets is called the Solar System (Fig. 1.2). The Sun itself is just one of the countless millions of stars that populate the Universe. The Earth revolves around the Sun and makes one complete revolution in its orbit in about 365¼ days (the *year* as it is called). Since the Moon revolves around the Earth the actual path of the Moon in space is like a wavy circle (Fig. 1.3). We have just mentioned that the Moon moves around the Earth. This is not quite correct; the two bodies actually revolve around their common center of gravity or center of mass to be precise. Gravity is the force that keeps planets circling around the Sun instead of wandering off into space. It is this same force that keeps the Moon in its orbit around the Earth.

Because of the great difference in the masses of the Earth and Moon (the ratios are Earth : Moon 81 : 1) the center of mass of the two bodies actually lies well within the Earth and is called the *barycenter*. It is around this that the Earth and Moon rotate. The same is true of the Earth and Sun. The Sun is enormously more massive than the Earth and the center of mass around which the two bodies revolve is well within the Sun.

For all ordinary purposes no great error is incurred if we consider the Moon as revolving around the Earth or the Earth as revolving around the Sun.

The satellites of the planets of the Solar System are all very much smaller than the planet around which each revolves. However, as a satellite our Moon is proportionally unusually large and massive when compared with the Earth although in absolute terms it is average in size when compared with some other satellites in the Solar System (Fig. 1.4). Because of this it is probably better to consider the Earth and Moon as a double planet rather than as a planet and satellite.

Lunar co-ordinates and quadrants

Before describing the Moon's surface features it will first be necessary to explain the system used to indicate directions and positions on its surface.

As seen with the naked eye, the north pole of the Moon is at the top of the disc and the south pole at the bottom. When viewed with an astronomical telescope, the Moon's image appears inverted, as does that of any object as explained in Chapter 3. Hence, all lunar maps, charts and drawings

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made before the 'Space Age' show the Moon inverted with south at the top and north at the bottom, for ease of comparison with the telescopic image. Again, as seen with the naked eye, the right hand limb of the Moon is closer to the observer's western horizon and the left hand limb is closer to the eastern horizon. Hence, ever since telescopic observation of the Moon began, the Moon being considered a purely celestial object, the 'right'

Fig. 1.2 The Solar System

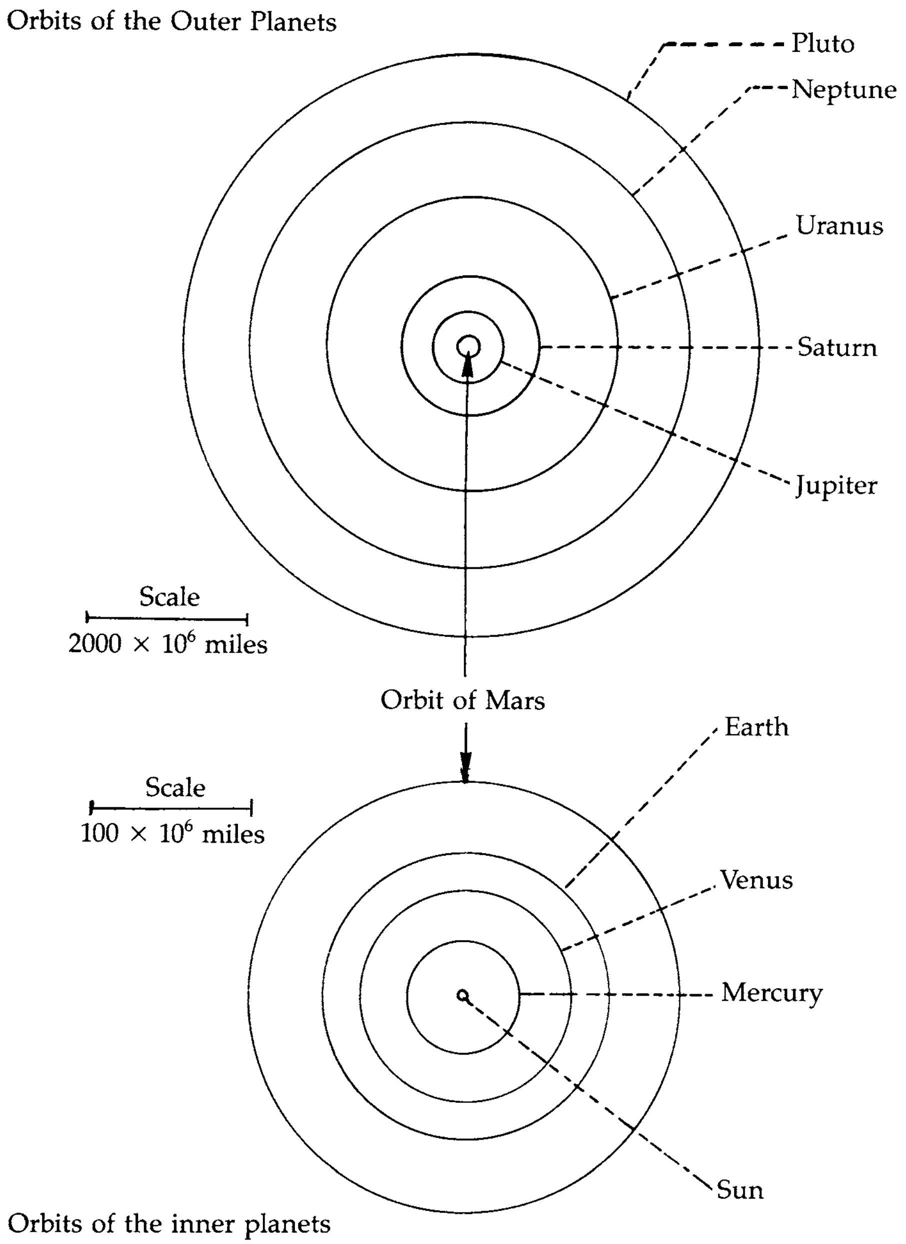


Fig. 1.3 Path of the Moon in space (not to scale)

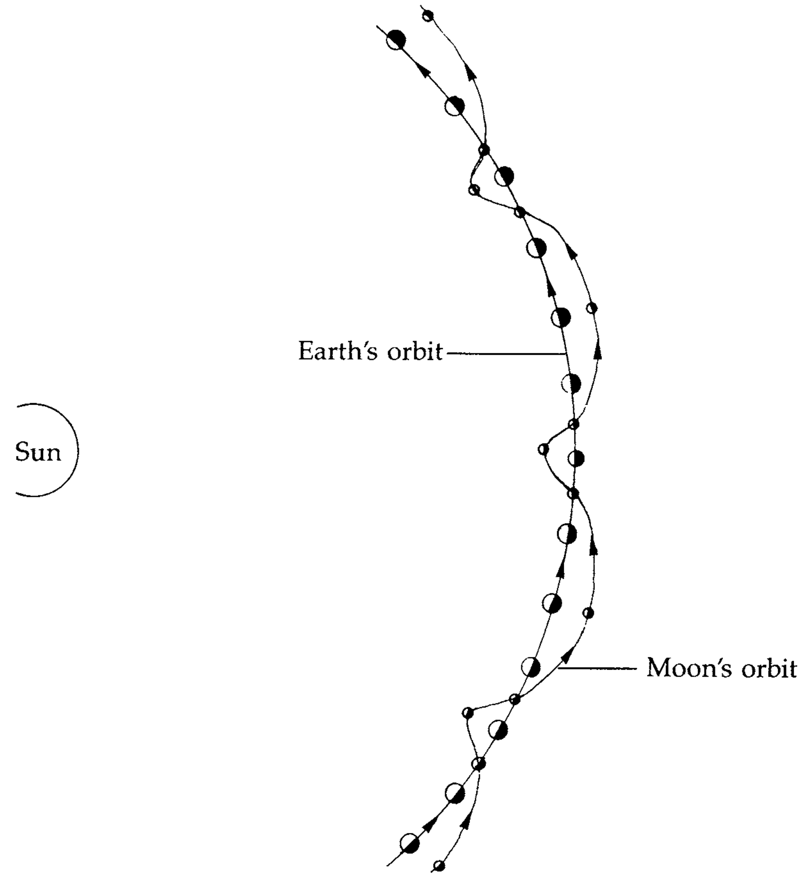
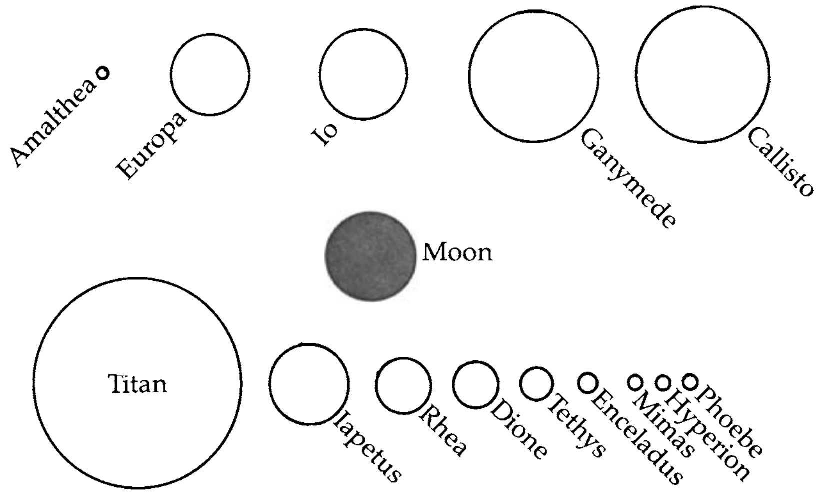


Fig. 1.4 Comparative sizes of our Moon, satellites of Jupiter (above) and satellites of Saturn (below).

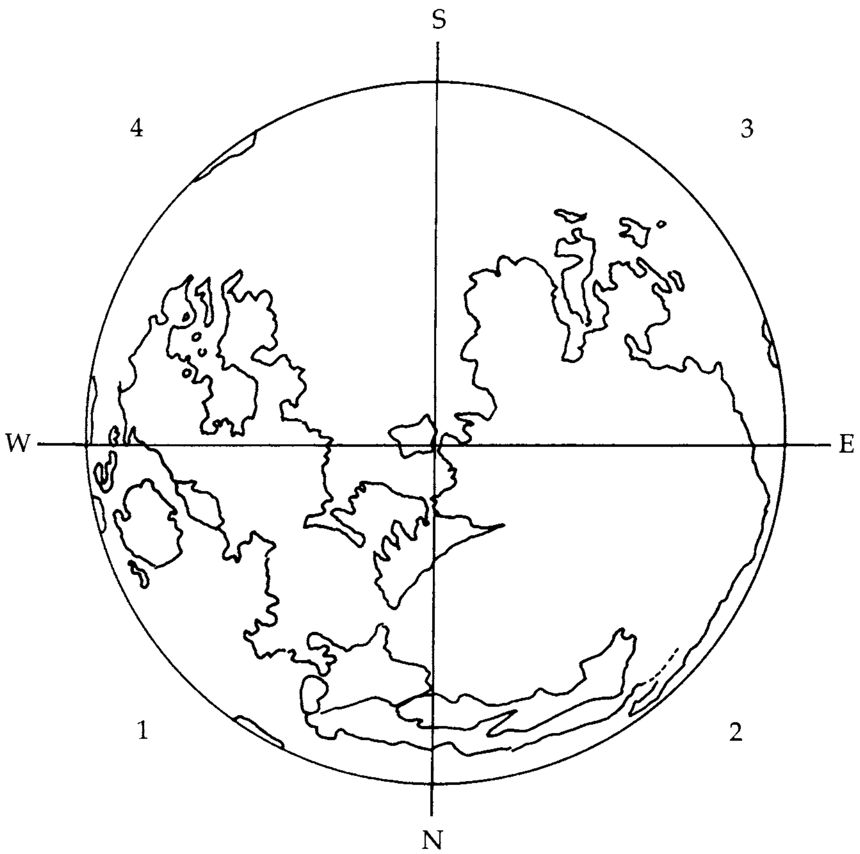


and 'left' limbs of the Moon have customarily been designated the west and east limbs, respectively. In the inverted telescopic image of the Moon the four cardinal points are therefore arranged as in Fig. 1.5. This illustration also shows the traditional division of the Moon's disc into four quadrants; beginning with the north-west quadrant they are numbered 1–4 in a counterclockwise direction.

The time-honored convention of designating the naked eye 'right' and 'left' limbs of the Moon as west and east is the reverse of the west and east directions used for the Earth so that to an observer on the Moon the Sun would rise in the west and set in the east.

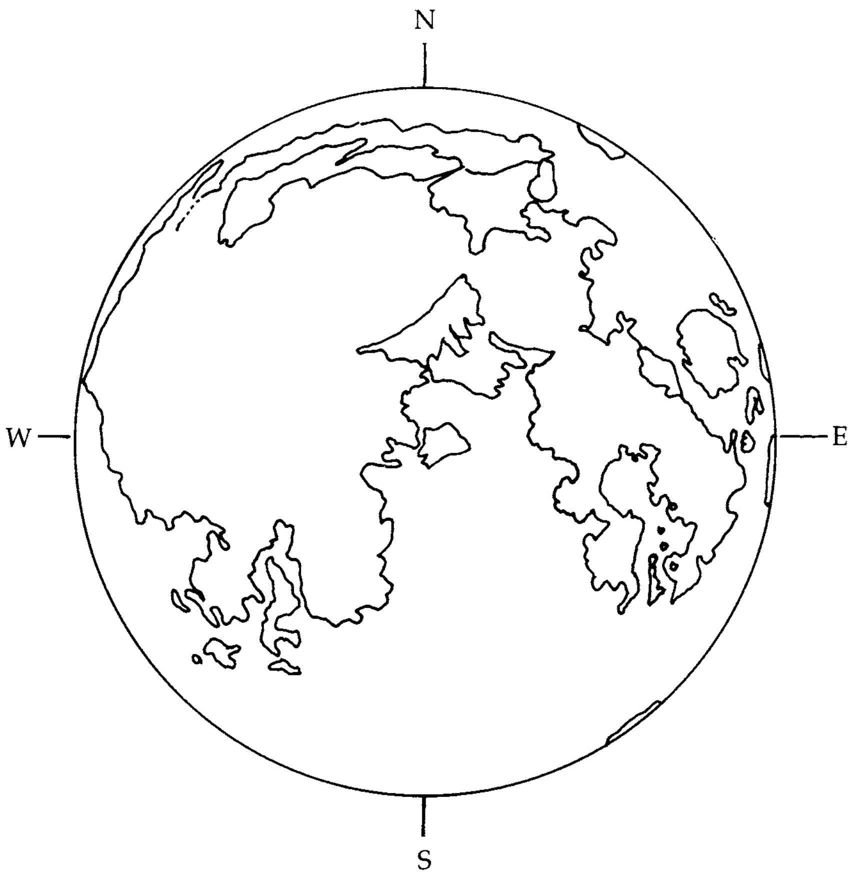
The first lunar astronauts decided that they couldn't get used to all this so the matter was debated by the International Astronomical Union (IAU). It was decided overwhelmingly to reverse the centuries-old convention of designating east and west on the Moon and this was made official in 1961. Soon afterwards, lunar maps and charts began to appear with the Moon 'right way up' with north at the top and with the east and west limbs in the same positions as they are in terrestrial maps, i.e, the reverse of what

Fig. 1.5 Lunar cardinal points (classical, with inverted telescopic image)



they were in all previous lunar literature, charts and maps (Fig. 1.6). This creates a problem for the practical lunar observer when consulting lunar literature and charts because in the vast bulk of it which is most likely to interest the observer the older (classical) cardinal points and east–west directions are used. To avoid confusion, especially that caused by reversal of the east and west directions in the IAU convention, I have decided to use the classical lunar coordinates throughout this book so that descriptions of the positions of lunar surface features, especially where the terms 'east' and 'west' are used, will be consistent with the similar usage in the literature most likely to be of interest to the practical observer. The lunar student will therefore be relieved of the necessity of constant mental switching of east and west when studying this literature as would be necessary if I had decided to use the IAU convention. Apart from anything else, the IAU system of coordinates gives rise to anomalies in nomenclature; for example, the so-called Mare Orientale (Eastern Sea) is now in the western hemisphere of the Moon!

Fig. 1.6 Lunar cardinal points (IAU convention)



The Moon's surface features

Many amateur astronomers are understandably fascinated by the Universe as a whole and delight in observing distant galaxies, nebulae, star clusters and other remote stellar objects. They either make for themselves or purchase the largest practicable telescopes and seek the darkest skies away from the light pollution of cities. There is a friendly rivalry among them as to who can 'pick up' this or that very faint or elusive hazy spot (galaxy or nebula, usually) in the sky. One of these 'deep sky' enthusiasts once facetiously remarked to me that 'the Moon is so boring, it is only a great ball of rock'. One is entitled to one's views, of course, but that mere 'ball of rock' is our nearest neighbor in space and has a special fascination of its own to many astronomers which is different from that of 'deep sky' objects. It is to these folk that this book is dedicated. In the words of Rev. T.W. Webb, 'Many a pleasant hour awaits the student in these wonderful regions'.

Until the advent of the rocket-propelled American and Russian lunar orbiting and landing vehicles and the 'Space Age', all our knowledge of the Moon's surface features was obtained entirely from Earth-based telescopic study. On July 31, 1964 the American Ranger 7 space vehicle hit the Moon's surface and destroyed itself, but during the preceding few minutes it transmitted to Earth over four thousand excellent photographs and the Moon's surface could be studied at really close range for the first time. The greatest contribution of the space program to lunar specialists interested in regional mapping was the series of five Lunar Orbiter photographic missions. These were completed in a year between August 1966 and August 1967. Orbiters I–III circled the Moon in nearly equatorial orbits so as to photograph possible landing sites for the Apollo space craft. Orbiter IV in a near-polar orbit secured pictures of the entire Earthward hemisphere and Orbiter V, also in near-polar orbit, gathered pictures of certain selected areas on the Earthward side and completed the coverage of the averted side. The total number of pictures obtained was 1950. These pictures reveal fine detail never before seen with Earth-based telescopes. As a result, it seemed that further telescopic study of the Moon from the Earth would be pointless, but there is no need for the amateur lunar observer to be discouraged, for the reasons mentioned in the Introduction.

In the following description of the Moon's surface features, frequent references will be made to the results of close-up lunar photography although our main concern will be with telescopic work in the rest of this book.

Our satellite has virtually no atmosphere and no liquid water has ever been detected on its surface so that the Moon is uninhabited and life as we know it could not exist there. Apart from the absence of oxygen implied by the absence of air the lack of an atmospheric mantle and clouds exposes the Moon's surface to extremes of temperature unknown on the Earth that virtually no known living thing could survive. The absence of atmosphere and clouds is, however, an enormous advantage for the observer of the Moon because the Moon's surface features will therefore not be obscured or rendered indistinct. In fact, the surface is always seen with startling sharpness and clarity.