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Unveiling the face of the Moon: new views and future prospects

Sarah K. Dunkin and David J. Heather

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Unveiling the face of the Moon: new views and future prospects

By Sarah K. Dunkin and David J. Heather

Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, UK

The Moon holds the key to unlocking the secrets of the origin and early evolution of the inner Solar System, and as such is the most studied planetary body outside of the Earth. At the peak of lunar exploration in the 1960s and 1970s, a vast amount of information was returned by both manned and unmanned spacecraft. Photographs, remote sensing data, even samples of lunar rocks and soil arrived on Earth for analysis. These data proved to be a treasure trove for scientists, and great advances were made in our understanding of the Moon. Despite this, the Moon remained enigmatic, and for every question answered, many more were raised.

The one thing we lacked above all else at the end of this period was a global dataset of any kind of the Moon, and it took over 20 years before new lunar missions remedied this. Data from these are now being analysed and once more we are advancing our knowledge of the Moon. These advances will continue into the new millennium with further unmanned missions designed to unravel some of the Moon's most complex problems. Looking to the future, we can envisage the Moon becoming far more than just a rocky satellite of Earth. It has the potential to become a geological laboratory, astronomical observatory, and maybe even home to the first human outpost away from the Earth. Perhaps this is science fiction at the moment, but we can be certain that without extensive manned and unmanned exploration, the Moon will withhold its secrets forever.

Keywords: Moon; exploration; Clementine; Lunar Prospector; Apollo; planetary science

1. Introduction

The Moon plays a pivotal role in planetary science. Preserved within its crust is an accessible record of the changing conditions in the inner Solar System over billions of years, a feature that is unique to the Moon as similar records have long been destroyed or obscured on the more active crusts of the inner planets. Because of this, the Moon holds the key to unlocking the secrets of the origin and evolution of the Earth and entire Solar System. As lunar scientists, the long term objective of our research is to describe the evolution of the Moon from its creation to the present day, and to be able to extrapolate to other planetary bodies where possible. This is not an easy task, and in many ways, despite its proximity to Earth, the Moon has proved to be a difficult object to analyse. For one, it reveals only one face to us (the nearside), keeping the other permanently turned away, and it was not until the advent of the space age in the 1960s that we got our first view of the lunar

Figure 1. An image looking down on the North Polar region of the Moon taken by the Galileo spacecraft in 1992. The nearside, with its smooth, dark maria, is to the left and contrasts with the heavily cratered highlands of the farside, just visible on the day–night boundary (NASA Press Release P-41483).

farside. The two faces are surprisingly different (figure 1), the nearside being the most diverse with its dark, smooth lava plains (maria) and bright mountainous areas (highlands). Centuries of telescopic observation and decades of spacecraft exploration of the Moon left us tantalizingly close to revealing some of the greatest mysteries of the early Solar System, but still our satellite refused to surrender its most precious secrets. However, recent lunar missions have sparked a period of renewed interest in the Moon. With exciting results being returned from these, a strong case for future exploration can be built, and we may at last be able to address key points that will lead us one step closer to understanding our enigmatic satellite.

2. The space age: a new era of exploration

The peak of lunar exploration, from 1959 to 1976, saw a flotilla of manned and unmanned spacecraft journey to the Moon. Although the original motives for these missions were political (with the 'space race' in full flow), a vast amount of science was also carried out as a necessity, and photographs, remote sensing data, even

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samples of lunar rocks and soil arrived on Earth for analysis. Humanity took its first steps on another world during this period, a historic event in its own right, but from a scientific perspective, the significance of putting a man on the Moon cannot be understated. Not only did the six manned landings in the Apollo programme return to Earth with over 380 kg of rock and soil samples, but without the drive to achieve those landings, the precursor unmanned reconnaissance missions (Lunar Orbiters 1–5) would never have flown, depriving us of an invaluable photographic dataset.

The data from these early missions proved to be a treasure trove for lunar scientists, and led to a drastic re-appraisal of theories relating to the origin and evolution of the Moon. Perhaps most importantly, the samples showed a stark contrast between the highland and mare rocks. Samples from the maria were found to be denser than the highlands and depleted in the trace element europium relative to other rare-earth elements, while the highland rocks exhibited a complementary europium enrichment. It was primarily these facts that provided the foundations upon which the currently favoured theory of lunar evolution is built. This theory, known as the 'magma ocean hypothesis', suggests that early in the Moon's history its upper layers were molten (Wood *et al*. 1970; Warren 1985). During this period, the lighter material, composed primarily of a mineral called plagioclase feldspar, floated to the surface, taking the europium with it, while the denser minerals, such as pyroxenes and olivines, sank (or, rather, did not float). The lighter material then solidified to form the highland crust, and the denser material, which would have remained molten for some time, later erupted as lava through fissures in the crust to form the vast maria, perhaps induced by the massive impacts which formed the circular features (basins) they now fill. While this theory, or versions of it, accounted for much of the evidence returned from the Moon, there still remained the problem of finding a mechanism for lunar origin. This topic had long been debated, and arguments refined to form three main scenarios:

(i) the fission hypothesis, in which the forming Earth threw off material to form the Moon;

(ii) the co-accretion hypothesis, with the Earth and Moon forming together from the solar nebula; and

(iii) the capture hypothesis, where the Moon formed in a separate part of the Solar System and travelled close enough to the Earth to be gravitationally captured.

It was hoped that data returned by the Apollo missions would pinpoint the correct theory, but it soon became clear that each had its problems. The capture hypothesis is physically unlikely, and the Apollo samples showed the oxygen isotopes of the Moon to exhibit the same trends seen on Earth, a strong argument for them having formed in the same part of the Solar System. This would support the fission and co-accretion models, but the Earth–Moon system does not appear to have enough angular momentum for the Earth to have flung material off in the manner required for the fission model. Co-accretion is unlikely due to the difference in volatile and iron contents between the two bodies. The strongest clue to the current theory came with estimates of the bulk composition of the Moon, which appears similar to the upper mantle of the Earth, perhaps indicating an inherent link between the two. The now widely accepted 'giant impact' hypothesis (Hartmann & Davis 1975; Cameron & Ward 1976) suggests that the Earth was impacted by a Mars-sized body very early

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in the history of the Solar System, and that the Moon formed from the debris thrown off by this impact. This would have incorporated a substantial amount of material from the Earth's mantle, although models suggest that the impacting body would comprise the majority of the Moon. However, these theories are based upon datasets with very restricted coverage of the lunar surface (the Apollo missions surveyed only equatorial regions, and samples were returned from only six selected sites), and wide variations in composition within these areas make extrapolation to the rest of the Moon impossible. In order to test the theories of lunar origin and evolution, a global compositional dataset was required, but, by 1976, interest in the Moon was waning as other Solar System bodies entered the limelight.

3. Our return to the Moon

It is sad that almost 20 years had to pass before another lunar mission flew. The authors of this review were not even born when Apollo 17, the last US mission to the Moon, returned to Earth in December 1972. In the intervening years, much work was done using the lunar samples to calibrate techniques to study the Moon remotely, particularly in the field of reflectance spectroscopy. All minerals have a unique spectral signature that can be determined by studying light reflected from their surfaces. The composition of a soil or rock can be inferred by observing the fingerprints of its constituent minerals in its reflected spectrum. Multispectral techniques refine this by making observations over several wavebands, increasing the number of minerals that can be identified and reducing ambiguity between them. The use of reflectance spectroscopy from Earth-based telescopes clearly demonstrated its potential as a powerful remote sensing device (McCord & Adams 1973), but was restricted by its poor spatial resolution and by its coverage (since the farside cannot be seen from Earth). To get the global compositional information needed to test the hypothesis of evolution and origin, a multispectral device would have to be flown on an orbiting spacecraft.

A taste of the science to come was provided by the Jupiter-bound Galileo spacecraft, when, in 1990 and 1992, it completed two lunar fly-bys and tested its multispectral cameras on the Moon. The resulting data covered seven wavebands, were of a poor spatial resolution (several kilometres per pixel) and surveyed only a portion of the lunar surface, but, despite these limitations, they were the first multispectral reflectance data of the Moon returned by a spacecraft, and they resulted in the completion of a significant amount of research (see, for example, McEwen *et al*. 1993; Pieters *et al*. 1993; McCord *et al*. 1994; Williams *et al*. 1995; Staid *et al*. 1996).

Two years later, in January 1994, the US Department of Defense launched the Clementine spacecraft, carrying a scientific payload provided by NASA, which included a multispectral camera. Its primary mission was to complete a fly-by of the near-Earth asteroid Geographos, but it would visit the Moon en route. Two months in lunar orbit saw the return of over 1 million digital images at resolutions of between 80 and 330 m pixel^{-1} (McEwen & Robinson 1997), and, although the spectral resolution was poor in comparison with Earth-based observations (with just 11 wavebands), the dataset was global. For the first time, we had a picture of the composition of the Moon as a whole, opening our eyes to large-scale processes rather than regional ones. The first global compositional maps to be constructed (e.g. iron distribution, Lucey *et al*. (1995)) showed exactly what would be expected if the Moon had been

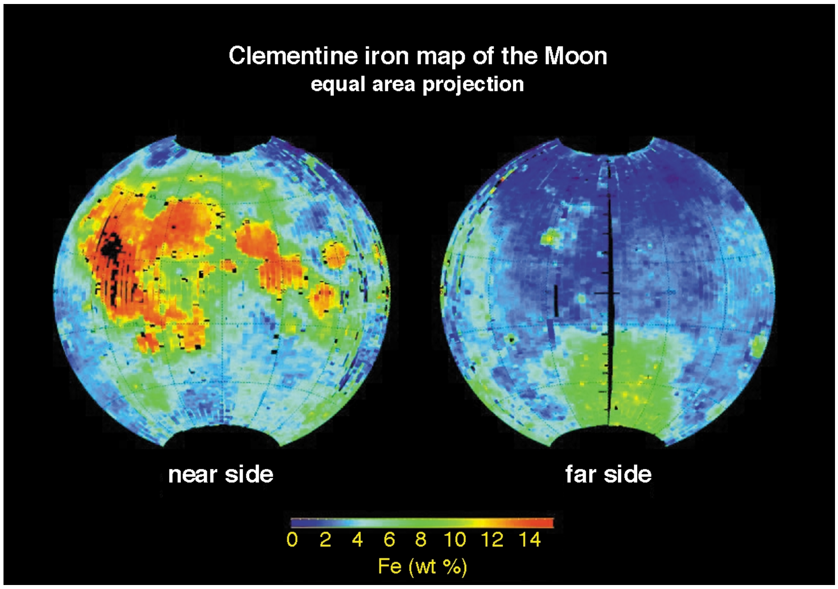

Figure 2. A map of the global iron distribution as measured by Clementine. Iron is concentrated in the maria on the nearside. The farside shows a generally low iron content, although higher concentrations are seen in the South Pole–Aitken basin (figure 3) and localized mare deposits (courtesy of the Lunar and Planetary Institute and HIGP).

molten and undergone the separation of materials suggested by the magma ocean hypothesis. Iron is more concentrated in the denser pyroxenes and olivines than in the plagioclase, so we would expect to see little iron in the lunar highlands compared with the maria, and observation now bears this out (figure 2). While this alone is not unequivocal evidence for a magma ocean having existed, it is one piece that fits the theory well. Further studies are required to complete the puzzle, and, with all of the Clementine datasets available, these are now being carried out. For example, studies of large impact craters are particularly useful as they excavate material from beneath the surface, giving direct compositional information about subsurface layers (see, for example, McCord *et al*. 1972; Pieters *et al*. 1994; Tompkins & Pieters 1999; Heather & Dunkin 1999*a*, *b*) and allowing us to probe the vertical structure of the crust (a key factor in models of crustal formation). Similarly, impact craters on maria may expose several distinct lava flows, and studies of these (Dunkin & Heather 1999) allow us to infer the volcanic history of an area. On a larger scale, this will help us address the question of the origin, evolution and distribution of mare volcanism, another vital issue in the evolution of the Moon (Head 1976).

In addition to multispectral analyses, topographic data from Clementine is helping us to study some of the oldest and most degraded impact basins on the Moon. This information has already enabled scientists to confirm the size of the huge South Pole–Aitken Basin on the farside of the Moon (figure 3). At 2500 km in diameter, it is the largest known impact structure in the Solar System and may have excavated material from the lunar mantle (Spudis *et al*. 1994). If this is the case, then compositional analyses will allow us to look deeper into the lunar interior than ever before, offering the opportunity to study the vertical structure of the crust in its entirety. However, the basin is ancient and degraded, and results to date have proven difficult to match

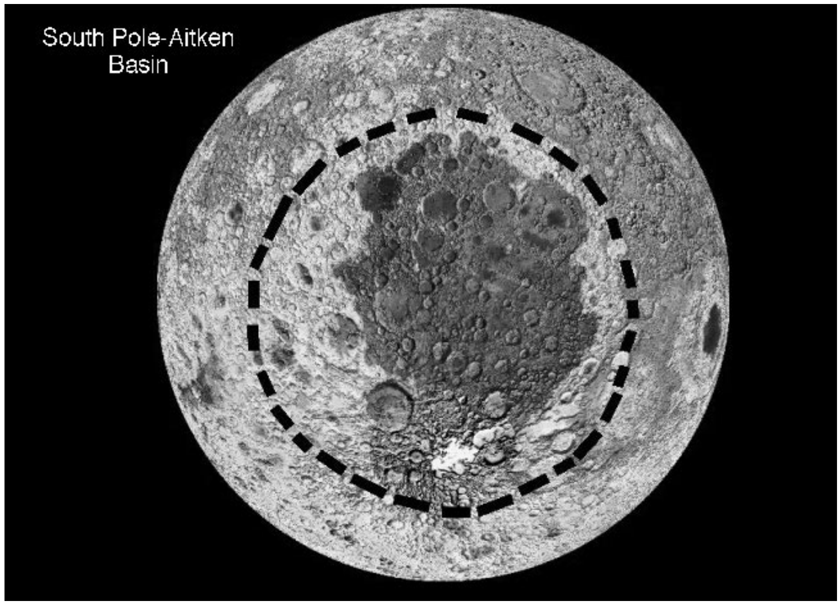

Figure 3. The South Pole–Aitken basin, measured by Clementine to be 2500 km in diameter, is the largest impact structure in the Solar System. The dotted line represents the rim of the impact basin (courtesy of the Lunar and Planetary Institute, Houston).

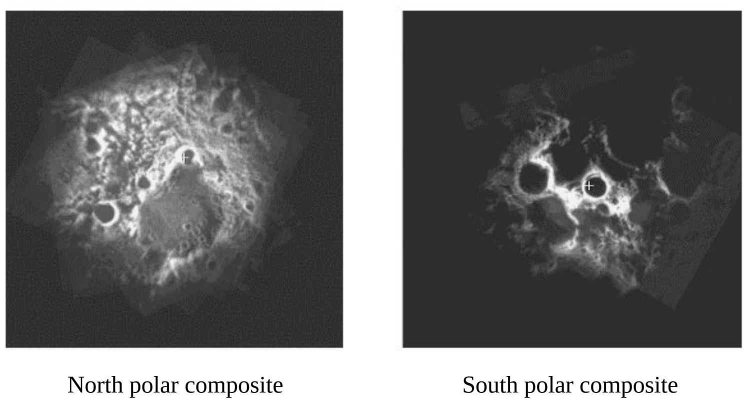

Figure 4. Composite images of the North and South Polar regions seen by Clementine, showing areas that may remain in darkness throughout the year (courtesy of the Lunar and Planetary Institute, Houston).

with existing models. Detailed analyses are required before this basin can be fully understood.

Perhaps the most exciting of all Clementine's discoveries stemmed from images of the lunar poles. The Moon has a very low inclination (1.5°) to the plane of Earth's orbit about the Sun, which means that incident solar radiation is almost horizontal at the poles. If there is a point high enough in these regions, it will be bathed in perpetual sunlight. Conversely, if there is an area deep enough (e.g. in the well of a crater), it will remain in permanent shadow and such areas would be cold enough for water ice to be stable, an incredibly exciting prospect. Clementine images revealed several areas in the South Polar region that could lie in perpetual darkness (figure 4), covering an estimated area of 30 000 km^2 (Shoemaker *et al*. 1994). Still more exciting was the news that the bistatic radar experiment from Clementine detected a signal that *may* have been due to the presence of water ice in this region (Nozette *et al*. 1994, 1996). This tantalizing hypothesis could not be proven with the instrumentation on board Clementine, but, fortunately, another mission was already in the pipeline that could shed more light on the situation.

Four years on from Clementine, in 1998, NASA launched Lunar Prospector, their first specifically targeted lunar mission since the end of the Apollo program in 1972. Prospector is classed as a 'discovery' mission; designed, built, launched and operated on as low a budget and short a time-scale as possible while maintaining an excellent standard of scientific return. It carried just five instruments with focused scientific objectives designed to complement existing datasets, providing the means to answer some of the key questions remaining in lunar science.

Prospector made observations in lunar orbit for over a year, much longer than any previous mission to the Moon. As with Clementine, observations are global, and with a polar orbit just 100 km above the lunar surface it was also the closest any orbiting spacecraft has come to the lunar surface for a sustained period. The first results from Prospector were recently published in a special edition of the journal *Science* (vol. 281, no. 5382), and these results are still being analysed in the context of how they can refine and update existing lunar models. Possibly the most important measurement is the mapping of the distribution of key elements, such as O, Si, Mg, Fe, Ti, Al and Ca, by the gamma-ray spectrometer. Together, these elements make up 98% of the mass of all lunar material (Binder 1998), so these data will help constrain models for the bulk composition of the lunar crust, a key unknown. Similarly, the distribution of material known as KREEP (so called due to its high concentrations of 'incompatible' elements such as potassium, rare-earth elements and phosphorus) is important in testing theories for lunar evolution as it may have been concentrated in the last remaining melt after the formation of the lunar crust. The gamma-ray spectrometer was specifically designed to look for the signature of KREEP, and found its distribution to be supportive of this theory, indicating that these rocks came from great depth (Lawrence *et al*. 1998). From a more visionary perspective, the global maps of elemental abundance may also be used as a resource for the location and utilization of construction materials in the future (Melendrez *et al*. 1994).

The gravity experiment on board Prospector has provided the most accurate gravity maps ever obtained for the Moon. These are helping to determine the crustal and mantle structure by looking for density anomalies. Data returned from the primary one-year mission has led to the discovery of three new anomalies, and there is a hint of four other new features on the farside (Konopliv *et al*. 1998) that could be confirmed from data returned during the six-month extended mission. Perhaps more importantly, coupled with the magnetometer, the gravity experiment has provided estimates of the size of the lunar core. Konopliv *et al*. (1998) believe it to be between 220 and 450 km in diameter, and although we have yet to confirm precisely how this affects models of lunar origin and evolution, it is certainly a critical factor to both.

Probably the best known and most provocative 'discovery' by Lunar Prospector came with confirmation of Clementine's suggestion that water-ice deposits may be present at the South Pole of the Moon; an extra twist came with the discovery of

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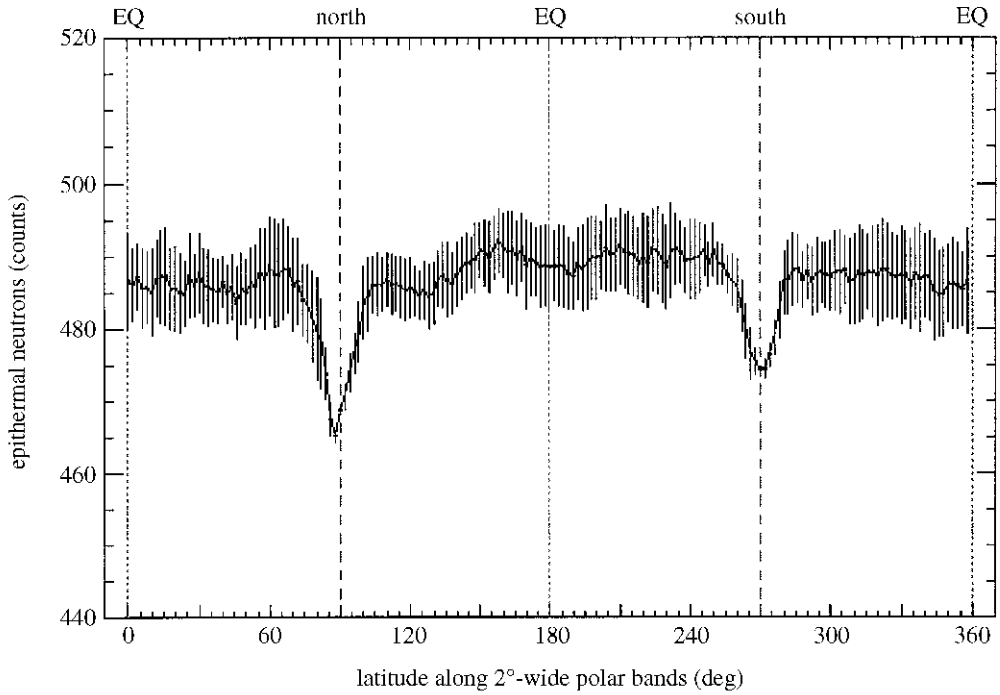

Figure 5. A plot of the epithermal neutron counts across the Moon. The decrease at the North and South Poles is indicative of the presence of large concentrations of hydrogen, perhaps in the form of water ice (courtesy of NASA Ames Research Center).

similar deposits at the North Pole (figure 5). The neutron spectrometer on Prospector is not able to detect water directly, but can locate concentrations of hydrogen, and although we know hydrogen can be locked up in many molecules, the conditions on the Moon make water-ice the most likely interpretation (Feldman *et al*. 1998). If these results *do* indicate the presence of water ice, then there could be as much as 3×10^9 t at each pole (Feldman *et al*. 1998). To put this into perspective, it is estimated that each person in London uses 55 000 l of water per year for drinking, washing, preparing food, etc. If we could take just 1% of the Moon's water, it would support 2000 such Londoners for over 500 years. Hence, if *direct* confirmation of the presence of water at the poles can be obtained, it will have huge implications for the long-term future of lunar exploration. It will certainly make the Moon more appealing for future manned missions, perhaps involving the construction of lunar bases and industrial outposts, and lunar science is a guaranteed beneficiary of all such missions.

In January 1999, Lunar Prospector embarked upon a six-month extended mission, having completed its highly successful primary objectives. The extended mission saw the craft drop to an altitude of just 40 km, where it remained for four weeks before moving closer still to just 25–30 km above the surface. Throughout this period, the five instruments continued to gather data of increasingly high resolution, and this will allow the construction of more accurate maps and for refined estimates of the concentration of hydrogen deposits at the poles to be made.

The Clementine and Prospector datasets collectively provide us with the oppor-

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tunity to unravel some of the Moon's (and Solar System's) most complex problems. However, there is still a good deal more to learn, and it is important that the recent interest in lunar science is maintained if we are to complete the puzzle. There are more missions to the Moon planned, but it is difficult to look forward more than 10 years in this climate of financial uncertainty. Even so, the following section gives one view of what the future may hold for us, including the known and the unknown; it will be interesting to come back to this paper in 30 years and see how far we have come.

4. Visions of the future

The recent results from lunar missions ensure that we will enter the new millennium with a far greater understanding of the Moon. However, as with all science, for every question answered, many more are raised and there is still much work to do if we are to fully understand the origin and evolution of our satellite and place it in context with the rest of the Solar System. Some of these questions may be addressed by upcoming missions. At the time of writing, Japan is preparing to launch its first lunar mission, called Lunar-A. Originally due for launch in mid-1999, its objectives are to fire three penetrometers into the lunar surface to monitor seismic activity over its one-year lifetime. Seismic data have not been collected from the Moon since the days of Apollo, and will provide valuable information regarding the structure of the lunar interior. Lunar-A is also the only mission currently planned with the capability of following up on Lunar Prospector's measurement of the lunar core. Europe did not go to the Moon in the 20th century, but will do so in the first years of the 21st. SMART-1 (Small Missions for Advanced Research Technology) is primarily a technology demonstration mission to the Moon, funded by the European Space Agency, but science will be carried out, including geological studies and topographic and mineralogical mapping (Foing & Racca 1998). The only other lunar mission currently in the planning stage is another Japanese venture called Selene. If funded, it will launch in 2003/2004 and is likely to consist of both an orbiter and a lander. The science to be carried out has yet to be determined, but it will certainly aim to address some of the fundamental questions that remain in lunar science.

Some of these questions will require a major, long-term effort in order to be solved and will probably require highly sophisticated unmanned craft and/or manned missions. For example, on a global scale, even though the Clementine and Prospector datasets have provided good insights into the crustal composition and topography of the Moon, a *detailed* assessment of the composition of the lunar crust will require the return of a comprehensive set of lunar rock and soil samples to Earth, representative of the Moon as a whole. The current sample collection represents less than half of the types of mare basalts known to be present on the nearside (Pieters 1978), and the farside remains completely unsampled. Another problem with the samples currently in our possession is that they were all found as debris strewn across the lunar surface via the impact process. Consequently, we have no way of ascertaining what their original surroundings would have been, and cannot construct a detailed picture of where they lie in terms of the timeline for crustal formation or volcanic history. With the orbital data now available, sites of interest can be selected that have the best chance of characterizing a particular area in composition and/or age, and these should be carefully explored, taking samples of rock from their natural

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surroundings. A good example of where such analyses would have been useful is the Apollo 15 landing site. The lunar module touched down near a volcanic feature called a sinuous rille, believed to have been created by the action of turbulent lava flows. The rille in this area (Hadley Rille) clearly showed layering of the rocks within the walls. If samples could have been taken from within these layers, we would have been able to determine the relationship between the layers in age and composition, something we have yet to achieve anywhere on the Moon. Knowledge of an accurate timeline for the events during which these and other features were formed would give us a clear insight into the most active periods in the Moon's history, both internally (e.g. volcanic activity) and externally (e.g. impact cratering events).

The method by which an increased sample database could or should be collected is a contentious issue. While samples could be returned by unmanned craft, the limitations inherent to this technique would strongly compromise the overall science return. The sharp contrast in the quantity, quality and diversity of the science returned from the manned Apollo missions, compared with that of unmanned sample-return programmes, is a powerful indication of the merits of manned spaceflight. This point is underlined by the three unmanned sample-return missions to the Moon in the 1970s, whose combined return of 300 g of lunar soil amounts to less than 0.1% of the total sample collection currently in our possession. In addition, because the craft were unable to rove around the surface, the samples could not be selectively chosen and had to be taken from directly under the craft. While it is true that technology has come a long way, and the hugely successful Pathfinder mission to Mars with its Sojourner rover (Golombek *et al*. 1997) has proven that unmanned missions need not be restricted to the spot where the mother craft landed, it is impossible to question the superior ability of a human being to make on-the-spot decisions, choosing specific samples based on years of training or experience that simply could not be programmed into a rover or unmanned craft. In spite of the advances made in rover technology, humans are also more manoeuvrable over rough terrain and can survey a much greater area. No machine now or in the immediate future has or will have the capability to observe, assess, select and preliminarily analyse rocks and samples to the degree that humans can. The arguments against sending humans into space are primarily economic, political and moral. Unmanned craft are substantially less expensive to send into space and do not require life support systems. Also there is very little room for error in a manned mission, and it is infinitely preferable for a machine to 'die' than a human on a mission to the Moon. These are strictly non-scientific arguments, however, and are best debated elsewhere. From a purely scientific viewpoint, manned spaceflight to the Moon is unquestionably the way forward in the new millennium.

Should manned lunar missions resume (and we certainly hope they do), the eventual goal would be to establish a base large enough to house several astronauts for extended periods of time, from weeks to months (analogous to the International Space Station in Earth orbit). From such a base, geological field excursions could take place, with samples analysed on the Moon itself, giving the opportunity for more interesting finds to be collected in a short space of time. Lunar science would not be the only beneficiary of such a base. Biological experiments could be carried out on plants, animals and humans over extended periods in reduced gravity conditions. Astronomy would benefit hugely from placing telescopes on the Moon; it is stable with a negligible atmosphere and has nights lasting approximately 14 days. Shielded

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from the Earth, the farside of the Moon is the only radio-quiet area in the inner Solar System, providing the perfect platform for radio astronomy. There would be many benefits to having a base on the Moon, not least to gain the experience of building and operating it in preparation for future manned missions, perhaps to Mars (for excellent reviews of lunar bases and their potential uses, see Mendell (1985, 1992)). Although the work would be difficult, the construction of a lunar base is probably not too far beyond our technological capabilities even now, and we are already gaining experience in constructing objects in space through the International Space Station project. A base is perhaps the next 'giant leap' in our exploration of the Moon, but the huge cost of transporting the materials required from Earth is one of the primary factors currently preventing this from happening. Before we can seriously consider manned exploration of the Moon in terms of bases occupied for periods of weeks or longer, we need cheap, easy and regular access to space. Hopefully, this can be achieved in the first decade or two of the new millennium, and we can then start to explore the Moon in greater depth and in more ways than ever before. Only then will we be able to piece together the complex puzzle that will provide a comprehensive view of our natural satellite.

5. Summary

Our understanding of the Moon has come a long way since the start of the space age. The data returned from spacecraft during the peak of lunar exploration (1959–1976) revolutionized our thinking about the origin and evolution of our satellite, and gave insights into the conditions prevailing in the inner Solar System at the very early stages of its existence. Despite the great advances in our knowledge of the Moon at that time, many gaps remained, and it took almost 20 years before these started to be filled by the Clementine and Lunar Prospector missions in 1994 and 1998. At the moment, the Moon is once again in the spotlight, with three more missions planned to launch over the next five to six years.

With its proximity to Earth, the Moon lends itself well to detailed study in a manner unparalleled by any other extraterrestrial body. This has already been proven with the quantity and diversity of data we have accumulated, and of course the samples of soil and rock we possess. In the future, however, a concerted effort must be made to resume sampling of the lunar surface, using manned or unmanned craft. Only then can we start to fill the gaps in our knowledge that prevent us from gaining a full understanding of the Moon.

In time, lunar bases should be established, both for the study of the Moon and for use by other sciences. This *can* be achieved, but to make the project economically viable we first need cheap access to space. Once we have this, the number of potential uses for a base would be enormous. In the short term, the scientific study of the Moon would certainly benefit from such a base, as could astronomy, biology and many other sciences. In the long term, the resources identified by recent lunar missions could be used to construct further bases (figure 6), and the water ice at the poles used for a variety of purposes such as life support and a supply for rocket fuel. In short, if a permanently manned base can be established, the Moon has the potential to become many things: a base for geological study; a platform for astronomy; a laboratory to study the long-term effects of reduced gravity on humans; a test bed for future manned missions to Mars; or even a launch pad for unmanned craft on their way

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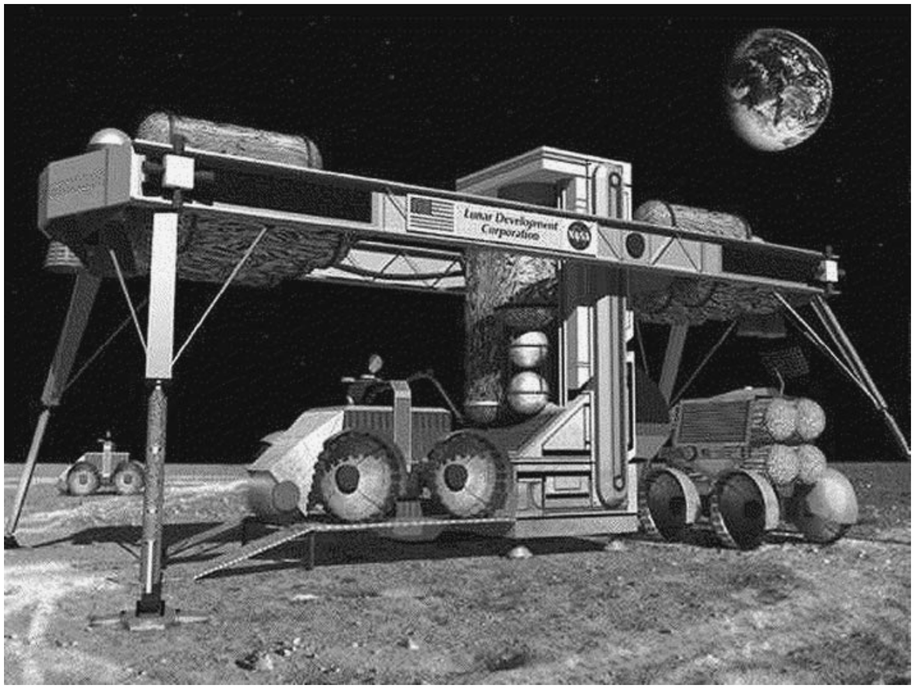

Figure 6. An artist's impression of the future on the Moon showing a processing plant extracting lunar resources. Although science fiction at the moment, it may become reality, and lunar science would benefit greatly from a manned presence on the Moon (courtesy of NASA Johnson Space Center).

to the outer reaches of the Solar System. Science fiction? Perhaps, at the moment, but current scientific investigations and growing public interest in the Moon could be setting us well on the way to it becoming reality.

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PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

AUTHOR PROFILES

S. K. Dunkin

Sarah Dunkin was born in South London, and became fascinated with astronomy and the Moon at a very early age. She studied astronomy at University College London and obtained a first class honours degree in astrophysics in 1994. Staying at UCL, she completed her PhD three years later, studying the spectroscopic properties of Vega-like stars and the dust around them. Her current post is that of PPARC Postdoctoral Research Fellow based at UCL studying planetary science, particularly the Moon. Sarah is 26, and especially enjoys communicating science to the younger generation and to the general public. Her hopes are that everyone will have the opportunity of travelling to the Moon, perhaps not in her lifetime, but in the not too distant future.

D. J. Heather

David Heather is also 26 years old, currently completing his PhD research in the Planetary Geology group at University College London, using Clementine data to analyse fresh impact craters on the lunar surface. He obtained his Bachelor's degree in astronomy from the University of Hertfordshire in 1995. David is very keen to advance the communication of science to the general public at all levels, from the enthusiastic amateur to the young 'scientists to be'. In this capacity, he has written and taught several courses in astronomy for evening classes and school groups. By making science accessible to the public, especially to the younger generation, David hopes he will be encouraging some of those who will one day explore the surfaces of the planets to follow their dreams.

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