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

Preface

G. M. Brown, G. Eglinton, S. K. Runcorn and H. C. Urey

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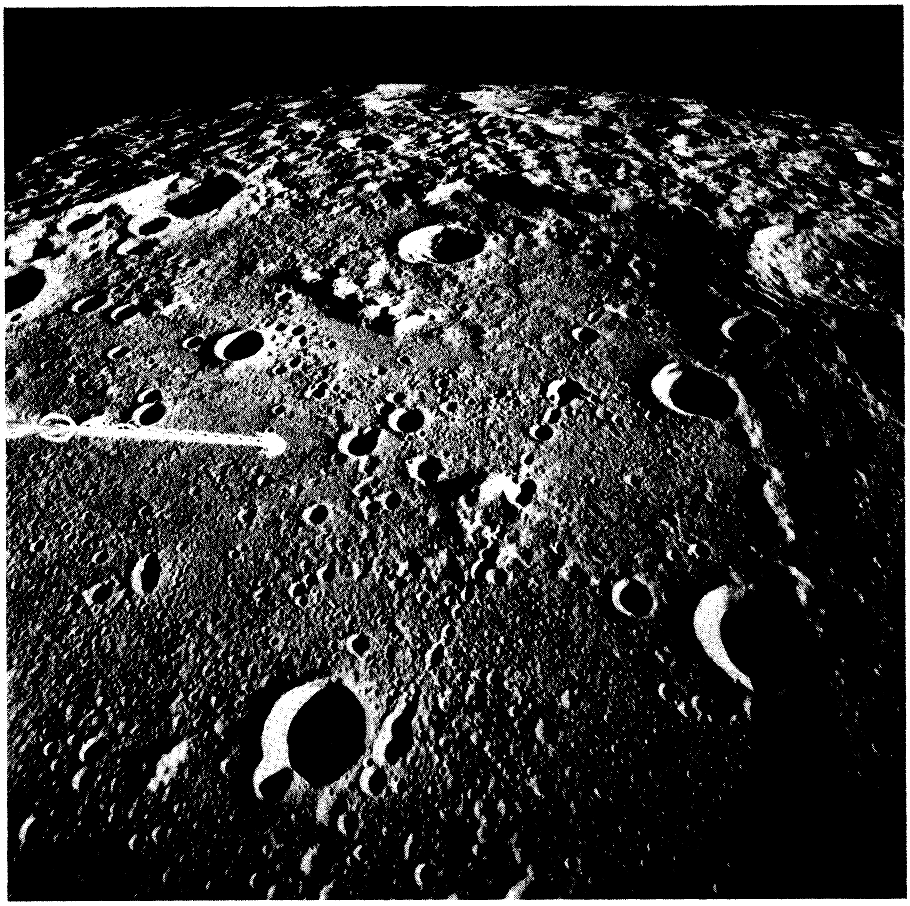
PREFACE

This volume presents papers delivered during the Royal Society discussion meeting held on 9–12 June 1975 under the auspices of the British National Committee on Space Research. The meeting was organized to present the findings of European and Commonwealth scientists who had participated in the analyses of lunar samples, both as principal and co-investigators in the Apollo lunar sample analysis programme and as analysts of the Luna samples provided by the U.S.S.R. Academy of Sciences under arrangements with national academies. Scientists from the U.S.A. and the U.S.S.R. were also invited to participate and so the meeting became sufficiently representative and its timing appropriate for the much needed attempt to review the whole of the work on lunar samples and the results of related space experiments. It was the purpose of the meeting, and of the Proceedings, to show how the new knowledge about the Moon, acquired over the recent decade from the intensive study made possible by the space technology developed in the U.S.A. and the U.S.S.R., had solved some and thrown light on other fundamental questions about the Moon. For practical reasons the meeting was over-weighted in favour of British and European contributions; but this gave an opportunity for these laboratories to express their appreciation to N.A.S.A. and to the U.S.S.R Academy of Sciences for the opportunity to participate in a unique scientific programme. We hope that the publication will perform a service in bringing before scientists, and indeed the public in general, the remarkable increase in our understanding of the Moon which has resulted from the space programme and will show how international collaboration has been such an important feature of it.

At some risk of mistaking majority opinion for scientific truth, we would like to summarize the main advances. In the past many geologists underestimated the role of meteoritic impacts in the fashioning of the lunar surface. A small minority of the craters may be volcanic but diagnostic evidence to decide in a particular case whether a crater is endogenic is not available. Craters of all sizes from those with diameters of hundreds of kilometres down to microscopic ones are impact-produced. We know now that the Moon is covered by a thick regolith which records this incessant bombardment. Micrometeorite impacts stir the regolith and constantly expose soil particles to solar and galactic fluxes. The surfaces of grains become saturated with solar wind elements; the interiors contain myriads of radiation damage tracks left by solar flare cosmic rays. The large craters are the result of impacts on a scale with which we are totally unfamiliar on Earth. Indeed it has been the overwhelming dominance of impacts over the geological processes with which we are familiar on the Earth which has made it possible to learn so much about the overall chemical composition of the Moon from the relatively few landings. We now know that lunar chemistry differs significantly from that of meteorites and of the Earth in the relative paucity of the volatile, chalcophile and siderophile elements; this finding is clearly telling us something fundamental about the origin of the Moon. From classical studies the lunar surface was thought to be very ancient but the space programme has made this qualitative idea quantitative and a most remarkably complete series of dates for the major events in the Moon's history is now available. Petrologists have clarified the nature of the dark mare surfaces; they are of lava from the interior of the Moon but were formed by partial melting in a closed system – unlike terrestrial lavas – and the true interpretation of this is not yet clear. The composition of the highlands is that of a material which is more aluminium-rich than the interior of the Moon. Extensive early melting and differentiation of much of the Moon



Above: Photograph of a boulder sampling station 6 at the Apollo 17 site; South Massif looms at the horizon.

Below: Apollo 16 metric photograph (2365) of the Mendeleev basin on the lunar far side. This view shows the southwest interior of the 300 km wide feature. A straight crater chain pointing toward the crater Tsiolkovsky lies on its floor.

took place but the exact events, and particularly the source of the heat, are matters on which we are ignorant.

The physics of the Moon has yielded major surprises, such as lunar magnetism, mascons and moonquakes. The positive gravitational anomalies over the circular mare show that the lunar lithosphere is more rigid and thicker than that of the Earth: the circular mare were evidently impact basins which filled with lava to depths greater than that required for isostatic equilibrium. Although the Moon possesses no magnetic field today, the remanent magnetization of the returned samples seems best interpreted on the hypothesis that it possessed one early in its history: the presence of an iron-rich core in the Moon, capable of sustaining dynamo action in the past, is much debated. The moonquakes, though many orders of magnitude less in energy than earthquakes and clearly not associated with terrestrial-like plate tectonics, nevertheless give us a hint that the Moon's interior is not entirely 'dead', so that endogenic phenomena such as gas emissions, volcanism and convection in the interior, though controversial aspects of lunar studies, merit sober investigation. It is clear that the Moon is a much more fascinating object than it seemed even 10 years ago when the Royal Society last organized a lunar meeting (*Proc. R. Soc. Lond.* A **296**, 243 (1967). The processes on its surface and in its interior remain a fascinating contrast with the Earth providing a challenge to geophysical and geological imaginations. For example, the Moon emerges as a valuable recorder of solar system history with much of the record awaiting decipherment.

The origin of the Moon remains an enigma: this may seem remarkable in view of the great increase of our knowledge, particularly regarding events and evolution in the first 10^9 years when there exists no comparable knowledge of the Earth. The present rate of retreat of the Moon from the Earth determined from astronomical data and resulting from tidal friction, seems unlikely to have changed dramatically over the last 500 million years. A theory of the lunar origin in which the Moon is close to the Earth at an early stage is therefore attractive. Historically this is why the fission mechanism was suggested by G. H. Darwin. But the mechanics of this process is unclear particularly the angular momentum requirements: nor are the chemical differences between the Moon and Earth satisfactorily explained. The alternative of capture of the Moon requires an exceedingly improbable event, a theory which could not account for the satellites of other planets without additional assumptions such as gaseous planetary nebula. A third group of theories involve the condensation of material orbiting in the vicinity of the Earth during or after its accretion. But again, the chemical differences of the two bodies, especially in the abundance of iron are not explained. In the subject of the origin of the Moon there seems at present too many ad hoc suppositions and even miraculous coincidences: a sure sign that some key information or idea eludes us.

We wish to thank the staff of the Royal Society, particularly Mr P. Wigley and Miss P. M. F. Green, and Mrs E. Marshall of the School of Physics, Newcastle upon Tyne, for the major part they played in the organization of the meeeting and of its publication. It is also a pleasure to record our appreciation of the enthusiasm of those who attended, some from great distances and at a busy time, which made this meeting unique in the annals of the Royal Society.

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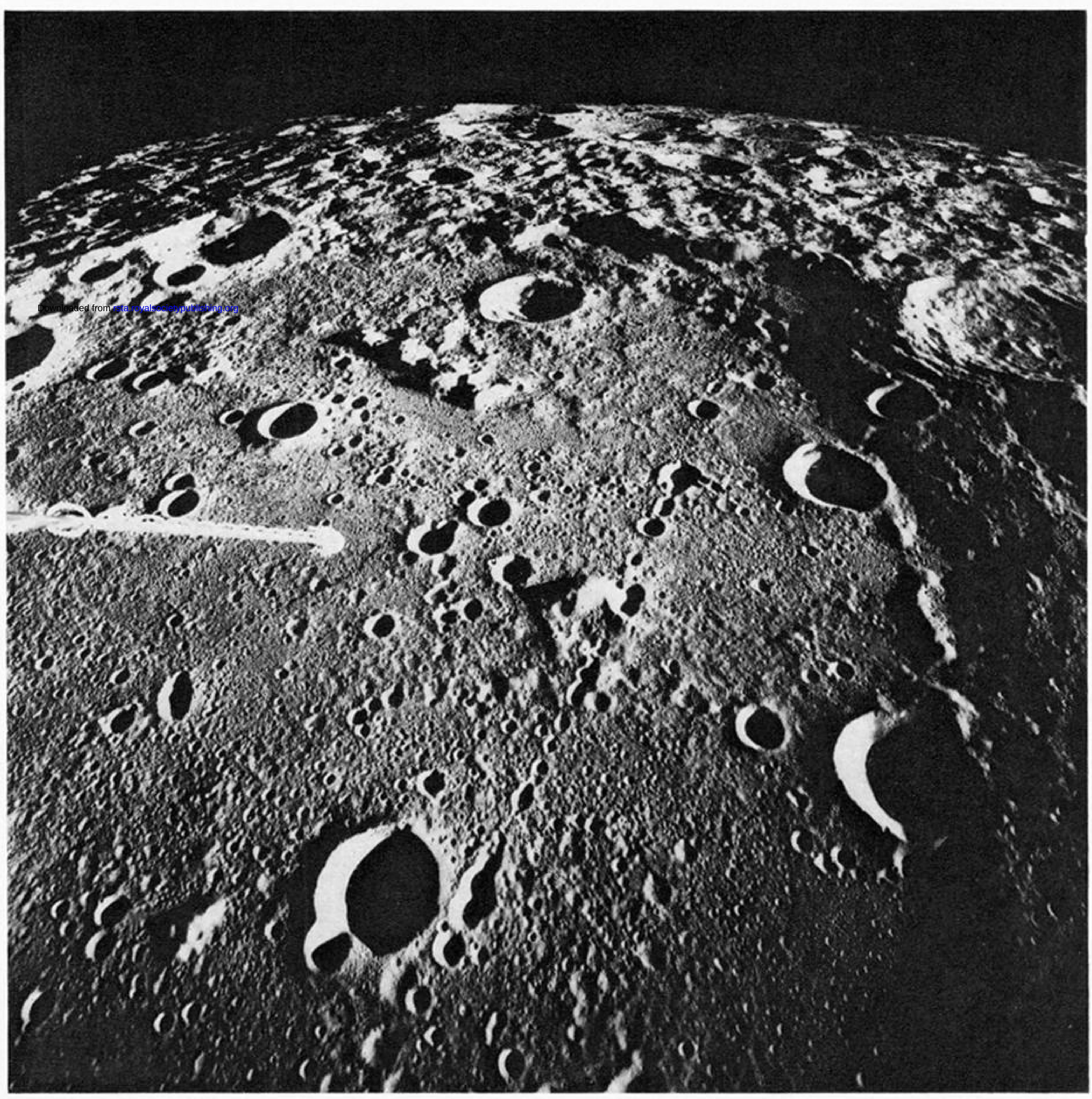

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