BIBLIOGRAPHY

Edited by Z. Kopal, M. D. Moutsoulas, and J. W. Salisbury

1. Motion of the Moon in Space and Dynamics of the Earth-Moon System; Lunar Astronautics

Dasenbrock, R. R.: 1972, 'Some Higher Order Analyses of Earth and Lunar Orbiters', NASA-CR-126635.

The accurate modelling of the translational behaviour of a drag-free satellite in an almost circular near-Earth orbit is investigated. All short and long period position fluctuations in the satellite's coordinates down to 1 m are determined. The general zonal and tesseral harmonic effects are considered as well as lunar and solar effects. A noncanonical approach is followed. A mean orbital plane is chosen so that no short period out-of-plane fluctuations greater than second order occur. Short period radial and cross-track fluctuations and in-track fluctuations are computed. Long period and secular rates of the mean elements which define the slowly varying plane of reference are determined to third order in the small quantities. The equations of motion are integrated analytically away from critical inclination and tesseral resonance. The resonant situation of a Sun-synchronous orbit is discussed as a special case. The long-period behaviour of a lunar orbiter is also considered, including the effects due to the inclination of the Earth's apparent orbit about the Moon and those described by Cassini laws on the equations of motion. Both resonant and nonresonant low orbits, and high orbits are discussed.

Fisher, D.: 1972, 'Analytical Short Period Lunar and Solar Perturbations of Artificial Satellites', NASA-TM-X-65869.

A short period luni-solar theory was generalized for application to arbitrary obliquity of the ecliptic and inclination of the Moon's orbit to the ecliptic. Analytic first order lunar perturbations to the elements were derived. The theory is illustrated by an application to the communication satellite Intelsat 3F3.

Green W. G. and Matthys, V. J.: 'Lunar Targeting Study: Lunar and Planetary Ephemeris Tapes', NASA-CR-123595

The Univac 1108 computer tape data formats are documented for the ephemeris tape generated by the Jet Propulsion Laboratory and the ephemeris tape used by the Quick Response Targeting Program (QRTP). Ephemeris tapes are used as the data source for the position and velocity components of those celestial bodies being considered in an integrated trajectory simulation program. The QRTP ephemeris tape has data only for lunar mission simulations. The JPL ephemeris tape has data for the Moon and the nine planets. The ephemeris tapes, the data formats, the coordinate systems, and units are defined. The transformation from the mean-of-1950 coordinate system to the nearest mean Besselian year is given.

Hartung, A. D.: 1972, 'Lunar Ephemeris and Selenographic Coordinates of the Earth and Sun for 1971 and 1972', NASA-SP-3057.

Ephemeris data are presented for each month of 1971 and 1972 to provide a time history of lunar

The Moon **6** (1973) 212–228. *All Rights Reserved*

coordinates and related geometric information. A NASA Manned Spacecraft Center modification of the Jet Propulsion Laboratory ephemeris tape was used to calculate and plot coordinates of the Earth, Moon, and Sun. The ephemeris is referenced to the mean vernal equinox at the nearest beginning of a Besselian year. Therefore, the reference equinox changes from one year to the next between 30 June and 1 July. The apparent discontinuity in the data is not noticeable in the graphical presentation, but can be observed in the digital output. The mean equator program used to compute and plot the ephemeris data is described.

Hartung, A. D.: 1972, 'Lunar Ephemeris and Selenographic Coordinates of the Earth and Sun for 1975 1973 and 1974', NASA-SP-3058.

Similar to the preceding reference, ephemeris-data for each month of 1973 and 1974.

Hartung, A. D.: 1972, 'Lunar Ephemeris and Selenographic Coordinates of the Earth and Sun for and 1976', NASA-SP-3059.

Similar to the preceding reference, ephemeris-data for each month of 1975 and 1976

3. Shape and Gravitational Field of the Moon

Bell, C. C.: 'Gravity Gradient Study', NASA-CR-123489.

The results of the noise and drift test, and the comparison of the experimental simulation tests with the theoretical predictions, confirm that the rotating gravity gradiometer is capable of extracting information about mascon distributions from lunar orbit, and that the sensitivity of the sensor is adequate for lunar orbital selenodesy. The experimental work also verified analytical and computer models for the directional and time response of the sensor.

Sjogren, W. L., Gottlieb, P., Muller, P. M., and Wollenhaupt, W. R.: 'S-Band Transponder Experiment', in '*Apollo 15 Preliminary Scientific Report*', NASA-SP-289.

The experiment which derives data from three lunar-orbiting objects, the command-service module (CSM), the lunar module (LM), and the subsatellite in the S-band is described. Each provides detailed information on the near-side lunar gravitational field. The primary emphasis is on the low-altitude (20 km) CSM data. The LM data cover a very short time span and are somewhat redundant with the CSM data. The resolution of the high-altitude (100 km) CSM data is not as great as that of the low altitude data. The low-altitude CSM and LM data coverage and the complementary coverage obtained during the Apollo 14 mission are presented. The experiment uses the same technique of gravity determination employed on the Lunar Orbiter, in the data of which the large anomalies called mascons were first observed. The data consist of variations in the spacecraft speed as measured by the Earth-based radio tracking system.

4. Internal Structure of the Moon.

Anderson, D. L. and Kovach, R. L.: 'The Lunar Interior', NASA-CR-125813.

The compressional velocities are estimated for materials in the lunar interior and compared with lunar seismic results. The lower crust has velocities appropriate for basalts or anorthosites. The high velocities associated with the uppermost mantle imply high densities and a change in composition to a lighter assemblage at depths of the order of 120 km. Calcium and aluminum are probably important components of the upper mantle and are deficient in the lower mantle. Much of the Moon may have accreted from material similar in composition to eucrites. The important mineral of the upper

mantle is garnet; possible accessory minerals are kyanite, spinel, and rutile. If the seismic results stand up, the high velocity layer in the Moon is more likely to be a high pressure form of anorthosite than eclogite, pyroxenite, or dunite. The thickness of the layer is of the order of 50 km. Cosmic abundances can be maintained if the lower mantle is ferromagnesium silicate with minimal amounts of calcium and aluminum. Achondrites such as eucrites and howardites have more of the required characteristics of the lunar interior than carbonaceous chondrites. A density inversion in the Moon is a strong possibility.

Latham, G. V., Ewing, M., Press, F., Sutton, G., Dorman, J., Nakamura, Y., Toksöz, N., Lammlein, D., and Duennebier, F.: 'Passive Seismic Experiment', in *Apollo 15 Preliminary Scientific Report*, NASA-SP-289.

The establishment of a network of seismic stations on the lunar surface as a result of equipment installed by Apollo 12, 14 and 15 flights is described. Four major discoveries obtained by analyzing seismic data from the network are discussed. The use of the system to detect vibrations of the lunar surface and the use of the data to determine the internal structure, physical state, and tectonic activity of the Moon are examined.

5. Thermal and Stress History of the Moon.

Comstock, G. M., Fvwaraye, A. O., Fleischer, R. L., and Hart, H. R.: 'Investigations of Lunar Materials', NASA-CR-115470.

The investigations were directed at determining the radiation history and surface chronology of lunar materials using the etched particle track technique. The major lunar materials studied are the igneous rocks and double core from Apollo 12, the breccia and soil samples from Apollo 14, and the core samples from Luna 16. In the course of this work two new and potentially important observations were made: (1) Cosmic ray-induced spallation-recoil tracks were identified. The density of such tracks, when compared with the density of tracks induced by a known flux of accelerator protons, yields the time of exposure of a sample within the top meter or two of Moon's surface. (2) Natural, fine scale plastic deformation was found to have fragmented pre-existing charged particle tracks, allowing the dating of the mechanical event causing the deformation.

French, B. M.: 'Shock-Metamorphic Effects in the Luna-16 Soil Sample from Mare Fecunditatis' NASA-TM-X-65805.

The results of intensive studies indicate that shock-metamorphic effects, characteristic of meteorite impact and virtually identical to those observed in Apollo samples, are common in fragments of the Luna-16 soil sample from Mare Fecunditatis. Two types of shock effects are present: (1) deformation and partial melting features in rock and mineral fragments (1-2% of fragments): and (2) heterogeneous glasses and glassy breccias produced by shock melting (70–80% of fragments). Shock effects were observed in pyroxene (deformation twin lamellae, multiple planar shock lamellae, extreme mosaicism, partial isotropization); in plagioclase (planar shock lamellae, complete isotropization to form maskelynite); and in basalt fragments (plagioclase isotropization, selective partial melting). The glasses exhibit several characteristics of shock melting, especially: (1) diversity in chemical composition; (2) association with shock mineral fragments and Ni-Fe spherules; and (3) heterogeneous schlieren and incipient fusion of mineral inclusions. Two types of source rocks are present in the Luna-16 sample; basaltic (85–90%) and feldspathic (10–15%). The basaltic rocks are predominant and generally occur as unshocked fragments, indicating that they form the bedrock underlying Mare Fecunditatis.

Hanks, T. C. and Anderson, D. L.: 1972, 'Origin, Evolution and Present Thermal State of the Moon', NASA-CR-126558.

The relative absence of lunar volcanism in the last 3 b.y. and the Apollo 15 heat flow measurement suggest that present-day temperatures in the Moon are approximately steady state to depths of 100 km. An exponential distribution of heat sources with depth is scaled by equating the surface heat flow to the integrated heat production of this exterior shell. Presumed present-day interior temperatures and the present-day surface heat flow of 30 ergs cm^{-2} s^{-1} are obtained. The estimated homogeneous concentrations of U, the chemistry of the lunar surface material and inferences to modest depth, and the short accretion time of the Moon necessary to provide large-scale differentation at 4.6 AE suggest that the Moon had its origin in the rapid accretion of compounds first condensing from the protoplanetary nebula. The present thermal state of the Moon may involve at least some partial melting through all the lunar interior deeper than 200 km. Such a thermal configuration is inconsistent neither with temperatures inferred from electrical conductivity studies nor with the nonhydrostatic shape of the Moon.

Walker, D., Longhi, J., and Hays, J. F.: 1972, 'Experimental Petrology and Origin of Fra Mauro Rocks and Soil', NASA-CR-126656.

Melting experiments over the pressure range 0 to 20 kbar were conducted on Apollo 14 igneous rocks 14310 and 14072 and on comprehensive fines 14259. The mineralogy and textures of rocks 14310 and 14072 are presumed to be the result of near-surface crystallization. The chemical compositions of the samples show special relationships to multipy-saturated liquids in the system: anorthite-forsterite-fayalite-silica at low pressure. Partial melting of a lunar crust consisting largely of plagioclase, low calcium pyroxene, and olivine, followed by crystal fractionation at the lunar surface is proposed as a mechanism for the production of the igneous rocks and soil glasses sampled by Apollo 14.

6. Chemical Composition of the Moon.

Adler, I., Trombka, J., Gerard, J., Schmadebeck, R., Lowman, P., Blodget, H., Yin, L., Eller, E., Lamothe, R., Gorenstein, P. *et al.*: 'The Apollo 15X-Ray Fluorescence Experiment', NASA-TM-X-65834.

The CSM spectrometric data on the lunar surface with respect to its chemical composition are presented for Al, Mg, and Si as Al/Si and Mg/Si ratios for the various features overflown by the spacecraft. The lunar surface measurements involved observations of the intensity and characteristic energy distribution of the secondary or fluorescent X-rays produced by the interaction of solar X-rays with the lunar surface. The results showed that the highlands and maria are chemically different, with the highlands having considerably more Al and less Mg than the maria. The mare-highland contact is quite sharp and puts a limit on the amount of horizontal transport of material. The X-ray data suggest that the dominant rock type of the lunar highlands is a plagioclase-rich pyroxene bearing rock, probably anorthositic gabbro or feldspathic basalt. Thus the Moon appears to have a widespread differentiated crust (the highlands) systematically richer in Al and lower in Mg than the maria. This crust is pre-mare and may represent the first major internal differentiation of the Moon.

Hislop, J. S. and Williams, D. R.: 'Use of Non-Destructive Gamma Activation for the Analysis of Rock and Biological Materials', AERE-R-6910.

High energy (35 to 40 MeV) gamma photon activation and high resolution gamma ray spectrometry were used for the intact analysis of the standard rock materials W-1, G-1 and BCR-1, and Apollo 12 returned samples 12022 and 12065, and the reference biological material kale. Simultaneous irradiation of appropriate synthetic standards containing thirty-nine elements showed that the technique is particularly valuable for the determination of iron, calcium, titanium, strontium, zirconium, cesium, antimony, thallium, arsenic, rubidium, lead, mercury and nickel. Provided chemical separations are carried out, sensitivities of 0.02 to 5 μ gm may be achieved.

O'Donnell, P. M.: 'Reactivity of Simulated Lunar Material with Fluorine', NASA-TM-X-2533.

Simulated lunar surface material was caused to react with fluorine to determine the feasibility of producing oxygen by this method. The maximum total fluorine pressure used was 53.3 kb per square meter (400 torr) at temperatures up to 523 K (250 °C). Postreaction analysis of both the gas and solid phases indicated that the reaction is feasible but that the efficiency is only about 4 % of that predicted by theory.

Baedecker, P. A., Schaudy, R., Elzie, J. L., Kimberlin, J., and Wasson, J. T.: 1972, 'Trace Element Studies of Rocks and Soils from Oceanus Procellarum and Mare Tranquillitatis', NASA-CR-115570.

Neutron activation data on Zn, Ga, Ge, Cd, In and Ir are reported for six rocks and two soils from the Apollo 12 mission. Comparison of these and similar data for Apollo 11 samples indicated extralunar components in the 12070 and 10084 soils of about 1.0 and 1.1 % expressed in terms of an assumed composition which is the same as the water-free portion of Cl chondrites. A relationship between the integrated flux of extralunar material and the increase in concentration of such material in the fines of the lunar regolith is derived. Apollo 12 rocks have concentrations of Zn, Ge, Cd, In and possibly Ir which are lower by factors of 60 or more, relative to terrestrial basalts. A mechanism is proposed for the late accretion of volatile-rich materials, including comets, in which a primitive terrestrial atmosphere is invoked to explain the significantly higher concentrations of such substances on the Earth.

Estep, P. A., Kovach, J. J., Waldstein, P., and Karr, C. Jr.: 1972, 'Infrared and Raman Spectroscopic Studies of Structural Variations in Minerals from Apollo 11, 12, 14 and 15 Samples; Volume 3. Final Report', NASA-CR-115581.

Infrared and Raman vibrational spectroscopic data, yielding direct information on molecular structure, were obtained for single grains (150 μ) of minerals, basalts, and glasses isolated from Apollo 11, 12, 14 and 15 rock and dust samples, and for grains in Apollo 14 polished butt samples. From the vibrational data, specification substitutions were determined for the predominant silicate minerals of plagioclase, pyroxene, and olivine. Unique spectral variations for grains of K-feldspar, orthopyroxene, pyroxenoid, and ilmenite were observed to exceed the ranges of terrestrial samples, and these variations may be correlatable with formation histories. Alpha-quartz was isolated as pure single grains, in granitic grains composited with sanidine, and in unique grains that were intimately mixed with varying amounts of glass. Accessory minerals of chromite and ulvospinel were isolated as pure grains and structurally characterized from their distinctive infrared spectra. Fundamental vibrations of the SiO_4 tetrahedra in silicate minerals were used to classify bulk compositions in dust sieved fractions basalt grains and glass particles, and to compare modal characteristics for maria, highland and rille samples. No hydrated minerals were found in any of the samples studied, indicating anhydrous formation conditions.

Laul, J. C., Wakita, H., Showalter, D. L., Boynton, W. V., and Schmitt, R. A.: 1971, 'Bulk, Rare Earth and Other Trace Elements in Apollo 14 and 15 and Luna 16 Samples', NASA-CR-127075.

The chemical abundances were measured by instrumental and radiochemical neutron activation analysis in a variety of lunar specimens. Apollo 14 soils are characterized by siginificant enrichments of AL_2O_3, Na_2O and depletions of TiO_2, FeO, MnO and Cr_2O_3 relative to Apollo 11 and to most of Apollo 12 soils. The uniform abundances in 14320 core tube soils and three other Apollo 14 soils indicate that the regolith is uniform to at least 22 cm depth and within approximately 200 m from the lunar module. Two Luna 16 breccias are similar in composition to Luna 16 soils. Four Apollo 15 soils (LM, STA 4, 9, and 9a) have variable compositions. Interelement correlations between MnO-FeO, Sc-FeO, V-Cr_2O_3 and K_2O-Hf negate the hypothesis that howardite achondrites may be primitive lunar matter, argue against the fission hypothesis for the origin of the Moon, and precludes any selective large scale volatilization of alkalies during lunar magmatic events.

Philpotts, J. A., Schnetzler, C. C., Nava, D. F., Bottino, M. L., Fullagar, P. D., Thomas, H. H., Schuhmann, S., and Kouns, C. W.: 'Apollo 14: Some Geochemical Aspects', NASA-TM-X-65877.

Chemical analyses were obtained for five samples of Apollo 14 regolith fines, three 14230 core samples, soil clod 14049, breccias 14305 and 14319, 14310 basalt, and some separated phases. The chemical uniformity of these Apollo 14 samples indicated thorough mixing and/or uniform source rocks. Basalt 14310 can be matched well in composition by a four to one mixture of soil and plagioclase. The Eu(2+)/Eu(3+) ratios calculated for 14310 pigeonite and plagioclase are similar to those for Apollo 12 and 15 mare-type basalt phases; this indicates similar redox conditions. Apollo 14 samples are chemically similar to Apollo 12 and 15 KREEP as distinct from Apollo 11, 12, and 15 and Luna 16 mare-type basalts.

Wachi, F. M., Gilmartin, D. E., Oro, J., and Updegrove, W. S.: 1971, 'Differential Thermal Analysis and Gas Release Studies of Apollo 11 Samples, December 1969–January 1970', Aerospace Corp., AD-736428.

The liquidus-solidus behaviour of Apollo 11 lunar fines and the evolution characteristics of CO, N_2, He, Ne, and Ar were investigated by use of the combined techniques of high-vacuum differential thermal analysis (DTA) and mass spectrometry between 100 and 1500 °C. The DTA thermogram has shown that the lunar fines undergo partial melting over a broad range of temperature from about 915 to 1300 °C, with a significant initial melting of glassy and crystalline components within the fines at about 1140 °C. The thermal evolution curves for the noble gases have indicated that these gases come from several sources, the principal sources being the solar wind, radiogenic decay reactions and spallation processes.

7. Lunar Exosphere

Brownlee, D. E.: 1971, 'A Search for Interplanetary Dust', Ph. D. Thesis, University of Washington, Seattle.

Experiments conducted for collecting interplanetary particulate matter in the micron size range included four in the stratosphere using high altitude balloons, three in the mesosphere with sounding rockets, two in Earth orbit using manned satellites, and one on the lunar surface as a result of the return of the Surveyor 3 TV camera by Apollo 12. The satellite and lunar experiments set reliable upper limits on the flux of micron-sized micrometeoroids. The lunar experiment established an upper limit to the flux of micrometeoroids larger than 2 × 10 to the minus 11th g of 0.000075 part. m^{-2} s^{-1}/ (2 π sterad). The impact rate of secondary micrometeoroids on the lunar surface is roughly 1000 times the flux of extralunar particles. The balloon experiments allowed placing limits on the maximum amount of extraterrestrial particulates in the stratosphere; very few particles were collected but two are thought to be extraterrestrial. Techniques were also developed to enable fast, accurate location of small hypervelocity craters on surfaces exposed in space.

Classen, J.: 1970, 'Gase auf der Mondoberflaeche? (Gases on the Surface of the Moon?)' *Sternwarte Pulsnitz* publ-8 (In German).

The transient phenomena observed occasionally on the Moon can be most easily explained by luminescent gases which sometimes emanate from the interior of the Moon. Frequently, the lunar transient events have decided colours. Some gases and vapours are investigated which, when luminescing, show similar colours as the lunar transient events.

Clay, D. R., Goldstein, B. E., Neugebauer, M., and Snyder, C. W.: 'Solar Wind Spectrometer Experiment, in *Apollo 15 Preliminary Scientific Report*, NASA-SP-289.

With the deployment of the Apollo 15 lunar surface experiments package, two identical solar-wind spectrometers (SWS), separated by approximately 1100 km, are now on the lunar surface. The spectrometers provide the first opportunity to measure the properties of the solar plasma simultaneously at two locations a fixed distance apart. It is hoped that these simultaneous observations will yield new information about the plasma and its interaction with the Moon and the geomagnetic field. At the time of preparation of this report, magnetic tapes of only 20 hr of simultaneous data had been received. These data are discussed.

Gross, F. C. and Park, J. J.: 'Analysis of Surveyor 3 Television Cable after Residence on the Moon', NASA-TN-D-6599.

The Apollo 12 astronauts brought the Surveyor 3 television camera back from the Moon in November 1969. Chemical analyses of a portion of television cable revealed changes in the glass fabric sleeve and in the wire insulation as a result of exposure to the lunar environment. Loss of volatile constituents from the glass fabric and a discoloration of the glass occurred. The Teflon layer on the wire showed a slight discoloration and possibly a slight change in its infrared spectrum. Both the polyimide layer and the Teflon layer of the wire insulation showed changes in tensile strength and elongation.

Meng, C.-I. and Mihalov, J. D.: 1972, 'On the Diamagnetic Effect of the Plasma Sheet near 60 R_E', *J. Geophys. Res.* **77**, 4661–4669.

The two-dimensional (*YZ* plane) spatial distribution of magnetic field magnitudes in the geomagnetic tail at the lunar distance is given in both the solar magnetospheric and the neutral-sheet coordinate systems by using 3 yr of data from the Ames magnetometer on Explorer 35. The effect of changes in geomagnetic activity is also presented. In the magnetotail near 60 R_E a broad region in which the magnetic field intensity is relatively weak in comparison with that in the other region of the tail is located adjacent to the solar magnetospheric equatorial plane and the calculated neutral sheet. This depression of the field due to the diamagnetic effect of the plasma sheet is more evident during times of minimum geomagnetic activity ($K_p \leqslant 1+$). Plasma energy densities of 200–300 Ev cm^{-3} in the plasma sheet are inferred by interpreting the field magnitude decrease as the effect of plasma diamagnetism.

Smith, R. E.: 1971, 'Space and Planetary Environment Criteria Guidelines for Use in Space Vehicle Development; 1971 Revision', NASA-TM-X-64627.

A consolidation of natural environment data is presented for use as design criteria guidelines in space and planetary exploration vehicle development programs. In addition to information in the disciplinary areas of aeronomy, radiation, geomagnetism, astrodynamic constants, and meteoroids for the Earth's environment about 90 km, interplanetary space, and the planetary environments, the upper atmosphere model currently recommended for use at MSFC is discussed in detail.

Torney, F. L. and Dobrott, J. R.: 1972, 'Lunar Mass Spectrometer Test Program', NASA-CR-126772.

The procedures are described along with results obtained in a test program conducted to demonstrate the performance of a candidate lunar mass spectrometer. The instrument was designed to sample and measure gases believed to exist in the lunar atmosphere at the surface. The subject instrument consists of a cold cathode ion source, a small quadrupole mass analyzer and an off-axis electron multiplier ion counting detector. The major program emphasis was placed on demonstrating instrument resolution, sensitivity and S/N ratio over the mass range 0–150 amu and over a partial pressure range from 10 to the -9th power to <10 to the -13th power torr. Ultrahigh vacuum tests were conducted and the minimum detectable partial pressure for neon, argon, krypton and xenon was successfully determined for the spectrometer using isotopes of these gases. With the exception of neon, the minimum detectable partial pressure is approximately 4×10 to the -14th power torr for the above gases.

8. Lunar Coordinates and Mapping of the Moon.

Sweet, H. J.: 'An Investigation to Improve Selenodetic Control through Surface and Orbital Lunar Photography', NASA-CR-125613.

The use of lunar surface photography to achieve the photogrammetric transfer of available selenographic coordinates from future lunar landing sites to neighboring, photoidentifiable features was investigated. It can be implied from the procedures developed that overhead photography, were it available, could be utilized and would provide a material strengthening of the total solution. By the methodic selection of features and confirmation that they can in reality be identified from orbital photography, a modest selenodetic control system can be expanded into a net that could ultimately control all future, manned or unmanned, orbital photographic missions.

9. Morphology of the Lunar Surface.

Gurshteyn, A. A., Shingarava, K. B., Konopikhin, A. A., and Shashkina, V. P.: 'The Luna 17 Automatic Station on Mare Imbrium', (transl. into English from *Priroda*, No. 11, pp. 2–4), NASA-TT-F-14176.

The area of Mare Imbrium explored by Lunokhod 1 and the Luna 17 lunar probe is described in general terms.

Pronin, A. A., Popova, Z. V., and Povich, V. D.: 'Morphology of Small Craters in the Lunar Maria', (transl. into English from *Priroda*, No. 11), NASA-TT-F-14177.

A crater classification system is presented, and the concept of the impact explosion origin of small craters is discussed and confirmed.

Pronin, A. A. and Popovich, V. D.: 'Statistics on Small Craters from Lunokhod 1 Data', (transl. into English from *Priroda*, No. 11, pp. 6–7), NASA-TT-F-14178.

The utility is demonstrated of using statistical analysis of crater distribution on lunar maria to determine their relative ages.

Zezin, R. B. and Dubin, P. A.: 'Statistical Analysis of Rock Distribution from Lunokhod 1 Data', (transl. into English from *Priroda*, No. 11, pp. 9–11), NASA-TT-F-14180.

Statistical analysis of rock distribution on the lunar surface is discussed. It can be used to establish the direction taken by erosion processes and provide a basis for determining the relative age of different sections of the lunar surface.

10. Origin and Stratigraphy of Lunar Formations.

Bazilevskiy, A. T. and Polosuhkin, V. P.: 1972, 'Exogenetic Processes on the Surface of Lunar Maria' (transl. into English from *Priroda*, No. 11, pp. 13–15), NASA-TT-F-14182.

The manner in which the structure of the surfaces of lunar maria has evolved is discussed, and a four-layer model is presented.

Oberbeck, V. R.: 'Simultaneous Impact and Lunar Craters', NASA-TM-X-62141.

The existence of large terrestrial impact crater doublets and crater doublets that have been inferred to be impact craters on Mars suggests that simultaneous impact of two or more bodies can occur at nearly the same point on planetary surfaces. An experimental study of simultaneous impact of two projectiles near one another shows that doublet craters with ridges perpendicular to the bilateral axis of symmetry result when separation between impact points relative to individual crater diameter is large. When separation is progressively less, elliptical craters with central ridges and peaks, and circular craters with deep round bottoms are produced. These craters are similar in structure to many of the large lunaı craters. Results suggest that the simultaneous impact of meteoroids near one another may be an important mechanism for the production of central peaks in large lunar craters.

11. Physical Stucture of the Lunar Surface.

Carrier, W. D. and Heiken, G.: 'Lunar Surface Closeup Stereoscopic Photography at Fra Mauro (Apollo 14 Site)', NASA-TM-X-58072.

A total of 17½ stereopairs of lunar surface rocks and soil was taken on the Apollo 14 mission. The close-up stereopair photographs are presented with a preliminary interpretation for those interested in lunar soil formation, impact phenomena, and soil mechanics.

Gold, T.: 'Study and Interpretation of Lunar Close-up Stereo Photography', NASA-CR-115500.

The lunar close-up stereoscopic camera was used successfully on Apollo 11, 12 and 14 flights. It functioned without any technical faults and was judged convenient to use by all three crews. It recorded a variety of surface textuıes in the lunar soil, both disturbed and undisturbed, a number of rock surfaces in the undisturbed condition, and a number of surface samples of materials brought to the Moon whose interaction with the lunar soil was to be tested. A resolution of approximately 80 μ was aimed for in the design of the camera and was indeed obtained on all pictures. Stereoscopy played a major part in interpreting surface textures and small scale structure.

Gold, T., O'Leary, B. T., and Campbell, M.: 1971, 'Some Physical Properties of Apollo 12 Lunar Samples', NASA-CR-115585, pp. 2–24.

The size distribution of the lunar fines is measured, and small but significant differences are found between the Apollo 11 and 12 samples as well as among the Apollo 12 core samples. The observed differences in grain size distribution in the core samples are related to surface transportation processes, and the importance of a sedimentation process versus meteoritic impact gardening of the mare grounds is discussed. The optical and the radio fıequency electrical properties are measured and are also found to differ only slightly from Apollo 11 results.

Haystack Observatory: 'Semiannual Report, July 1–December 31, 1971', NASA-CR-115454.

Radio astıonomy programs comprise three very-long-baseline interferometer projects, ten spectral line investigations, one continuum mapping in the 0.8 cm region, and one monitoring of variable sources. A low-noise mixer was used in mappıng observations of 3C273 at 31 GHz and in detecting of a new methyl alcohol line at 36,169 MHz in Sgr B2. The new Mark 2 VLBI recording terminal was used in galactic H20 source observations using Haystack and the Crimean Observatory, U.S.S.R. One feature in W29 appears to have a diameter of 0.3 ms of arc and a brightness temperature of 1.4×10 to the 15th power K. Geodetic baseline measurements via VLBI between Green Bank and Haystack are mutually consistent within a few meters. Radar investigations of Mercury, Venus, Mars, and the Moon have continued. The favorable opposition of Mars and improvements in the

radar permit measurements on a number of topographic features with unprecedented accuracy, including scarps and crater walls. The floor of Mare Serenitatis slopes upward towards the northeast and is also the location of a strong gravitational anomaly.

Ivanov, A. V., Basilevskiy, A. T., and Rode, O. D.: 'Lunar Soil in Mare Imbrium', (transl. into English from *Priroda*, No. 11, pp. 11–12), NASA-TT-F-14181.

The study of the soil sample brought back by Lunokhod 1 is discussed in brief with respect to regolith findings previously recorded.

Mitchell, J. K., Bromwell, L. G., Carrier, W. D., III, Costes N. C., Houston, W. N., and Scott, R. F.: 'Soil Mechanics Experiment', in *Apollo 15 Preliminary Scientific Report*, NASA-SP-289.

The Apollo 15 soil-mechanics experiment has offered greater opportunity for study of the mechanical properties of the lunar soil than previous missions, not only because of the extended lunar-surface stay time and enhanced mobility provided by the lunar roving vehicle (rover), but also because four new data sources were available for the first time. These sources were: (1) the self-recording penetrometer (SRP), (2) new, larger diameter, thin-walled core tubes, (3) the rover, and (4) the Apollo lunar-surface drill (ALSD). These data sources have provided the best bases for quantitative analyses thus far available in the Apollo program.

Namiq, L. I.: 1970, 'Stress-Deformation Study of a Simulated Lunar Soil', Ph. D. Thesis, California University, Berkeley.

The mechanical properties of lunar soil were studied and analytical tools were developed which would be useful for terrestrial applications. A lunar soil simulant was prepared which behaves under applied load similarly to actual lunar soil. An extensive analysis of the properties and behaviour of this simulant under terrestrial conditions was made and the results were transferred to the lunar surface by means of an analytical model. The method of study used was an analytical-experimental approach which led to the formulation and solution of a boundary value problem. Experimental work included laboratory measurements of strength, stress-strain, and compressibility parameters, and performance of model plate load tests. Analytical work included: (1) mathematical description of the strength, stress-strain, and compressibility parameters, including their dependence of soil density (2) use of the finite element method to simulate the model plate load tests for both terrestrial and lunar gravity conditions.

Nicholson, D. E.: 1971, 'Gravity Flow Powder in a Lunar Environment 1: Property Determination of Simulated Lunar Soil', U.S. Bureau of Mines, RI-7543.

The mechanical behaviour of fine soils in a lunar environment in engineering gravity-flow bins is studied. The ultrahigh vacuum, absence of moisture, and a lunar gravity one-sixth that of Earth gravity represents a unique environment, both advantageous and detrimental to these systems. On Earth, moisture and gases contained in powder masses can be responsible for complex descriptions of gravity flow. The properties of a dry soil powder, its behaviour under one-dimensional compression, and its torsional and direct shearing under Earth atmosphere are described. These properties provide the parameters for a finite/element analysis to optimize the design of bins.

Pariseau, W. G.: 1971, 'Gravity Flow of Powder in a Lunar Environment. 2: Analysis of Flow Initiation', U.S. Bureau of Mines, RI-7577.

A small displacement, strain, finite element technique utilizing the constant strain triangle and incremental constitutive equations for elastic-plastic media that are nonhardening and obey a Coulomb

yield condition was applied to the analysis of gravity flow initiation in a V-shaped hopper. Three methods of loading were examined. Of the three, the method of computing the initial state of stress in a filled hopper prior to drawdown by adding material to the hopper layer-by-layer is superior. Results of the analysis of a typical hopper problem show that the initial state of stress, the elastic moduli, and the strength parameters have an influence on material response subsequent to the opening of the hopper outlet.

Shevchenko, V. V.: 'Physical Selenography' (transl. into English from *Priroda*, No. 1, pp. 37–45, Jan. 1971), NASA-TT-F-13960.

Physical selenography is discussed in light of the most recent observations (Lunokhod-1, Apollo, observations from the Earth). The gas distribution, surface composition, and other physical features of the Moon are discussed.

12. Photometry of the Moon.

Evsjukov, N. N.: 1972, 'The Structure of Lunar Maria from the Data on their Albedo', *Astron Zh.* **49**, 1088–1093.

The albedo distribution in lunar maria for the red region of the spectrum is given. Two types of distributions – chaotic and that with concentric structure are detected. The first type is characteristic for irregular maria, the second one – for circular maria. Possible reasons of distinction of albedo distributions in maria, as well as the influence on albedo of continental ejections and that of age of the surface, are discussed.

Gold, T., O'Leary, B. T., and Campbell, M.: 1971, 'Optical and High Frequency Electrical Properties of the Lunar Sample', NASA-CR-115585, pp. 25–39.

Reflectivity and polarization laws for the powder sample and its spectrum are close to the mean for the lunar maria. Solid samples show a marked absorption feature at 1 μ. The low albedo appears to be due to a surface coating on dust grains rather than volume absorption. The high frequency electrical properties resemble those of a fine powder made from typical dense terrestrial rocks, and are consistent with previous ground-based radar estimates. The differential mass spectrum is almost constant from 100 μ particles down to 0.1 μ; most particles are smaller than 0.3 μ. Their shapes disclose a variety of generation processes.

Greenman, N. N. and Gross, H. G.: 'Luminescence Analysis of Lunar Samples Returned by Apollo: Luminescence of Apollo 14 and Apollo 15 Lunar Samples', NASA-CR-115512.

Luminescence measurements were made of Apollo 14 lunar samples with far UV, X-ray, and proton irradiation and of Apollo 15 lunar samples with X-ray irradiation. Preliminary efficiencies with the far UV are in the range 0.001 to 0.01; efficiencies with X-rays and protons are in the range 10 to the −8th to 10 to the −6th powers. The crystalline igneous rocks show higher efficiencies, in general, than the breccias and glasses, and the ratio of intensity of the green to the blue luminescence peak tends to be higher for the crystalline igneous rocks than for breccias and glasses. Therefore, both the efficiency and the spectral character appear to have a systematic relationship to lithologic type (granitic versus gabbroic versus fragmental) and to geologic history and processes on the Moon (shocked versus unshocked or only mildly shocked material).

Murcray, D. G., Murcray, F. H., Amme, R. C., Hewitt, J. G., Jr., and Barker, D. B.: 'Non-Stellar Celestial Backgrounds', AFCRL-71-0424; AD-733708.

The spectral emissivity of several lunar surface features as measured during two balloon flights are reported. The wavelength of the peak emissivity is found to differ among the surface features investigated. After the two flights reported the spectrometer utilized for the lunar measurements was converted to an absolute filter radiometer with a 15″ field of view for martian radiance measurements. The modifications are described.

The effects of solar wind protons on the lunar surface were simulated with a low-energy ion beam accelerator installed on a differentially-pumped, ultra high vacuum system.

13. Thermal Emission of the Lunar Surface.

Langseth, M. G., Jr., Clark, S. P., Jr., Chute, J. L., Jr., Keihm, J., and Wechsler, A. E.: 'Heat Flow Experiment', in *Apollo 15 Preliminary Scientific Report*, NASA-SP-289.

The heat flow experiment installed on the lunar surface during the Apollo 15 flight is described. Subjects discussed are: (1) the experiment concept and design, (2) the operations of the experiment, (3) the employment of the experiment on the lunar surface at Hadley Rille site, (4) subsurface lunar temperatures, and (5) extrapolation of sensor temperatures to equilibrium values. Graphs of the data obtained from the experiment are provided.

Shorthill, R. W., Saari, J. M., Baird, F. E., and LeCompte, J. R.: 1970, 'Eclipse Cooling of Selected Lunar Features', NASA-CR-115563.

Thermal measurements were made in the 10 to 12 μ band of the lunar surface during the total eclipse of December 19, 1964. A normalized differential thermal contour map is included, showing the location of the thermal anomalies or hot spots on the disk and the eclipse cooling curves of 400 sites, of which more than 300 were hot spots. The eclipse cooling data is compared to a particulate thermophysical model of the soil.

Ulich, B. L., Cogdell, J. R., and Davis, J. H.: 'Planetary Observations at Millimeter Wavelengths', NASA-CR-125849.

Observations of the Sun, Moon, Mercury, Venus, Mars, Jupiter, and Saturn were made at 3.1 mm and 8.6 mm wavelengths with a 16-ft radio telescope between March and August, 1971. Absolute brightness temperature data are given. All errors are one standard deviation and include uncertainties in antenna gain calibration. The solar and lunar temperatures are in excellent agreement with published observations. The planetary measurements at 3.1 mm are consistently higher than previous results. The implications of higher temperatures with respect to existing atmospheric and surface models are discussed.

14. Electromagnetic Properties of the Moon.

Anderson, K. A., Chase, L. M., Lin, R. P., McCoy, J. E., and McGuire, R. E.: 1972, 'Solar-Wind and Interplanetary Electron Measurements on the Apollo 15 Subsatellite', *J. Geophys. Res.* **77**, 4611–4626.

Measurements of high-energy solar-wind electrons have been made from a low orbit around the Moon. Solar-wind electrons can be identified up to energies of $\sim$ 3000 eV, at which an electron population of entirely different characteristics becomes dominant. The solar-wind cavity on the Moon's antisolar side shows evidence of being filled by plasma coming from the downstream direction. When the direction of the interplanetary field corresponds to solar ecliptic azimuth angles of about 90°, a partial solar-wind cavity extends across most of the eastern sunlit side of the Moon within $\sim$ 20° of the noon meridian. There are localized increases in the $\sim$ 500-eV electron flux over much of the sunlit hemisphere. These increases are highly persistent and stable in their location over a 2½-day period and hence are not due to intrinsic variations in the solar wind. They are usually associated with disturbances in the magnetic field. These increases are interpreted to be the result of an interaction between the solar wind and the Moon that deflects some of the solar-wind flow and results in limb shocks.

Bassett, H. L. and Shackelford, R. G.: 1972, 'Complex Permittivity Measurements of Lunar Samples at Microwave and Millimeter Wavelengths', NASA-CR-115571.

The relative dielectric constant and loss tangent of lunar sample 14163, 164 (fine dust) were determined as a function of density at 9.375, 24, 35, and 60 GHz. In addition, such measurements have also been performed on lunar sample 14310, 74 (solid rock) at 9.375 GHz. The loss tangent was found to be frequency independent at these test frequencies and had a value of 0.015 for the lunar dust sample.

Coleman, P. J., Jr., Schubert, G., Russell, C. T., and Sharp, L. R.: 'The Particles and Fields Subsatellite Magnetometer Experiment', in *Apollo 15 Preliminary Scientific Report*, NASA-SP-289.

A preliminary analysis of magnetometer data from Apollo 15 subsatellite is concluded. Remnant magnetization is a characteristic property of the Moon, and the distribution is such that a complex pattern is produced. A mapping of the distribution is feasible with the present experiment. Lunar induction fields produced by transients in interplanetary magnetic field are detectable at satellite orbit. Magnetometer data will provide estimates of the latitude and longitude dependences of interior conductivity. The plasma void extends to some altitude below the satellite orbit and probably the lunar surface. Solar wind near the limbs is usually strongly disturbed.

Dyal, P., Parkin, C. W., and Sonett, C. P.: 'Lunar Surface Magnetometer Experiment', in *Apollo 15 Preliminary Scientific Report*, NASA-SP-289.

The Apollo 15 lunar-surface magnetometer (LSM) is one of a network of magnetometers that have been deployed on the Moon to study intrinsic remanent magnetic fields and global magnetic response of the Moon to large-scale solar and terrestrial magnetic fields. From these field measurements, properties of the lunar interior such as magnetic permeability, electrical conductivity, and temperature can be calculated. In addition, correlation with solar-wind-spectrometer data allows study of the solar-wind plasma interaction with the Moon and, in turn, investigation of the resulting absorption of gases and accretion of an ionosphere. These physical parameters and processes determined from magnetometer measurements must be accounted for by comprehensive theories of origin and evolution of the Moon and solar system.

Gillen, R. J., Brady, J. C., and Collier, F.: 'Apollo Experience Report: Lunar Module Environmental Control Subsystem', NASA-TN-D-6724.

A functional description of the environmental control subsystem is presented. Development, tests, checkout, and flight experiences of the subsystem are discussed; and the design fabrication, and operational difficulties associated with the various components and subassemblies are recorded. Detailed information is related concerning design changes made to, and problems encountered with, the various elements of the subsystem, such as the thermal control water sublimator, the carbon dioxide sensing and control units, and the water section. The problems associated with water sterilization, water/glycol formulation, and materials compatibility are discussed. The corrective actions taken are described with the expectation that this information may be of value for future subsystems. Although the main experiences described are problem oriented, the subsystem has generally performed satisfactorily in flight.

Housley, R. M.: 'Lunar Sample Analysis', NASA-CR-115465.

A simple and convenient method of making quantitative magnetic separations of the lunar fines is described. The fractions obtained from groups containing distinctively different particle types; thus it appears that magnetic separation in itself may be a useful way of characterizing lunar fines. Mossbauer studies of fines 10084 show that the metal can not contain more than about 1.5% Ni implying that by far the bulk of it results from reduction rather than being a direct meteoritic addition. Mossbauer data also places an upper limit on the magnetite content of the fines at least an order of magnitude below that required to account for the characteristic ferromagnetic resonance observed. Microscopic examination of magnetic separates from the 15101 fines suggests that reduction of Fe accompanies every major impact event on the Moon and also suggests that the bulk of the material at the collection site has at one time been in an impact plume.

McAllister, F.: 'Apollo Experience Report: Crew Provisions and Equipment Subsystem', NASA-TN-D-6737.

A description of the construction and use of crew provisions and equipment subsystem items for the Apollo Program is presented. The subsystem is composed principally of survival equipment, bioinstrumentation devices, medical components and accessories, water- and waste-management equipment, personal-hygiene articles, docking aids, flight garments (excluding the pressure garment assembly), and various other crew-related accessories. Particular attention is given to items and assemblies that presented design, development, or performance problems: the crew optical alinement sight system, the metering water dispenser, and the waste-management system. Changes made in design and materials to improve the fire safety of the hardware are discussed.

Sonett, C. P., Smith, B. F., Colburn, D. S., Schubert, G., and Schwartz, K.: 'The Induced Magnetic Field of the Moon: Conductivity Profiles and Infrared Temperature', NASA-TM-X-62153.

Electromagnetic induction in the Moon driven by fluctuations of the interplanetary magnetic field is used to determine the lunar bulk electrical conductivity. The present data clearly show the north-south and east-west transfer function difference as well as high frequency rollover. The difference is shown to be compatible over the mid-frequency range with a noise source associated with the compression of the local remanent field by solar wind dynamic pressure fluctuations. Models for two, three, and four layer; current layer, double current layer, and core plus current layer Moons are generated by inversion of the data using a theory which incorporates higher order multipoles. Core radii conductivities generally are in the range 1200 to 1300 km and 0.001 to 0.003 mhos m^{-1}; and for the conducting shell 1500 to 1700 km with 0.0001 to 0.0007 mhos m^{-1} with an outer layer taken as non-conducting. Core temperature based on available olivine data is 700 to 1000°C.

15. Exploration of the Moon by Spacecraft.

Allen, J. P.: 'Summary of Scientific Results', in *Apollo 15 Preliminary Science Report*, NASA-SP-289.

The major scientific results of the Apollo 15 flight are summarized. The objectives of the flight are given as: (1) to carry out extensive geological exploration, comprehensive sampling, and photographic documentation of the Apennine Front at Hadley Delta, Hadley Rille, and the mare plain, (2) to emplace the ALSEP near the landing site, and (3) to perform a series of survey experiments with the scientific instrument module (SIM) equipment from lunar orbit and during transearth coast.

Baldwin, R. R.: 'Mission Description', in *Apollo 15 Preliminary Science Report*, NASA-SP-289.

The Apollo 15 manned lunar-landing mission is discussed. As compared with previous Apollo manned lunar-landing missions, the mission 15 is characterized by increased hardware capability, a larger scientific payload, and a battery-powered lunar roving vehicle (Rover). Benefits resulting from these additions to Apollo 15 were a mission duration of $12\frac{1}{3}$ days, a lunar stay time of nearly 67 hr, a lunar-surface traverse distance of 27.9 km traveled at an average speed of 9.6 km $hr.^{-1}$, and a scientific instrument module (SIM) containing equipment for orbital experiments and photographic tasks not performed on previous missions. The primary scientific objectives of the mission were to perform selenological inspection, survey, and sampling of materials and surface features in a preselected area of the Hadley-Apennine region; to emplace and activate surface experiments; and to conduct inflight experiments and photographic tasks from lunar orbit.

Chamberlain, J. W. and Watkins, C. (eds.): 1972, *The Apollo 15 Lunar Samples*, The Lunar Science Institute, Houston, Texas.

The Lunar Science Institute, at the suggestion of NASA's Lunar Sample Analysis Planning Team, undertook to produce this volume of short papers, similar in scope to the expanded abstracts of the Conference papers published immediately after the Third Conference. These short papers are in no way intended to substitute for more detailed discussion published in the *Proceedings of the Lunar Science Conferences* and in the standard journals. This volume is, however, intended to focus attention on the variety of research being conducted on Apollo 15 samples.

Dietrich, J. W. and Clanton, U. S.: 'Photographic Summary', in *Apollo 15 Preliminary Scientific Report*, NASA-SP-289.

The photographic objectives of the Apollo 15 mission were designed to support a wide variety of scientific and operational experiments, to provide high-resolution panoramic photographs and precisely oriented metric photographs of the lunar surface, and to document operational tasks on the lunar surface and in flight. Detailed premission planning integrated the photographic tasks with the other mission objectives to produce a balanced mission that has returned more data than any previous space voyage. The return of photographic data was enhanced by new equipment, the high latitude of the landing site, and greater time in lunar orbit. New camera systems that were mounted in the scien tific instrument module (SIM) bay of the service module provided a major photographic capability that was not available on any previous lunar mission, manned or unmanned.

Farkas, A. J.: 'Apollo Experience Report: Lunar Module Display and Control Subsystems', NASA-TN-D-6718.

The lunar module display and control subsystem equipment is described with emphasis on major problems and their solutions. Included in the discussion of each item is a description of what the item does and how the item is constructed. The development, hardware history, and testing for each item are also presented.

Gurshteyn, A. A. and Shingarev, K. B.: 'Soviet Space Probes Study the Moon' (transl. into English from *Priroda*, No. 1, pp. 2–6, Jan. 1971), NASA-TT-F-13959.

The Luna-16, Luna-17, Zond-8 and Lunokhod-1 Moon missions of September–November 1970 are described.

Kokurin, Iu. L., Kurbasov, V. V., Lobanov, V. F., Sukhanovskii, A. N., and Chernykh, N. S.: 1972, 'Laser Location of the Light-Reflector Mounted on the Lunokhod-1' (transl. into English from *Kosm. Issled.* **9**, 912–919). National Translations Centre, John Crerar Library, Chicago, *Ill.* 60616.

Results are presented for experiments on laser location of the light reflector mounted on the Lunokhod 1. Reflection parameters, and a description of the laser locating apparatus, are given. It is shown that measurement accuracy is within +3 m.

NASA: 'Apollo-12 70 mm Photographic Catalog', NASA-TM-X-68811.

Proof prints of the 70-mm photography are presented, sorted by magazine and frame number. The 28 lunar surface panorama mosaics and a listing of the mosaics are included. The catalog is designed to be used in conjunction with the 'Apollo 12 Photography 70-mm, 16-mm, and 35-mm Frame Index', which makes it possible to locate the area covered by each frame.

NASA: 'Apollo 12 Photography 70-mm, 16-mm, and 35-mm Frame Index', NASA-TM-X-68810.

For each 70-mm frame, the index presents information on: (1) the focal length of the camera, (2) the photo-scale at the principal point of the frame, (3) the selenographic coordinates at the principal point of the frame, (4) the percentage of forward overlap of the frame, (5) the Sun angle (medium, low, high), (6) the quality of the photography, (7) the approximate tilt (minimum and maximum) of the camera, and (8) the direction of tilt. A brief description of each frame is also included. The index to the 16-mm sequence photography includes information concerning the approximate surface coverage of the photographic sequence and a brief description of the principal features shown. A column of remarks is included to indicate: (1) if the sequence is plotted on the photographic index map and (2) the quality of the photography. The pictures taken using the lunar surface close-up stereoscopic camera (35 mm) are also described in this same index format.

NASA: 'Preliminary Examination of Lunar Samples', in *Apollo 15 Preliminary Scientific Report*, NASA-SP-289.

The morphology, mineralogy, petrology, and chemistry of the samples returned from the Apollo 15 landing site are discussed. A selenological description of the area from which the samples were taken is given. The diversity of the samples and the variety of sample environments found at the Apollo 15 site have resulted in several hypotheses that relate individual samples to local situations after even a preliminary examination of the samples. Several somewhat speculative hypotheses that relate individual samples to a geological framework are discussed in the hope that the hypotheses will provide guidelines for more detailed studies of the samples to arrive at an integrated understanding of the selenology of the Apollo 15 site.

Podolskiy, A. D.: 1971, 'Soviet Robots on the Moon' (transl. into English from *Weltraumfahrt Raketentech.* **22**, 171–195), NASA-TT-F-14300.

Luna 16 explored the Sea of Fertility in 1970, for age, type of soil, color, density, etc. Soil samples were returned to Earth for study for the first time, and confirmed that the plains were flooded by lava. Lunokhod 1, landed by Luna 17 in November 1970, confirmed the theory of the formation of the lunar crust by its experiments near the edge of the western section of Mare Imbrium. Lunokhod 1, a self-propelled laboratory on wheels, explored over 10 km over a period of 10 months prior to ceasing operation. Experiments ranged from determining bearing capacity of the surface, mechanical properties, and soil analysis, to the study of the decrease in the intensity of cosmic radiation, proton eruptions, X-ray radiation, the exploration of distant regions of space by X-ray telescope, and joint experiments with the French with a laser reflector.

Schowalter, D. T. and Malone, T. B.: 'The Development of a Lunar Habitability System', NASA-CR-1676.

Lunar shelter habitability requirements and design criteria are presented. The components of lunar shelter habitability studied are (1) free volume, (2) compartmentalization, (3) area layout arrangements, (4) area use frequency/duration furnishings, (5) equipment operability, (6) decor, (7) lighting, (8) noise, (9) temperature, and (10) growth potential.

Scott, D. R., Worden, A. M., and Irwin, J. B.: 'Crew Observations', in *Apollo 15 Preliminary Scientific Report*, NASA-SP-289.

Crew observations of the Apollo 15 flight are presented. The observations are concerned with the following phases of the flight: (1) translunar and transearth coasts, (2) lunar landing and ascent, (3) standup extravehicular activity, (4) surface experiment deployment, (5) lunar traverse geology, and (6) orbital observations.

Simmons, G.: 'On the Moon with Apollo 16: A Guidebook to the Descartes Region', NASA-EP-95.

This guidebook gives in simple terms information about the Apollo 16 mission of scientific exploration of the Descartes region of the Moon.

Swann, G. A., Bailey, N. G., Batson, R. M., Freeman, V. L., Hait, M. H., Head, J. W., Holt, H. E., Howard, K. A., Irwin, J. B., Larson, K. B. *et al.*: 'Preliminary Geologic Investigation of the Apollo 15 Landing Site' in *Apollo 15 Preliminary Scientific Report*, NASA-SP-289.

The Apollo 15 lunar module (LM) landed on the mare surface of Palus Putredinis on the eastern edge of the Imbrium Basin. The site is between the Apennine Mountain front and Hadley Rille. The objectives of the mission, in order of decreasing priority, were description and sampling of three major geologic features – the Apennine Front, Hadley Rille, and the mare. The greater number of periods of extravehicular activity (EVA) and the mobility provided by the lunar roving vehicle (ROVER) allowed much more geologic information to be obtained from a much larger area than those explored by previous Apollo crews. A total of 5 hr was spent at traverse station stops, and the astronauts transmitted excellent descriptions of the lunar surface while in transit between stations.

Watkins, C. (ed): 'Lunar Science. 3: Revised Abstracts of Papers Presented at the Third Lunar Science Conference', NASA-CR-175605.

Prior to the meeting some 375 preliminary abstracts were printed for distribution to conference participants, with the provision that revised abstracts of up to three typed pages could be submitted before the end of the conference. These updated expanded abstracts are collected here.