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The COSPAR Meetings in Prague

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On 11–24 May 1969 in Prague, Czechoslovakia there took place the 12th Plenary Meeting of COSPAR, the Committee on Space Research of the International Council of Scientific Unions. These meetings provide an annual forum for international exchange of scientific information on space investigations. They are largely devoted to such near-space topics as the Earth's upper atmosphere, but increasing attention is being given to space vehicle investigations of the Moon and planets. In conjunction with the Plenary Meeting there were three specialized symposia, one on the thermosphere, one on satellite dynamics, and one on biological rhythms and problems of nutrition of man in space. The following report is devoted largely to the work of the newly established Working Group VII on "Space Related Studies of the Moon and Planets." The chairman and vice chairman of Working Group VII are, respectively, A. D. Kuzmin of the Soviet Union and Carl Sagan of the United States.

The first session of the open meeting of Working Group VII was held on May 21 and devoted to the lunar surface. It was chaired by A. Dollfus of France, who had with his father the previous weekend won a manned balloon race sponsored by the city of Prague. The session began with a lead paper by Col. Frank Borman of the United States, the command pilot of the Apollo 8 mission. Colonel Borman's comments accompanied a color film which dramatically portrayed the launch, lunar orbit, and recovery of Apollo 8. Particularly striking were the number of new bright halo craters discovered in this mission. Borman indicated that some eight landings, stretched over perhaps a two-year period, are scheduled after the Apollo 11 lunar mission. In all cases the upper limit on the dwell time on the lunar surface is some three days. In line with Borman's new responsibilities in the development of large manned orbiting stations, he raised the possibility that scientists of all nations might be able to actively participate in space in scientific experiments by the middle to late 1970s. After Borman's discussion the following papers were presented:

(1) *Lunar Surface: Recent Spacecraft Observations*, by Leonard D. Jaffe, USA. This excellent and well-illustrated summary of recent space vehicle exploration of the Moon had the following abstract:

> Recent lunar-orbiting and landing spacecraft of the Luna, Lunar Orbiter, Explorer, Surveyor, and Apollo series have supplied many measurements of lunar characteristics. These show that both maria and highlands are covered with a layer of particles, of sizes predominantly 2–60 micrometers. The layer has a strong vertical gradient of physical properties, and a depth, in the maria, of a few meters. It was evidently produced from underlying more cohesive material, primarily by meteorite impact. The content of major elements in this material is similar to that of high-iron basalt in the maria and probably to low-iron basalt in the highlands. A variety of rocks, up to tens of meters in diameter, lie on and in the fine matrix. Rock shapes, fractures, and burial demonstrate erosion. Craters of sizes down to a few centimeters are visible; many craters are clearly of impact origin and many others clearly volcanic. Downhill transport of material is visible on scales of centimeters to kilometers. Mass concentrations on a scale of hundreds of

kilometers are present, but there is considerable evidence of past large-scale melting and flow.

Jaffe argued that the photographic appearance of a number of craters observed by orbiting spacecraft showed very deep cracks, indicating high strength of materials which he attributed to lava. One of his slides showed a track of a 1 cm diameter boulder. In the lively discussion which followed it became clear that there are three competing hypotheses for the general low albedo of the lunar surface: solar proton bombardment, high iron content, and a possible high carbon content.

(2) *Comparison of the Chemical Composition of Lunar Surface Material Determined by Radioastronomical Observations with the Results of Chemical Analysis Obtained by Surveyor*, by V. S. Troitsky, USSR. The starting point of this paper is the finding, based on experimental measurements of rocks at Gorky University, that the quantities $a = (\sqrt{\epsilon} - 1)/\rho$ and $b = \tan \Delta/\rho$ are virtually independent of density but depend strongly on composition. Here ϵ is the dielectric constant; $\tan \Delta$, the loss tangent; and ρ, the density of rocks in question. It is then claimed that ground-based radioastronomical measurements of lunar loss tangents and dielectric constants give a relative composition of eight abundant atoms on the lunar surface which agrees to remarkably high accuracy (within a few percent) with the results of the α back-scattering experiment of the Surveyor spacecraft. The paper was criticized on the grounds that it was unlikely that two equations could be used to derive eight unknowns.

(3) *Some Data on Lunar Surface Microstructure Deduced from Studies of the Moon's Infrared and Ultraviolet Radiation Obtained from the Zond III Space Probe*, by G. A. Leikin, T. E. Shvidkovskaya and V. A. Krasnopolsky, USSR. This paper was a discussion of the observed lunar photometric function in two wavelength ranges observed by Zond III, 3.5 to 3.9 microns in the near-infrared, and 2100 to 2700 Å in the near-ultraviolet. In the infrared it is found that the observed photometric function is represented very well by the Hapke function; this is not the case in the ultraviolet. The difference is attributed to a roughness on the lunar surface at a scale of about 0.5 micron so that diffraction as well as geometric optics are important.

(4) *Structure of the Lunar Surface*, by S. Hayakawa, T. Matsumoto, T. Nishimura, and H. Okuda, Japan. This paper primarily reports the interpretation of ground-based near-infrared observations of lunar phase function obtained at Nagoya University. It is deduced from the phase dependence that the average grain size is several tens of microns. A modification of Hapke's phase function is made to allow for diffraction and the modification results in a rather good fit for the phase function from the visible through the infrared both for maria and for highlands. The particle sizes invoked are consistent with those observed by lunar landing vehicles.

(5) *The Measurement of Scattering Characteristics of the Local Lunar Regions from Space Vehicles*, by N. N. Krupenio, USSR. The scattering characteristics referred to in the title are observed by radar experiments at 3-cm wavelength on Luna 9 and Luna 13. The results are compared with Surveyor and ground-based radar observations of the Moon. The variations in the radar scattering characteristics with locale appears to be very small.

(6) *On the Origin of Lunar Relief*, by P. Feschotte, Switzerland. This paper presented a set of speculations on the origin of lunar surface features based upon laboratory experiments in which liquid droplets of high viscosity are dropped onto surfaces of similar composition and phase. It was suggested that the Moon was formed from a molten Earth.

(7) *Electrical Conductivity and Internal Temperature of the Moon*, by N. F. Ness, USA. This paper is an extension of the author's previous conclusions, from the absence of a bow shock wave behind the Moon, that the electrical conductivity of the lunar interior is very low (10^{-5} to 10^{-6} mhos/meter) and that therefore a very

low interior temperature (less than 1200°K) is implied. These conclusions have been supported by studies of the propagation of discontinuities in the interplanetary magnetic field. The low interior temperatures could be explained, for a Moon with radioactive heat sources comparable to those of chondritic meteorites, by assuming that the Moon must be a relatively young body, less than about 1×10^9 years old. In the discussion Harold Urey pointed out that if the Moon were this young the impact events which have shaped its surface must have occurred less than 1×10^9 years ago; if the Moon was then in the vicinity of the Earth similar impacting events should have occurred on the Earth. But there is no trace in the geological record for such events. Urey proposed instead that the Moon has a smaller complement of radiogenic heat sources than typical chondrites.

The second open session of Working Group VII was chaired by the Chairman and Vice Chairman of the Working Group. The first five papers of this session were on the question of mass concentrations on the Moon and planets, largely recapitulating discussions already published or about to be published in the literature, but providing an opportunity for very vigorous debate. The titles and authors of the papers presented follow: *Mascons on the Moon* by H. C. Urey, USA; *Lunar and Planetary Mass Concentrations* by B. T. O'Leary, M. J. Campbell, and Carl Sagan, USA; *Lunar Gravimetrics*, by Paul M. Muller and W. L. Sjogren, USA; *The Nature of Lunar Mascons* by J. J. Gilvarry, USA; and *Interpretation of Lunar Mass Concentrations* by W. M. Kaula, USA.

One of the most interesting debates was on the nature of the mascons. Urey advocated that the mascons are residua of the impacting objects which produced the circular basins with which the mascons are associated. Gilvarry, Muller, and Sjorgen advocated the idea that the mascons are due to sediments which filled the circular basins after an epoch of isostatic compensation. Such extensive sedimentation requires the existence of relatively deep bodies of water on the Moon for extensive periods of time—a hypothesis which Urey opposed because of the absence of great lunar river valleys and which Muller supported from Lunar Orbiter photography suggesting a variety of flows by liquids of low viscosity. These debates will almost certainly be short-lived: analyses of returned lunar samples of mare material should surely determine whether they are of sedimentary origin.

The planetary session began with two papers on Venus, one by G. P. Kuiper, USA, on *The Venus Atmosphere*, the other by A. Dollfus, France, on a *Nouvelle détermination du diamètre optique de Vénus au Niveau Supérieur de la Couche Nuageuse*. Kuiper found from ground-based observations of the Venus crescent, with the 61-inch Arizona telescope during the past inferior conjunction, that the radius of Venus in visual and red light is some 6100 km, and in ultraviolet light (3600 Å), 6145 km. The absolute scale was calibrated with double stars. Dollfus, from recent double-image micrometry measurements (at Meudon) of Venus and after an exhaustive discussion of all previous observations, found for the radius of Venus 6110 ± 16 km at the visible clouds and 6150 ± 20 km for suspended particles in the high atmosphere. The results of Kuiper and Dollfus seem to be in excellent agreement. The 6110-km clouds correspond to the tropopause in the Mariner 5 atmospheric structure; the particles at 6150-km altitude approximately to the mesopause. The existence of such scattering particles in the Venus stratosphere, incidentally, points to the possible importance of such particles in spectral line formation. Kuiper also reported results with his interferometric/spectrometric observations of Venus from a NASA Convair 990 aircraft at stratospheric altitudes during a February 1969 flight. The total water vapor content to the effective scattering level was found to be 3 microns of precipitable water, corresponding to a water vapor mixing ratio of about 1 part per million.

J. B. Pollack, USA, in a paper called *The Implications of Recent Spacecraft Results for the Composition of the Venus Atmosphere*, summarized a number of recent results found by him chiefly in collaboration with A. Wood, D. Morrison, and C. Sagan. Comparison of Mariner 5 and Venera 4 spacecraft results imply that carbon dioxide constitutes no more than 95% of the Venus atmosphere, with the remainder being some other gas, perhaps nitrogen. An analysis of the passive microwave spectrum of Venus, drawn to a uniformly calibrated scale, was compared with theoretical models of the Venus atmosphere in which pressure-induced dipole transitions and pressure-broadened water vapor are included. It was found that the spectrum cannot be understood in terms of a pure CO_2–N_2 atmosphere, but *is* consistent with the addition of a few tenths of a percent of water vapor uniformly mixed through the troposphere. This is, however, merely a consistency test and not a demonstration of the existence of ~0.5% water vapor in the lower atmosphere of Venus.

In a paper by F. F. Marmo, USA, *On the Presence of Carbon Atoms in the Upper Atmosphere of Venus,* the ultraviolet rocket spectra of Venus obtained in 1967 by Moos *et al.* are reinterpreted. An otherwise puzzling continuum feature between 1600 and 1800 Å is interpreted in terms of a 1675 Å resonance scattering of solar radiation by carbon atoms in the upper atmosphere of Venus. The presence of such carbon atoms are calculated to be not implausible by known photochemical mechanisms.

A paper by D. L. Coffeen and T. Gehrels, USA, on *Ultraviolet Polarimetry of Planets* concentrated on the results of the observations of Mars and Venus with the 71-cm Polariscope balloon telescope operating at altitudes of some 36 km. Preliminary polarizations at 2250 Å are +6% for Mars at 25° phase angle, and +22% for Venus at 78° phase angle. Interpreting the Venus results by Rayleigh scattering from optically thin layers, Coffeen obtains results consistent with upper cloud pressures below 50 millibars, upper cloud particles with a mean diameter of some 2.5 microns, and a mean refractive index with real part near 1.5 and imaginary part nonzero but less than 10^{-3}.

The final paper at the open session of Working Group VII was a review by Donald G. Rea, USA, of *NASA Planetary Programs—Present and Future.* He described NASA's approved planetary program which includes two Mariner flybys of Mars in 1969, two Mariner orbiters of Mars in 1971, and two combined lander/orbiter missions dubbed Viking in 1973. Other approved programs include Pioneer flybys of Jupiter in 1972 and 1973 which may entail observations of the asteroid belt along the way. NASA hopes, in addition, to launch a 1973 flyby of Mercury using Venus for a gravity assist, and a small stabilized orbiter of Venus in 1973. Possible missions to the outer Jovian planets including alternatives to the "Grand Tour" were also discussed, and it was made clear that opportunities in the 1970s for the exploration of the Jovian planets will not recur for some time. For example, the next opportunity after 1978 for a "grand tour" of Jupiter, Saturn, Uranus, and Neptune in swing-by mode does not recur until 2155. The paper by Rea, who is Deputy Director of Planetary Programs at NASA, ended with a discussion of the significant increase in information about Venus that we have due to the fortuitous fact that Mariner 5 concentrated on the upper atmosphere of Venus and Venera 4 on the lower. He concluded with the words,

> The meshing of these results was pure happenstance, since there was no advance exchange of information between the USA and the USSR regarding these flights, let alone intentional coordination. The latter is probably unrealistic at this point in history, but surely the former is possible. So let me close with a plea to my Soviet colleagues to join with NASA in a mutual exchange of planning information. Such an exchange could be only beneficial and would accelerate the widening of our understanding of the exploration goals without a corresponding increase in budgets.

The Prague meeting of COSPAR inaugurated a new activity, annual reviews of space research. One of these reviews was presented by A. D. Kuzmin, USSR, on *Modern Data on the Planet Venus*, in a session chaired by Yu. Grigoriev, USSR. This paper laid very heavy stress on the Venera 4 and Mariner 5 results, discussed the radius and rotation of the planet, its atmospheric composition and structure, the question of temperature difference between the illuminated and unilluminated hemispheres and some questions about the upper atmosphere and the magnetic field. One of Kuzmin's conclusions was that the joint results of Venera 4, Mariner 5, and ground-based radioastronomy lead to the conclusion that the mean surface temperature and pressure are, respectively, $700 \pm 100°K$ and 75^{+50}_{-25} atmospheres. He stressed an apparent discrepancy in the Mariner 5 S-band occultation results between early and later papers on the atmospheric temperature difference between illuminated and unilluminated hemispheres. Kuzmin also gave as an average of all ground-based radar measurements of the Venus radius 6053 ± 5 km.

Some of the papers presented at the open meetings of Working Group V—Space Biology, are of interest for the Moon and planets. It has been postulated that the high ultraviolet flux on Mars is not as dominantly lethal an agent there as might otherwise be expected, because atmospheric aerosols and soil particles are expected to have a high ultraviolet opacity. This expectation was confirmed by E. J. Hawrylewicz, C. A. Hagen, B. T. Anderson, and M. L. Cephus, USA, in a paper entitled *Effect of Ultraviolet on Survival of Bacteria Air-Borne in Simulated Martian Dust Clouds*. It was found that limonite and other possible soil particles are very effective in protecting representative spore-forming and non-spore-forming bacteria from Martian doses of ultraviolet radiation. In addition to demonstrating that the ultraviolet flux on Mars does not make the planet self-sterilizing for terrestrial contaminants, the paper also suggests that the ultraviolet flux need not be a serious impediment to hypothesized indigenous Martian organisms. An apparatus for the simulation of Martian conditions and subsequent inoculation with terrestrial microorganisms was described by E. G. Zaar, V. G. Zelikson, M. G. Kitaigorodsky, L. K. Losinsky, G. V. Koshelev, and M. A. Rybin, USSR, in a paper entitled, *The Apparatus "Photostat-I" Imitating Martian Environmental Conditions*. Experiments in a similar chamber were reported by A. A. Imshenetsky, L. A. Kusjurina and V. M. Jakshina, USSR, in a paper entitled *Multiplication of Certain Soil Microorganisms under Simulated Martian Conditions*. Previous results showing that thin soil layers protect buried microorganisms from ultraviolet radiation were confirmed. Some xerophytic microorganisms were found to multiply in limonite soils under simulated Martian conditions and at very low humidities. A number of other papers were presented by authors from the United States and the Soviet Union on sterilization techniques and possible life detection systems.

Regrettably, in many COSPAR sessions, some 30% to 40% of the papers were presented *in absentia*, a practice which makes detailed query of the reported results difficult.

A new Panel on Planetary Quarantine of COSPAR had its first meeting in Prague on May 17, 1969, replacing the earlier panel on Standards for Space Probe Sterilization. Working Group VII made preliminary steps directed towards the ultimate establishment of reference atmospheres for the planets Mars and Venus.

The arrival of the Soviet space vehicles Venera 5 and 6 into the Venus atmosphere occurred less than a week before the COSPAR planetary discussions and no results from these missions were available at the time of the meeting. It seems likely that the 13th Plenary Meeting of COSPAR scheduled to be held in May 1969 in Leningrad will have a rather thorough discussion of the results of Venera 5 and 6, Mariner 6 and 7 to Mars, and perhaps some results from Apollo 11 and follow-on missions.