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MARS SURFACE FORMATION, SURFACE MATERIALS, AND TERRAIN

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by
Herbert H. Hoop

September 1966

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30 September 1966 RSIC-592

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ABSTRACT

This summary and annotated bibliography is a selection of the more accepted literature from the enormous quantity which covers the range of hypotheses as to Mars surface formation, surface material, and terrain. Various hypotheses and the few generally accepted facts are discussed. Included is a selected bibliography, author index, and subject index.

FOREWORD

This literature survey and annotated bibliography was made at the request of Mr. Otha H. Vaughan, Jr., Aerospace Environment Division, Aero-Astrodynamics Laboratory, Marshall Space Flight Center, Huntsville, Alabama. Emphasis was placed on literature which postulates Martian surface materials and terrain.

The primary sources searched are as follows:

1) Redstone Scientific Information Center document card file.
2) Defense Documentation Center abstract bulletins and bibliographic service.
3) National Aeronautics and Space Administration tape search which references International Aerospace abstracts and Scientific Technical Aerospace reports.
4) Astronomical and scientific publications.
5) Communications with Jet Propulsion Laboratory on Mariner IV.
6) Geophysical abstracts.
7) Science abstracts.

CONTENTS

Section I. INTRODUCTION

Engineers concerned with designing Mars landing craft and vehicles for the exploration of the surface will search for the latest facts and most widely accepted theories which describe the environment and surface of Mars. Many literature surveys, books, and bibliographies have been prepared on Mars which may be used to plan these missions. (See Subject Index.) Two writers, Robert B. Owen, Marshall Space Flight Center, National Aeronautics and Space Administration, and D. G. Rea, Space Science Laboratory, University of California, have made recent intensive literature surveys and discussed conflicting opinions. These reports may be presently influencing the preliminary design of exploratory craft.

Owen's report[1] covers surface features, surface atmospheric conditions, the blue haze, and atmospheric constructions. The report by Rea[2] covers the atmospheric pressure and composition, bright and dark surface areas, surface environment, and surface materials. The majority of the better known authors who have covered the formation and materials of the Martian surface are represented in the references of both reports.

Before the Mariner IV fly-by of Mars, all information on the planetary surfaces could be interpreted in numerous ways. There was no alternative but to compare remote measurements with measured earth properties. Mariner IV photographs of Mars and the Surveyor I and Orbiter photographs of the moon have greatly added to the store of knowledge on the history of the planets. There appear to be very few facts at present on Mars on which there is complete agreement. This is possibly because of the difficulty in viewing Mars.

Tombaugh[3] emphasized the difficulty of studying Mars from the earth and the reasons for differences in opinion as to what can be seen. He said, "The finest details are visible only by glimpses for a second or two during an extraordinary lull in the smearing effect of our atmosphere. The delicate features which are highly dependent on seasonal events and those which are governed by some peculiar secular development were visible to me for a total of less than one minute over my span of 37 years! When a magnification of several hundred diameters is employed, the apparent area of the Martian disk is too great for a simultaneous surveillance. One must confine his gaze to some portion of the planet's disk and wait for the superglimpses to come along, then shift his attention to another, and then another. From chance, it is likely that an observer will not have covered the disk with equal thoroughness.

Also, he may spend too much time trying to get a better look at some feature that especially interests him. Even if every observer had the same skill in drawing, it is not surprising that their drawings made at the same hour should show some disagreement. Unfortunately, the recording of fine detail in visual observations is subject to personal error in both perception and representation, depending on the competency and experience of the observer. In areas of congested detail, it is exceedingly difficult to be sure of the embochure position with connection features. Often the quality of seeing is not uniform over an area as small as Mars."

The 200-inch Palomar reflector gives a view of Mars no better than the view of the moon through ordinary binoculars.[4] Tombaugh[5] studied Mars for over 30 years to cover two equivalent years of Martian seasons.

By comparing a limited number of observations and interpretations with known earth forming processes, many scientists have attempted to predict the surface of Mars. The observed features have been the subject of controversy since the planet was first viewed by telescope in early 1600. The controversy has been over such general subjects as the nature of the polar caps, the dark and light areas, the canals, reasons for the color of the planet, the atmosphere, and surface materials and terrain.[1,2,5,6,7]

Section II. MEASUREMENTS

Before the landing of Surveyor I on the moon, all data which could be used to predict the surface properties of the planetary bodies were received on earth or from craft circling the earth or sun. The reflective and radiating properties of the Moon, Mars, Venus, and other planets have been used to predict their surface and atmospheric properties.

Smith and Brison[8] review remote lunar measurements which correspond to those made on the planets. In the visual range, albedo, color, backscatter, and polarization have been used to gain information on atmospheres and surface layers. Infrared has been used to estimate surface material temperatures and thermal properties. In addition to these, radar and radio measurements have been used to indicate various properties of the terrain and subsurface. References covering remote astronomical measurements and predicted surface and atmospheric properties of Mars are listed in the Subject Index.

Section III. SURFACE FORMATION

1. General

Astronomers are not in agreement as to the forces which have formed the Martian surface or the nature of the surface; however, there is no great number of different opinions. The main disagreements are on the composition of the atmosphere, surface materials, the nature of the polar caps, and as to whether the dark areas are covered with vegetation or volcanic ash.

The rims of the large Martian craters show slight erosion,[9] yet they are believed to be from two to five billion years old. The conditions of the surface and the suggested age indicate that the eroding forces of Mars are minute compared to those on earth.[10] Mariner IV data gave evidence of very low atmospheric pressure. The absence of erosion indicates that Mars has always had a very thin atmosphere which contains very little water,[11] if the area viewed by Mariner IV was representative of the major portion of the planet. The Martian polar caps are often offered as evidence of water on Mars. The polar caps are believed to be frozen water, frozen carbon dioxide, or a combination of the two. Free water is not believed to be in sufficient quantity to have participated in the erosion of the surface.[2,4,5,10,12,13,14] Winds, volcanoes, dust, surface shrinkage, vegetation, and chemical reactions are credited with creating the dark areas and canals and producing visible changes in color.

Because of the low pressure and temperature and elements of the Martian atmosphere, the production of soil-like materials by both mechanical and chemical weathering must be at a very reduced rate compared to that on earth. Mechanical weathering may have been the major process in the rounding of crater rims and in the production of soil.[15]

Volcanoes, meteorite impacts, shrinkage, and vegetation are listed among the major forces which have shaped the observed features of Mars. It has been concluded that Mars does not experience quakes or surface wrenching jolts like those experienced on earth.

The low density, high velocity winds, slow chemical reactions, surface temperature fluctuations, the growth of vegetation, meteorite impacts, and volcanoes have possibly formed and deposited the majority of the materials of Mars which could be classified as soils.

Mariner IV photographs of Mars at close range emphasized the accuracy or inaccuracy of scientists in understanding the nature and magnitudes of the forces which have formed its crust. Most of the scientists and astronomers were amazed by the number and conditions of the craters and the primitive appearance of the surface.[16] In answer to a press conference question, Dr. Leighton,[9] Mariner IV principal investigator, stated, "In view of the fact that Mars has a known atmosphere which does move material around on the surface and has somehow been eroding the craters away, I think it makes it very surprising that in the time that must have elapsed since those craters were formed that there is so much of them left. That's an extremely astonishing thing to me."

The round dark dots known as oases are thought to be the impact craters formed by the collision of asteroids.[3,17] They are possibly visible because of vegetation which grows only in the warmer and denser air in the bottom of these craters. The canals which appear to lead away from the dots may be cracks in a brittle crust caused by the impacts.[3,17] These craters, canals, and seas may be areas of low elevation which are filled with deposited soil, contain warm dense air, and support a vegetation which will reappear soon after being coated with dust or ash.

2. Environmental Forces

In Owen's survey,[1] he found sharp disagreement on the atmospheric conditions (temperature, pressure, and components) which play a major part in the forming of materials on the surface. Table I shows the ranges of predicted parameters at the time of the publication of his report. A number of these have been altered since the Mariner IV fly-by. The air temperature is expected to always be below freezing, while the ground surface probably goes above freezing. The quantity of water in the atmosphere is still believed to be very small.

The atmospheric pressure is presently believed to be between 4 and 10 millibars and to be lower in the southern hemisphere than in northern hemisphere. CO_2 has been selected as the primary component of the atmosphere.[18] By comparing the physical characteristics of Mars with the earth and moon and by noting the similarity of the three surfaces, a clearer picture of the true Martian surface may emerge.

Mars may have experienced chemical weathering in the past;[15] however, the present atmosphere does not seem to contain the elements necessary for extensive decomposition of the surface minerals.

Table I. Atmospheric Parameters of Mars[1]

Parameter	Maximum	Minimum	Most Probable
Diurnal Mean Surface Temperature (°K)	300	200	230
Surface Pressure (mb)*	135	10	25 to 40
Surface Density	1.488×10^{-4}	2.26×10^{-5}	1.28×10^{-4} gm/cm^3
Surface Wind Velocity	60 km/hr	Mild	10 km/hr
Water Content	0.01 gm/cm^2	Trace	$1.4 \pm 0.7 \times 10^{-3}$ gm/cm^2
CO_2 Content (%)*	60	0.55	2
N_2 Content (%)	98	40	94
Argon Content	30%	Trace	4
Oxygen Content	0.06%	Trace	0.04%
Molecular Weight	39	28	28.8
Tropopause (km)	24	11	17
Troposphere Lapse Rate (°K/km)	-4.170	-3.636	-3. 7

*Some interpretations of the Mariner IV data place the surface pressure between 3 and 40 millibars and list CO_2 as the main atmospheric component.

When comparing the soil forming forces on Mars with those on the moon and earth, the effects of surface temperature differences may be expected to be equal to the effects of the differences in atmospheric components. The temperature of the three bodies differ greatly in average temperatures and periodic temperature variations. Surveyor I, the soft-landed lunar spacecraft, is exposed to temperature extremes ranging from 260° to -245°F.[10] The surface of Mars (excluding the polar regions) is thought to vary from approximately 40° to -10°F.[9] The land regions of the earth have a low on the order of that expected on Mars; however, the average high is approximately midway between the high on Mars and that on the moon. According to some interpretations of

Mariner IV data, the surface temperature of Mars is not expected to rise above the freezing point of water.[20] Some typical predicted Martian temperatures are given in Table II.

Table II. Predicted Martian Temperatures

Temperature	Area	Type Data	Literature Cited
219° to 233°K	Total	Radiative Equilibrium	1
240°K	Equator	Thermal Emission	1
200° to 210°K	Pole	Thermal Emission	1
230°K	Total	Compiled Observations	1
-70°C	Night at Equator	From Review	25
	Day at Equator	From Review	25
33°C	Sunlit Side, Dark Area	From Review	25
20°C	Sunlit Side, Light Area	From Review	25
25°C	Day at Equator, Max	Estimated	22
-50°C	Night at Equator, Min	Estimated	22
10° to -10°C	South Polar Region	Vacuum Thermocouple	26
20° to 25°C	South Temperate Zone	Vacuum Thermocouple	26
20° to 30°C	Center of Disc	Vacuum Thermocouple	26
0° to 20°C	North Temperate Zone	Vacuum Thermocouple	26
-25° to -40°C	North Polar Region	Vacuum Thermocouple	26
230 ±42°K	Total	From Brightness	21
217°K	Total	Radiation Equilibrium	24
-35° to -45°C	Equator	Mean	27
Below Freezing (Water)	Total	Review Mean	23
180° to 178°K	Total	Mariner IV	20

Previous to the Mariner IV mission, the accepted value for the Martian surface atmospheric pressure was 85 millibars, 8.5 percent the surface pressure of the earth. However, some interpretations of Mariner IV data place the pressure below 10 millibars, that it is between one-half and one percent of that of the earth.[16]

3. Volcanoes

The subject of volcanoes on Mars has been discussed very infrequently. Some writers and dates mentioned by McLaughlin[28] are: Arrhenius-1918, Pickering-1926, Antoniadi-1930, Jarry-Desloges-1951, and Saheki-1955.

The numerous dark markings of the Martian surface are explained by McLaughlin in terms of natural mechanisms - "formative activity."[28] He sees the shape and color of the bays, dark areas with sharp vertices, as evidence of volcanoes and the direction of the prevailing winds.[29,30] The fact that a number of canals appear to enter the maria at the pointed bays is an indication to him that these are ash drifts carried by prevailing winds. The possibility of vegetation that can grow only in areas subject to frequent falls of fresh ash and the moisture that accompanies it is offered as an explanation of seasonal changes.

4. Canals and Craters

Mariner IV photographs revealed the unexpected fact that the surface of Mars more closely resembles the moon than the earth; that is, it is peppered with craters.[16] Meteorite impacts, not volcanoes, are credited with forming these craters. Tombaugh reasons that since Mars is near the asteroid belt, many asteroids of large size should cross its orbit and it should have been hit many times.[5] He sees the oasis-canal patterns as evidence of such impacts. The larger craters ranged in size from a few miles to approximately 70 miles in diameter.[9]

The canals have been recognized as fractures of the crust, the craters as collisions with asteroids, and the maria as the sunken surface which is filled with materials from the areas of higher elevation. Crustal fracturing may have produced the visible angular features. While some maria exhibit features that suggest monocline folding, other maria have sharply defined and fixed boundaries that are difficult to explain unless faulting has been involved.[17] Among the latter are certain maria in which canals have been seen at their borders during their late summer season. In still others, such as the apex of the Syrtis Major, the coastlines are exactly aligned with canals on the adjacent desert, which suggests that the canals are the result of faulting or crustal fracturing. The crustal readjustments produced by internal convection cells could have created horsts and grabens.[3,17]

Mars may have developed basins similar to those which make up the oceans of the earth.[17] This could have been accomplished by folding or faulting. The earth has many fracture zones on both the continents and ocean basins. If the earth ocean basins were drained of the water, the steep escarpments of the continental shelves would resemble the maria of Mars and the earth's atmosphere would drain into these basins and cause the continents to be cold, barren plateaus.

Another class of features, known as "carets," appears to be the product of faulting.[17] These are the very dark and very sharply defined small triangles found along the northern edges of Mare Sirenum, Mare Cimmerium, and Sabaeus Sinus, and they are exactly determined by the angles of two canals converging at the coastline.

5. Soil Formation by Impacting Meteorites

A hypervelocity particle is vaporized upon impact with a surface along with a portion of the surface material. Even huge meteors would be partially vaporized. The quantity of surface material vaporized is a function of the mass and impact velocity of the projectile.[31, 32] The condensed vapor would settle as a superfine flour. Surface and subsurface materials would be scattered by the high temperature, high pressure explosions caused by the impacts. The Mariner IV dust detector shows that the frequency of micrometeorite impacts increased as the craft moved from earth's orbit to that of Mars. The number of impacts decreased as the craft neared the orbit of Mars. This suggests that the orbital path of a planet is swept clean of dust by the planet.[16] Because of a higher quantity of material vaporized by meteoric impacts, Mars may be expected to have more of a powdery, pulverized surface than the moon.[9, 33] Since Mars is believed to have high velocity winds, a large portion of this dust may be expected to be carried great distances and deposited in the low areas.

6. Physical Forces

The surface and atmospheric characteristics of a planet are directly related to its physical characteristics. Owen[1] tabulates the physical characteristics of Mars (Table III) which are listed by a number of recognized authors. A careful analysis and comparison of the effects of these factors in forming the atmosphere and surface of the earth and the moon may produce a closer approximation to the Martian surface.

Table III. Tabulation of Physical Characteristics of Mars[1]

Mean Distance From Sun (A)	1.523691 A. U.
Inclination of Orbit to Ecliptic (I)	1.84991 deg
Eccentricity of Orbit (e)	0.093372 (1964)
Mean Daily Motion (η)	0.524033 deg/Sidereal Day
Mars Orbit to Mars Equator	25.20 deg
Mean Orbital Velocity	24.13 km/sec
Circular Velocity at Surface	3.55 km/sec
Escape Velocity	5.04 km/sec
Mean Solar Constant	0.840 cal/cm^2 min
Sidereal Year	686.980 Earth Sidereal Days
Mean Synodic Period	779.935 Earth Sidereal Days
Mass	0.642×10^{27} gm
Bulk Density	4.04 gm/cm^3
Mean Surface Gravity	375 cm/sec^2
Radius (Equator)	3374 km
Albedo (Integrated)	0.25
Perihelion Distance	1.381428 A. U.
Aphelion Distance	1.665954 A. U.
Sidereal Day	24 hr 37 min 22.668 sec
Solar Day	24 hr 39 min 35.247 sec

The absence of a Martian magnetic field[34] means that the top of the atmosphere is bombarded by all solar and cosmic radiation since there is no magnetic shielding. This undoubtedly affects the Martian environment.

Section IV. SURFACE MATERIALS

1. General

Mars, the fourth planet from the sun, was named for the God of War because of its red color. This color offers the first indication of possible surface materials of the planet. The bright orange areas give it a reddish hue.[35]

The Martian soil and surface characteristics, or presumed characteristics, may presently be influencing the design of exploratory vehicles. Many unusual lunar soil models and wheels designed to move over these soils were produced before the Surveyor I landed on the moon. Many of these will not be useful now but the vehicle design engineers cannot always wait for conclusive evidences. For preliminary design considerations, Andrisan offered a model Martian atmosphere and surface which could be used in the design of a vehicle.[36] Several others have listed possible characteristics.[22]

2. Fine Grain Material

Evidence and reasoning still support the hypothesis of a dust-covered Martian surface even though the predicted loose dust cover for the moon was not shown by Surveyor I photographs. There is no evidence yet to prove that the small clumps of material on the moon are not made up of fine grains. From earth observations, loose dust is indicated as a covering for a major portion of Mars.[38] Polarization and brightness curves from the reddish-brown desert is closely approximated by pulverized limonite.[22] The deserts may be vast plains of sand which have undergone extensive weathering,[22] both mechanically and chemically; however, recent Mariner IV photographs show very slight weathering. It is suggested that the surface may consist of sandy soil with admixtures of rock fragments. The bearing pressure may be expected to be from 20 to 30 pounds per square inch.[22]

Surface temperature studies support the hypothesis that the Martian surface consists of finely divided material having a characteristic size not more than a few microns.[37] Soil conductivity, density, and specific heat are the characteristics of powdered minerals at low gas pressure[23, 38]

Because of the similarity of the Martian surface and the lunar surface, as viewed from several thousand miles, the interpretations of the Orbitor and Surveyor I data will be of high interest to those studying Mars.

Both appear to have been peppered by meteorites for billions of years. The lunar surface[39] has the appearance of a plowed rocky field after a light rain. This pulverized appearance is at least partially caused by the endless pounding of the surface with meteorites of all sizes which have produced a soft fine grain material which tends to form clods because of a slight cohesive force between grains. The blocks and rubble strewed over the area could be the fragments of low velocity meteorites or lunar material possibly blown out of the craters by the impact and explosions of large meteorites. They appear to be partially covered by the fine grain material. Because there is no atmosphere and wind on the moon, the thickness of the layer of fine grain materials may be approximately independent of elevation. On Mars, the depressions may be filled with the fine grain materials which have been removed from the highlands by the high velocity winds.[40,41] This fine material may cover the bottoms of the craters, canals, and basins. This layer of fine grain material may have similar characteristics to that on the moon; that is, a bearing capacity of about five pounds per square inch with a cohesion in the range of 0.02 to 0.05 pound per square inch and a friction angle between 30 and 40 degrees at a density of approximately three slugs per cubic foot.[39]

3. Iron Oxide

The fact that Mars has no detectable magnetic field[42,43] suggests that a migration of iron to the core has not occurred and that more iron may be on the Martian surface than on the terrestrial surface.[43]

The abundance of iron oxides on the surface of Mars may be partially the results of bombardment by asteroidal meteorites and the oxidation of their fragments.[6,43]

An iron oxide composition appears to constitute a significant portion of the Mars surface. The Martian surface material most often mentioned is the mineral limonite ($Fe_2O_3 \cdot nH_2O$), a ferric oxide polyhydrate.[43] The ferric oxides have remarkable photometric, colorimetric, and polarimetric properties.[43] Many minerals have been found to match the Martian reflectivities but limonite only matches the bright areas in color.[43]

Kiess and Birney[44] and Bliss[22] list powdery limonite as the chief constituent of the bright areas as evident from the photometric and polarimetric observations of several observers. Pulverized limonite is indicated by the visible and near infrared spectra according to Sagan, Phaneuf, and Ihnat.[45]

Further evidence supporting the limonite theory is offered by Adamick. The partial pressure of water in the Martian atmosphere according to his calculations is approximately that expected from the dissociation pressure of limonite. The vegetation in the dark areas may be linked with a limonite surface;[15] that is, the environment of limonite may provide a suitable echological basis for respiratory and photosynthetic organisms. The water of crystallization may function as a water reservoir for growing microorganisms.[46]

Opik and others studied the polarization characteristics of several hundred minerals.[6,45] Of these, the polarization curves of limonite ($2Fe_2O_3 \cdot 3H_2O$), geothite ($Fe_2O_3 \cdot H_2O$), and similar iron oxides showed almost complete agreement with the polarization curves produced from the Martian surface reflection.[6,47]

Dollfus selects limonite, $Fe_2O_3 \cdot nH_2O$, as the most likely material in the bright areas as a result of his studies of the polarization of reflected light from the surface of Mars.[46] Sharonov (1961) found brightness and color-index matching between the Martian surface and limonite. The yellow ochre variety, only, matched the bright areas.[45]

Sinton assumes that a very small part of the surface materials are silicates because of the absence of characteristics emission spectra in the midinfrared.[15] Kuiper found the best spectral agreement was with pulverized brown felsite.[35]

4. Nonferric Materials

The most common constituent of the present Martian surface, according to Van Tassel and Salisbury, is the minerals most abundant and resistant to abrasion - something more common than limonite.[15] The color and reflectivity of the Martian deserts could be due to some minor constituent of the soil. The surface may be fine or coarse-grained silicates covered with fine limonite. Rea states that the softness of limonite could act to concentrate it on the surface well above its natural abundance.[37] Because the lack of characteristic infrared emission spectra of silicates could be used in the argument against silicate material, the emission spectra of powdered rock and mineral samples were obtained in the laboratory to aid in evaluating measurements.[15,37]

The surface of Mars could be composed of fine-grained silicates with iron-oxide impurities to explain the observed spectrum and color.[15]

The low density of Mars, which indicates a low metal content, should have some bearing on surface materials. Elements of lower density than iron may be expected to make up most of the surface.[15]

Silicon and aluminum are far more common than iron in the minerals of the earth's crust and may be expected to compose a larger portion of the minerals on Mars.[15] Van Tassel and Salisbury state that hydrated iron oxides could not cover a major portion of the Martian surface.[15] They produced experimental data that showed powdered silicates could have similar spectra characteristics to powdered limonite.

Tombaugh sees evidence that the Martian deserts consist of rhyolitic igneous rock.[3,5,17] He does not see spectral and polarization analyses as sufficient evidence for minerals like felsite.[48] The lack of water erosion would prevent the exposure of granitic and metamorphic rock.[3]

5. Organic Matter

The arguments for the existence of Martian life are the colors, seasonal changes in albedo and polarization, the ability of the dark areas to regenerate after extensive dust storms, and the presence of absorption bands attributed to organic molecules.[49] Weak absorption bands in the infrared spectra indicate the presence of organic molecules and support the hypothesis of life on Mars.[50] Spectrographic curves of the center of Mars over a wavelength range from 3850Å to 3100Å show undulations which may be produced by organic compounds.[51]

The wave of darkness which sweeps toward the equator as the polar caps melt is attributed to vegetation.[52] Dust carried by the winds would not produce the same pattern each year and could not be used to explain the movement of the wave.[53] Animated microorganisms may be present on this powdery surface and are most active during the growing season.[54]

The vegetation on Mars is probably dissimilar to most known earth vegetation. It has been suggested that the vegetation does not produce chlorophyll[55,56] and may be extremely resinous.[57] Algae and lichens do not show spectrographic absorption of infrared reflections characteristic of chlorophyll-bearing plants.[56]

Sinton and others give observational evidence of vegetation in the dark regions of Mars.[58] Sinton showed evidence of hydrocarbons. The oldest evidence is the seasonal variation. It has recently been found that the polarization properties of these areas vary with the season.[58] Characteristic infrared absorptions of organic matter are present in the dark regions.[35,58]

Evidence against vegetation was produced by Kuiper who found that the dark areas do not have the near-infrared reflection properties of chlorophyll, and he suggests that they may be lava fields.[35,59] McLaughlin suggests that these areas are volcanic dust.[28] Smaluchowski suggests that some of the regional color variations may have inorganic explanations.[60] One possibility is that some color variations may be the results of solar flares.[60] The low atmospheric pressure, as indicated by Mariner IV data, would not be conducive to earth type plant life.[14,15,37]

Section V. TERRAIN

1. Elevation

Fitch and Miller[61] predicted that Mars will not possess any system of orogenic mountain belts comparable with these on earth. Any relief on its surface sould be of volcanic or volcano-tec-tonic origin as on the moon.

The borders of some maria are sharply defined in appearance and do not migrate. This indicates abrupt vertical relief produced by faulting. Tombaugh reasons that the intensity and persistence of vegetal darkening may be an indicator of altitude of the terrain.[17] Under the extremely dry and cold conditions prevailing on Mars, vegetation could better survive in regions where the air is denser and warmer which would be in the low elevation areas.

The dark areas were first thought to be bodies of water; presently, they are pictured both as depressions and elevated mountain ranges. There has been no conclusive evidence that these areas are either of the these.

Wells[62] offers his opinions and those of others on the nature of the dark areas and on the variation of surface elevation. He concluded that the dark areas could be mountain ranges of considerable height but with gentle slopes. According to Well's survey, Lowell is of the opinion that no mountains in excess of 2500 feet exist. This was concluded because of the absence of visible shadows. Wells also discussed the findings of Focas and Dollfus who recorded a number of instances where white clouds were observed to form over bright desert regions bordering dark areas and to remain stationary for some time. This was given as evidence of mountain ranges.[62]

Mariner IV radio measurements indicated that the Electris area of the southern hemisphere is on the order of 16,500 feet higher than the northern hemisphere's Mare Acidalium.[7] Crater rims may rise hundreds of feet above the surrounding terrain.[16] The maximum slope measured up to 10 degrees.[16] One large elevation change was estimated at 13,000 feet.

2. Canals

Schiaparelli, the discoverer of the canals, regarded the canali, a network of dark lines, as a possible system of channels which were built by intelligent Martians for irrigation purposes.[63] Lowell, a partner in this theory who saw the canals as bands of vegetation along irrigation canals, worked to prove it until his death in 1916. Dr. Barnard and Dr. Wallace, the former of which was Lowell's strongest opponent, insisted the canals were of natural formation such as surface cracks.[12] Tombaugh ruled out such a possible civilization due to a lack of resources.[5]

There are many theories which attempt to explain the canals. The canals may be major fault zones in which the surface irregularities have trapped volcanic ash, rift valleys, related to fault zones, or igneous dikes.[29] Pickering describes the canals in terms of broadness, haziness, and mixed regularity and irregularity.[64] Delmotte proposed that the Martian canals were of similar origin to the lunar and terrestrial lineaments.[65] Banman believed the canals were cracks in frozen seas and ran from volcanic islands.[66] According to Gallo, the canals are merely natural depressions of the soil and occur at different levels.[67] McLaughlin stated that the canals are most likely strings of small volcanoes aligned along crustal fractures linking the impact craters with themselves and with major volcanoes.[29]

Tombaugh[48] sees the canals as depressions which may be havens for vegetation and as radial lines related to the oasis and maria which may indicate a sudden shift in elevation.

de Vaucouleurs[68] saw the geometric and canal network which was widely discussed at the turn of the century as optical illusions. Many other astronomers, such as Dollfus who studied the canals, agreed with de Vaucouleurs. Many who had not seen them doubted their existence.

The reappearance of some of the famous canals after long periods of invisibility remains one of the most puzzling and intriguing problems of Mars.[68] Questions about the existence of canals are yet to be answered. There is no doubt, however, that some of the broader streaks such as Nilosyrtic have real existence, but the presence of finer canals is very much in doubt.[63]

3. Polar Caps

The nature of the polar caps has been a subject of speculation since they were discovered by Cassini in 1666. The most popular opinion is that they are composed of snow. Frozen water, carbon dioxide, and oxides of nitrogen have been selected as compounds which could form the caps. The latest evidence produced by Leighton and Murray points toward frozen carbon dioxide.[23] They believe that the frozen carbon dioxide may be covered by a thin layer of water ice. Recent evidence including the analysis of Mariner IV data which indicates that the atmosphere is predominently carbon dioxide[23] supports the theory that the polar caps are dry ice, frozen CO_2 .

Section VI. CONCLUSIONS

If Mars is not covered by a fine soil but by hard rock, there is little reason to be concerned with vehicle wheel design; however, if the surface is largely covered by a loose dust, as the accumulated evidence indicates, the engineer must assume soil characteristics in designing an optimum wheel. Soil mechanics texts classify soil as gravel, sand, silt, and clay according to the grain size. If the high velocity winds on Mars[4, 24, 28, 53, 62, 69] have had a significant part in the transportation of dust, the lowlands may be expected to have a cover of clay or silt. More rocks and sand may be exposed in the highlands. Soils are generally light in color if composed of crushed minerals which have undergone little chemical weathering but are darker and have different characteristics if they contain decayed organic matter and have experienced chemical reactions. Chemical weathering must take place at a very low rate on Mars because of the low atmospheric pressure and temperature; however, in the very low elevation regions, basins and craters, both temperature and pressure should add to increase this rate Many Mars writers consider the dark areas as vegetation havens and of low elevation. The Martian explorer may expect to find materials in the lowlands somewhat similar to earth materials and more like the moon in the upper regions. The fine grain materials may be expected to exhibit some cohesion, to contain both silicates and metallic oxides, to have lower density than earth clays, and to exhibit lower compressive strength than earth soils.

Mars appears to have fewer craters of 10 kilometers (six miles) and less than the moon, with the highest concentration of small craters on the rims of large craters.[18] This suggests something special about the location or composition of the rim. This may indicate that the rim is much harder than the surface at other locations. Possibly, some of these craters were formed along with the large one by fragments trailing far behind the main body or by fragments of the main body and surface which were blown out by the impact explosion. If the rim is very hard and at higher elevation, these craters may experience negligible erosion and may be swept clean by periodic high velocity winds. Craters of this size on the flat surface may be hidden by a deposited layer.

Ranger, Mariner IV, Surveyor, and Orbiter have added facts and confidence to those searching for clues to the evolution of the solar system and will probably inspire the writing of many revised theories on the environments of the planets.

Section VII. RECOMMENDATIONS

A sample of simulated Martian material and a better understanding of the Martian lowland soil could possibly be obtained by passing high velocity, low density dry air over crushed rock after each impact by the hammer. Both silicates and iron oxides should be used. The dust samples would be collected in sinks in the downstream circulation system. These samples should be induced to compact and be stored dry for a reasonable length of time before being tested. Some samples probably should be given static charges.

A better sample of the powdery surface might be produced by bombarding the rock samples with hypervelocity meteoric-like projectiles.[31,32] The fine grained material and condensed vapor should also be removed from the impact area by the high velocity air simulated Martian air and collected downstream. If a gun which could fire the high velocity projectiles could not be built economically, the rock dust could be blasted from a surface by exploding conductors embedded in the surface or on the surface.[32]

Consideration should be given to landing the first Martian-wheeled exploration vehicle on the edge of a desert near one of the seas which has a migratory border.

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Investigation of the relative rates of crater formation on Mars and the moon for the purpose of determining the age of the lunar and Martian craters. It is shown that the rate of crater formation on Mars is about 25 times higher than that on the moon. The crater density observed by Mariner 4 points to an age only one-sixth that of the lunar maria, or 300 to 800 x 10^6 years. Hence, no conclusions can be drawn from the Mariner 4 photographs concerning the early Martian environment.

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The aspects of providing a surface roving vehicle capable of being transported to and landed on the Martian surface by current spacecraft should enhance our Mars exploration program. Advocating a small simple vehicle design employing techniques and components developed during the ALSS/AES/AAP program and permitting the vehicle to perform only a few scientific experiments assures a greater margin of success.

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Polarization of Venus and Mars at seven wavelengths was observed. Measurements of Venus from 1959 to 1965 show fairly good repetition when observed with infrared, red, and green filters. With the ultraviolet filters, however, appreciable differences are found from year to year. The differences are presumably caused by variations in the optical thickness of the molecular atmosphere above the cloud layers. Observations were made with the 21-inch reflectors of the Steward Observatory in Tucson and the Lunar and Planetary Laboratory in the Santa Catalina Mountains north of Tucson. For both telescoped and instrumental polarization was determined by observations on nonpolarized stars. A few strongly polarized stars were also observed. A good set of measurements was obtained on the polarization of Mercury. Polarization of the whole moon was observed by using the photometers with a one-inch lens instead of the usual telescope.

12. Author Unknown
CRATERS FOUND ON MARS, Science News Letter, 7 August 1965, p. 82.

The Mariner 4 photographs of Mars, man's first close-up pictures of another planet, revealed the totally unexpected fact that the Martian surface, like earth's moon, is peppered with craters.

The Scientists studying Mariner 4's photographs conclude from the "remarkable state of preservation of such an ancient surface" that no atmosphere much more dense than the tenuous one now found has been present on Mars since its surface was formed.

13. Author Unknown
LIFE ON MARS? Missiles and Rockets, 6:3, 18 January 1960, pp. 32-33.

According to Kucherov, the observed color of the dark spots or "seas" changes according to the time of the year; blue-green in the spring, brown or grey-brown in the fall; also they change outline and size. Tikov demonstrated that the spectral curves of the "seas" of Mars coincide with the same curves for earth plants growing in severe climatic conditions. The Soviets plan further study of Mars at the new Planetary Division to be opened at the Pulkovo Observatory.

14. Author Unknown
MARS ATMOSPHERE COOLER, Science News Letter, 2 October 1965, p. 213.

Mariner 4 measurements show that electron density at different levels of the Martian atmosphere is lower than predicted, indicating that the atmosphere is cooler than thought.

Previous models of Mars' atmosphere indicated nitrogen as the main constituent. Mariner, however, has shown carbon dioxide to be abundant, meaning that radiative cooling is more effective in the upper atmosphere than was believed.

Surface temperatures, according to Mariner, are probably between about -135° and -150°F.

The density of the atmosphere at the surface, measured by its effect on Mariner's signal, probably ranges from 4.0 to 7.0 millibars of pressure.

15. Author Unknown
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Continuing analysis of Mariner 4 Mars radio occultation experiment shows a difference in atmospheric density between the northern and southern hemispheres which could be explained by a small simple planetary orbiter.

16. Author Unknown
MARTIAN SURFACE SHOWS MOON-LIKE QUALITY,
Aviation Week & Space Technology, 2 August 1965, pp. 30-31.

ABS - Scientists who first analyzed photographs of the Martian surface returned by Mariner 4 were awed by the unexpected number and size of craters resembling those on the moon and by other topographical features which showed few signs of the erosion that earth has experienced over the same billions of years.

17. Author Unknov
VARIATIONS IN MARS' SURFACE HEIGHT FOUND, Science News, 89:418, 28 May 1966, p. 418.

Regions on the surface of Mars vary in height by as much as three miles, measurements made during the Mariner 4 fly-by of the red planet.

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MARS: AN ESTIMATE OF THE AGE OF ITS SURFACE,
Design Considerations for Mars Vehicle, Presentations Made at AIAA/AAS Stepping Stones to Mars Meeting, March 1966, pp. 28-30.

Intercomparisons of crater counts on Mars and the moon suggest that the age of the visible Martian surface is approximately 340 to 680 million years.

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The following aspects are discussed· the surface structure of Mars and the colors and color variations of the Martian continent, seas, and canals; the color and color variations of the polar caps (albedo in different spectral regions); the variations of the size and darkness of certain spots on the planet's surface that comprise vast moistened continental regions; the different types of bright regions on the surface and in the atmosphere; the variations of atmospheric transparency; and the variation and degree of polarization of the different formations on the planet.

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PHYSICAL CONDITIONS ON MARS (FIZICHESKIYE USLO VIYA NA MARSE), Translated into English by the National Aeronautics and Space Administration, Washington, D. C., Report No. NASA TT-F-165, N63-19862, August 1963, (Vestnik Akademie Nauk SSSR (Moscow), No. 10, 1962, pp. 18-25).

A discussion is presented in an effort to clarify what is reliably known about Mars, what is in the realm of more or less probably conjecture, and finally what is still completely unexplainable. Significant areas for future research toward determining the physical aspects of planets are indicated.

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PRELIMINARY RESULTS OF OBSERVATIONS OF MARS (PREDVARITEL'NYE REZUL'TATY NABLYUDENII MARSA), Translated into English by the American Meteorological Society, Boston, Massachusetts, Report No. AmMetSoc T-R-426, TT 64 11834, AD-602 193, Contract No. AF19 628 3880 (Akademiya Nauk SSSR, Vestnik, 1957, Vol. 27, No. 5, pp. 34-36).

The observation period covered nearly five months in 1956. The atmosphere and surface of Mars were studied intensively with various astronomical instruments. On 3 to 4 December 1956, a conference was held, at which the participants in the observations reported on their investigations and discussed a number of questions connected with processing the results.

22. Barabashov, N. P. and Garazha, V. I.
SOME REMARKS ON THE DUST AND HAZE FORMATIONS ON MARS (Foreign Title Not Available), Translated into English by the Kharkov Astronomical Observatory, July-August 1960, Vol. 4, No. 1, pp. 1-186 (Translated from the Astronomicheskii Zhurnal, Vol. 37, No. 3, May - June 1960, pp. 501-507, Vol. 37, No. 1, January - February 1960, pp. 3-192).

In the present article, inferences based on an examination of the brightness distribution curves during the 1956 opposition and the rearward portions of indicatrices are drawn as to the structure of the Martian solid surface, and as to the properties of the yellow clouds and mist which often appear in the Martian atmosphere.

23. Barker, R.
THE ASH THEORY OF MARTIAN FEATURES, Journal of the British Astronomical Association, Vol. 65, pp. 235-236.

On the basis of visual observations, objections to the volcanic ash theory of Martian dark areas are raised. Marked parallelisms exist on the moon but lunar volcanism would seem very improbable. The maria of Mars have distinctly shaped outlines and the thin atmosphere on Mars would seem to contraindicate patterns of ash laid down by trade winds. The wave of darkness sweeping towards the equator as the polar caps melt can be attributed only to vegetation. Weak points in the Martian crust may hold volcanoes, but any ash deposits would soon be covered by windblown dust from the desert. The volcanic theory would seem to be untenable in the light of available evidence for vegetation's causing the dark areas of Mars.

24. Barricelli, N. A.
PROSPECTS AND PHYSICAL CONDITIONS FOR LIFE ON VENUS AND MARS, Scienta, Milano, 96:11, November 1961, pp. 337-343.

A review is given of the physical conditions including density, size, surface temperature, and atmospheric properties including water content on Mars and Venus. It is thought that conditions for developing organisms with properties of living beings do not need to be similar to conditions on earth. The evidence for life on Mars and Venus is reviewed and analyzed, and generalized speculation as to types and properties of any organisms already present is made.

25. Beller, W.
MARINER TO TEST MARS LIFE THEORIES, Missiles and Rockets, 10:16, 16 April 1962, pp. 31-32.

The schedule and plans of the Mariner A, B, and R projects for the fly-by of Venus and Mars are discussed. The theories concerning the properties of life to be found on Mars are reviewed. The types of plants and certain aspects of metabolism of Martian life are discussed, as well as the role of the Mariner projects in the verification of these theories.

26. Binder, A. B. and Cruikshank, D. P.
COMPARISON OF THE INFRARED SPECTRUM OF MARS WITH THE SPECTRA OF SELECTED TERRESTRIAL ROCKS AND MINERALS, Tucson, Arizona, University of Arizona Press, 1964, pp. 193-196, Grant No. NsG 161-61 (Communications of the Lunar and Planetary Laboratory, No. 36-39, A65-23262).

Comparison of Kuiper's low-dispersion IR spectrograms of Mars (obtained with the 82-inch telescope of the McDonald Observatory) with laboratory and solar spectra obtained by the authors with the same equipment and matching resolution. The detector was a 0.1-mm PbS cell, used with a rapid scan rate (1.3 μ/min), giving a resolution of about 60 at 1.5 μ. This resolution is sufficient to resolve the CO_2 bands at 2.01 and 2.06 μ. The rock and mineral samples were observed using solar illumination in the laboratory at Tucson. The results indicate that if a Martian analogy can be drawn with terrestrial deserts, it may be assumed that the Martian surface is composed partly of stained outcrops, rock fragments, and finer material.

27. Bliss, P. H. and Hall, B. W.
PRELIMINARY DESIGN OF MARS BASING, Advances in the Astronautical Sciences, Exploration of Mars, Vol. 15, 6 June 1963, pp. 446-467.

This paper is an attempt to focus attention on the design and construction problems for a Martian base; an immediate, prefabricated, inflatable shelter is proposed for the first crew that lands on Mars which will serve for headquarters while additional base construction is performed. The design and construction of basing facilities on Mars appear to be within the limits of present technologies, but designs proposed in this paper will probably require modifications as more information concerning Mars is obtained.

28. Bongers, L. H.
IS THERE LIFE ON MARS? Space/Aeronautics, Vol. 40, August 1963, pp. 86-88 (A63-23009).

Brief discussion of the forms of life which might be expected to be found on Mars, and of the sampling methods which could be used, from unmanned Mars vehicles, to establish the existence of these life forms. The possibility of life on Mars is discussed in terms of the Martian atmosphere and in terms of the hypothesis that the Martian surface markings are caused by vegetation. Among the possible sampling methods briefly described is the Gulliver system, which would detect the metabolic activity of Martian biota by measuring the radioactive carbon dioxide formed by organisms taken from the Martian surface and placed into a C^{14}-labeled nutrient broth.

29. Briggs, M. H.
NEW EVIDENCE OF MARTIAN LIFE, Spaceflight Today, London, England, Iliffe Books, Ltd., 1963, pp. 223-227 (A64-80565).

Studies of the infrared spectra of Mars demonstrated the presence of absorption bands probably due to organic compounds. These absorptions are characteristic of the spectra from the dark areas of the surface. This evidence points to the existence of complex organic substances in these areas of Mars. Absorptions which are typical of carbohydrate molecules were found.

30. Briggs, M. H. and Revill, J. P.
THE CHEMISTRY OF MARS, II-THE SURFACE, Journal of the British Interplanetary Society, 17:12, November-December 1960, pp 459-461.

The physical conditions at the Martian surface are reviewed and the various hypotheses as to its chemical nature are discussed. Night temperatures on Mars are in the region of - 70°C; daylight temperatures at the equator on the sunlight side are around 20°C; and 33°C has been recorded for the dark areas. Polarization studies have shown Mars to be dusty with a surface of crumbled rock. Polar ice caps melt and reform seasonally and are presumed to be frost. Reddish deserts may be of the following:

1) Hydrated ferric oxide, indicating a past history of oxidizing atmosphere.
2) Folsitic rhyolite, which provides no clue to the Martian atmosphere.

Dark surface markings or maria change seasonally from green and blue to brown and red, probably indicating vegetation consisting of simple plants with low oxygen output. Infrared analyses show absorptions similar to carbon-hydrogen bonds which may or may not be of biotic origin. The possibility that the maria are of volcanic origin is considered as a secondary nypothesis.

31. Burgess, E.
THERE ARE "CANALS" ON MARS, Spaceflight, Vol. 8, Feburary 1966, pp. 46 - 47, 74 (A66-20472).

Study of the presumed existence of canals on the surface of Mars. The Mariner experimental team announced that examination of the reconstruction of the photographs of Mars from digital data showed no canals. Unfortunately, this interpretation of the Mariner photographs appears to be incorrect. At least one photograph includes a very clearly defined linear feature in the position of a Martian canal.

32. California University, Berkeley, California
SOME COMMENTS ON "THE COMPOSITION OF THE MARTIAN SURFACE" by R. A. Van Tassel, J. W. Salisbury, and D. G. Rea, Report No. NASA-CR-60258, NSG-101-61, X65-35465, 819648 (Unclassified Report).

Abundant and abrasive resistant minerals should constitute the Martian surface layer. Silicates coated with fine limonite could satisfy photometric and polarmetric observations.

33. California University, Space Sciences Laboratory, Berkeley, California
THE ATMOSPHERE AND SURFACE OF MARS, A SELECTIVE REVIEW by D. G. Rea, 1965, Report No. NASA-CR-68136, N66-12974, Contract No. NASr-220, Grant NsG-101 (Presented at the Lunar and Planetary Seminar, California Institute of Technology, Pasadena, California, 17 September 1965) (Unclassified Report).

Recent significant developments in our knowledge and understanding of the Martian atmosphere and surface are reviewed. The surface pressure estimates using different techniques are roughly as follows: near infrared spectroscopy, 3 to 90 mb; ultraviolet albedo and spectrum, 3 to 30 mb. The atmospheric abundances are: CO_2, 45 m atmosphere; H_2O, 14 μ precipitable H_2O, variable in time and space; no others detected. Of the latter, two of the most important are O_2 and O_3 whose upper limits are two cm atmosphere and four μ atmosphere, respectively. The atmosphere probably contains a semi-permanent load of submicron particles (CO_2 or H_2O crystals, or dust) giving the "blue haze." The blue and white clouds are attributed to ice or CO_2 particles. The surface is characterized by bright and dark areas. The bright areas are covered with dust which is evidently a weathering product of the dark areas. The color is attributed to the ferric ion, but its concentration relative to silicon need not be higher than the relative solar abundance. Dust storms originate in the bright areas, indicating that the local winds at an altitude of one meter are higher than 145 km hr^{-1}, and may be as high as 300 km hr^{-1}, or higher. The dark areas consist of maria, oases, and canals. It is suggested that the maria are extensive deposits of volcanic ash, the oases impact craters of small asteroids, and the canals loci of small volcanoes oriented along crustal cracks connecting the oases with themselves and with the volcanoes.

34. Campbell, W. W.
THE PROBLEM OF MARS, Publications of the Astronomical Society of the Pacific, Vol. 30, 1918, pp. 133-147.

The controversy over the canal systems of Mars is reviewed in the form of a series of quotations by Pickering and Lowell. Lowell supports the visual detection of fine, regular systems, possibly artificial. Pickering describes the canals in terms of broadness, haziness, and mixed regularity and irregularity. The canals, as observed by two capable astronomers, differ completely and it is suggested that in view of the limited diameters of the telescopes employed, the features of the canals might be beyond visual acuity.

35. Coblentz, W. W. and Lampland, C. O.
RADIOMETRIC MEASUREMENTS ON THE PLANET MARS, Physics Review, Vol. 29, 1957, pp. 372-376.

Measurements with vacuum thermocouples interrupting only 0.01 of the area of Mars' image show that the southern (summer) hemisphere is warmer than the northern hemisphere, the dark areas are hotter than the adjacent bright areas, and the forenoon side is cooler than the afternoon side. Estimates of temperatures as viewed on the central meridian are: south polar region 10° to -10°C, south temperate zone 20° to 25°C, center of disk 20° to 30°C, north temperate zone 0° to 20°C, north polar region -25° to -40°C.

36. Cross, C. A.
CONDITIONS ON MARS, Spaceflight Today, London, England, Iliffe Books, Ltd., 1963, pp. 192-203 (A64-80527).

The manner through which knowledge of the planet Mars can be deduced from astronomical observations is described. Aspects included are Martian topography and meteorology. The possibilities of the existence of vegetation on the surface of Mars and of the survival of man in the Martian atmosphere are discussed. In spite of the application of all the resources of modern astronomical technique, Mars still remains more the subject of speculation than of established fact. Only when vehicles from the earth have carried men or machines to Mars will this situation be substantially changed.

37. Cross, C. A.
CONDITIONS ON MARS, Spaceflight, 2:1, 1959, pp. 25-29.

In spite of the application of all the resources of modern astronomical technique, Mars remains more the subject of speculation than of established fact. Mars' polar caps are presumed to be ice, but water cannot be detected spectroscopically. Temperature measurements show that the atmosphere and surface are too cold to provide enough water vapor for detection by present techniques. Polar caps show temperatures around -50°C and evaporate by sublimation twice a year. Reddish areas or deserts with dust storms appear to be present. Dark areas in bands north and south of the equator with temperatures of 20°C show seasonal changes in color. A vegetation hypothesis is favored for these dark areas, especially since studies of Siberian vegetation indicate increased absorption coefficients in the long wave region by plants growing at very low temperatures. The constituents of the Martian atmosphere identified by spectroscopic technique register 1.5 percent CO_2, and water vapor and oxygen, if present, not in excess of 0.01 and 1.5 percent, respectively.

38. Cyr, D. L.
MARS REVISITED, Philadelphia, Dorrance, 1959, 120 pp.

Contents: Chapter 1: Mysterious Mars. Chapter 2: Crater Oases of Mars. Chapter 3: The Mystery of "Canals." Chapter 4: The Evidence for Marsitrons. Chapter 5: Missions of Marsitrons. Chapter 6: Is There Really Life on Mars? Chapter 7: The Natural History of Mars.

39. de Vaucouleurs, G.
GEOMETRIC AND PHOTOMETRIC PARAMETERS OF THE TERRESTRIAL PLANETS, Icarus, Vol. 3, 1964. pp. 187-235.

A critical examination is presented of the diameters, ellipticities, and spectral albedos of Mercury, Venus, and Mars derived by many observers in the course of the past 100 years. The systematic and accidental error in the various methods are discussed, and the results are weighted accordingly to produce best estimates of the diameters, ellipticities, and albedos for the three planets.

40. de Vaucouleurs, G.
MARS, Scientific American, 188:5, 1953, pp. 65-73.

Observations of the main features of the Martian surface and atmosphere are assembled. The review includes discussions of the polar caps, deserts, atmosphere, clouds, climate, dark areas, and canals. The plant-life hypothesis is considered to provide the most likely explanation of the seasonal variation of the dark areas. However, the characteristic reflection spectrum of chlorophyll is absent. This does not exclude the possibility that lower forms of plant life such as lichens, mosses, and algae may exist.

41. de Vaucouleurs, G.
OPTICAL STUDIES OF THE SURFACE AND ATMOSPHERE OF MARS, Exploration of Mars, North Hollywood, California, Western Periodicals Company, 1963, pp. 519-532 (Proceedings of the American Astronautical Society Symposium on the Exploration of Mars, Denver, Colorado, 6-7 June 1963, Advances in the Astronautical Sciences, Vol. 15, A64-10124).

Discussion of telescopic studies of Mars during the past 20 years which have confirmed and slowly added to our general knowledge of the planet. The fine structure of the surface, the so-called "canals," and the seasonal and irregular variations are described. The latest data on atmospheric composition and pressure are reviewed.

42. de Vaucouleurs, G.
PHYSICS OF THE PLANET MARS, Astronomical Society of the Pacific, Vol. 6, No. 251-300, April 1952.

The climate of Mars might be likened to that of a terrestrial desert shifted to the polar regions and lifted to stratospheric levels.

43. de Vaucouleurs, G.
THE PHYSICAL ENVIRONMENT ON MARS, Physics and Medicine of the Atmosphere and Space, New York, New York, Wiley & Sons, Incorporated, 1960, pp. 584-605.

The presence of a tenuous atmosphere on Mars is well established. Water vapor and oxygen remain so far undetected spectroscopically. The near-infrared absorption bands of carbon dioxide have been detected. Nitrogen must be the main constituent of the atmosphere, but is undetectable spectroscopically. Three main cloud types are recognized as white, blue, and yellow. There is an extreme diurnal temperature variation and a seasonal variation. The present status of the vegetative hypothesis of the dark regions on Mars is more that of a philosophical speculation than of a scientific hypothesis. McLaughlin hypothesizes that the dark areas may be due to volcanic action.

44. Dollfus, M. A.
ASTROPHYSICS - THE POLARIZATION OF REFLECTED LIGHT FROM THE DIFFERENT REGIONS OF THE PLANET MARS AND THEIR INTERPRETATION (ASTROPHYSIQUE - LA POLARIZATION DE LA LUMIÈRE RENVOYÉE PAR LES DIFFÉRENTES RÉGIONS DE LA SURFACE DE LA PLANÈTE MARS ET SON INTERPRÉTATION), Comptes Rendus Hebdomadaires Des Seances De L'academie Des Sciences, 6 August 1951.

New measurements have furnished curves of polarization of the areas of Mars between the phases 3 and 36 degrees. The clear regions are similar to pulverized limonite (bog iron ore). The darker areas differ from our areas of known vegetation except perhaps for microscopic plants. The white clouds consist of crystals. The violet mists call to mind those of Venus. In springtime, polar caps have condensed frosts.

45. Dollfus, M. A.
THE NATURE OF THE SURFACE OF MARS, Publications of the Astronomical Society of the Pacific, Vol. 70, 1958, pp. 56-64.

Polarimetric and photometric studies of the light and dark areas of Mars were made to provide new information about the nature and changes of the surface. Polarization curves of the light areas are very similar to comparison curves produced by pulverized limonite. The Martian dark areas would also seem to have a powdery or pulverized surface, but the polarization curves vary seasonally. Animated micro-organisms are very likely present on the powdery surface. The organisms must be pulverulent and very absorbent. Examples are given of terrestrial organisms of high adaptivity which possess a superficial colored pigment that offers protection against cold or excessive radiation by proper selective absorption of light. Chromogenic bacteria and highly colored elementary cryptogams are possible answers to explain the observational results.

46. Draper, A. L., Adamcik, J. A., and Gibson, E. K.
COMPARISON OF THE SPECTRA OF MARS AND A GOETHITE-HEMATITE MIXTURE IN THE 1 TO 2 MICRON REGION. Icarus, Vol. 3, May 1964, pp. 63-65 (A64-23723).

Discussion of the reflectance spectrum of goethite (hydrated iron oxide) and hematite mixture. The spectrum generally agrees with the spectrum of the bright areas of Mars in the 1- to 2-μ region. The procedure of preparation of goethite is described in detail. Both components are physically mixed in proportions possibly close to the composition of the surface soil of the bright areas of Mars. An iron oxide composition appears to constitute a considerable portion of the Martian surface.

47. Eberhart, J.
MARINER ALTERS PROJECTS, Science News Letter, 88:83 7 August 1965, p. 83.

Information on the density of the atmosphere on Mars received from Mariner 4 has already had profound effect on designs of future spacecraft.

48. Ebisawa, S.
PLANISPHERE OF MARS WITH THE LIST OF THE NAMES OF ITS SURFACE MARKINGS, Kyoto University, Institute of Astrophysics and Kwason Observatory Contribution No. 89, 1960, pp. 223-238 (N62-15741).

The planisphere of Mars was constructed from many photographic and visual observations made in the United States of America, South Africa, Europe, and Japan, from 1907 to 1956, including new dark markings and secular and temporal changes which took place since 1916. The list of surface markings include all of the names used by many observers.

49. Fielder, G.
ON THE TOPOGRAPHY OF MARS, Publications of the Astronomical Society of the Pacific, Vol. 75, No. 442, February 1963, pp. 75-76.

Not Abstracted.

50. Fielder, G.
PHOTOGRAPHS OF MARS TAKEN BY MARINER IV, Nature, Vol. 207, 25 September 1965, p. 1381 (A66-10883).

Brief discussion of the photographs of the Martian surface relayed by Mariner 4. It is suggested that the canals noted by earlier observers of Mars may have appeared to form, under certain poor visual conditions, by the subjective connection of many discrete patches of dark material arranged linearly on the surface of the planet. The patches might be widely separated ring structures, or groups of craters, arranged in linear chains, with floors of low albedo like many of the large lunar rings.

51. Fitch, F. J. and Miller, J. A.
SURFACE RELIEF OF MARS, Nature, Vol. 207, 21 August 1965.

The first reports from Mariner IV indicate that the planet Mars possesses a negligible magnetic field when compared with that of earth. This is strong confirmation of the view that Mars has not developed a core. In a recent communication to "Nature," we suggested that a cyclical process which can be discerned in the earth's history and is responsible for its major geological structures is related to the development of the earth's core. If our arguments are valid, then it can be predicted that Mars will not possess any system of orogenic mountain belts comparable with those of earth. Any relief on its surface would be of volcanic or volcano-tectonic origin as on the moon.

52. Focas, J. H.
SEASONAL EVOLUTION OF THE FINE STRUCTURE OF THE DARK AREAS OF MARS, Planetary and Space Science, Vol. 9, 1962, pp. 371-381.

The seasonal darkening of the dusky areas of Mars starts with maximum thickness of the winter polar clouds. The regional brightness of the polar caps is connected with the profile of the relief. The average intensity of the dark areas increases from the poles towards the equator; the amplitude of the darkening waves decreases from the poles towards the equator. The combined action of the two darkening waves shows that the action of the darkening generating element is constant for all areographic latitudes during the Martian year. The distribution of the total intensity of the dark areas, the sizes and frequency in areographic attitude of dark blocks or nuclei composing the dark areas of the planet, depend on the duration of the action of the darkening generating element.

53. French, H.
SOME NOTES ON THE ORIGIN OF THE COLOR OF THE MARTIAN DESERTS, Journal of the British Astronomical Association, Vol. 69, No. 1, 26 April 1959.

It is said that the color of the deserts of Mars is most likely due to ferrous oxide and that Kuiper has succeeded in matching the color of the deserts with that of light reflected by felsite. Felsite is not an exact term. It has been so loosely applied in the past that many petrologists gave up using it altogether in favor of more exactly defined terms. Many types of rock are or have been known as felsites, and they are found in many shades of color from green to grey, white, yellow, and red.

54. Gallo, J.
MARS, Publications of the Astronomical Society of the Pacific, Vol. 36, 1924, pp. 332-335.

Observations of Mars with a 38-cm telescope are discussed. The polar caps would seem to be made of snow, and therefore some canals become visible only when filled with an adequate amount of melted snow. These canals are merely natural depressions of the soil and occur at different levels. The deepest areas of Mars, Sinus Sabeus and the northern part of Cimmeruim, represent transient seas whose water is replaced by seasonal vegetation which is responsible for changes of the surface and coloration. The formation of the polar caps is apparently due to the continuous fall of snow at night. Visibility of the canals may be due in some respect to the light received from the sun, as in the marks in some craters of the moon.

55. Georgetown College Observatory, Washington, D. C.
RECENT STUDIES OF THE KNOWN PHYSICAL CHARACTERISTICS OF THE MOON AND THE PLANETS by C. C. Kiess and D. S. Birney, December 1960, Report No. AFCRL TN 60-666, AD-253 575, Contract No. AF19 (604)7203 (Unclassified Report).

Although the major features on the surface of Mars retain their identity from year to year, minor changes are noted in them that are, no doubt, ascribable to the seasonal changes of climatic conditions. Thus, the irregular boundaries between the light and dark areas undergo changes in contour that apparently are in response to the change in seasons. The so-called canals, of which many have been charted on maps of Mars, also appear to be sensitive to seasonal conditions, more being observable in some years than in others. In general, the polar caps follow a fairly regular pattern in their formation and decay; however, slight variations are noted in successive years.

56. Gifford, F. A., Jr.
THE MARTIAN CANALS ACCORDING TO A PURELY AEOLIAN HYPOTHESIS, Icarus, Vol. 3, 1964, pp. 130-135.

The suggestion is made that the Martian canals are chains of desert sand dunes. The necessary physical conditions for dune formation are reviewed; these conditions probably exist on Mars. Sand driving winds are a factor of seven higher; therefore,Martian dune chains should be longer than on the earth.

57. Gifford, F. A., Jr.
THE SURFACE-TEMPERATURE CLIMATE OF MARS, The Astrophysical Journal, Vol. 123, January-May 1956.

The Lowell Observatory radiometric measurements of Martian surface temperatures are analyzed, and surface-temperature climatological properties of Mars are obtained. Annual and diurnal temperature variations and seasonal isotherm maps are displayed and discussed.

58. Goldstein, R. M.
MARS - RADAR OBSERVATIONS, Science, Vol. 150, 24 December 1965, pp. 1715-1717 (A66-16731).

Radar studies of Mars indicate that certain areas are quite smooth. Rough, strongly reflecting regions have also been found as well as poorly reflecting ones. Mars as a whole is significantly smoother to radiation of 12.5-cm wavelength than Venus.

59. Goody, R. M.
THE ATMOSPHERE OF MARS, Journal of the British Interplanetary Society, Vol. 16, No. 2 and 75, April-June 1957.

All the planets, with the possible exception of Mercury, have atmospheres, but the Martian atmosphere has excited far more interest and has been studied more than any other. The reasons are not hard to find. Mars is one of our two nearest neighbors and can be studied in some detail. The atmosphere is transparent to visible radiation so that the surface and cloud forms can be directly seen, and there is reason to believe that its physical structure does not differ markedly from the earth's, so that the two atmospheres can usefully be compared. Lastly, there is great interest both on emotional and scientific levels in the possibility of some primitive form of life as known to us occurring on Mars.

60. Grandjean, J. and Goody, R. M.
THE CONCENTRATION OF CARBON DIOXIDE IN THE ATMOSPHERE OF MARS, The Astrophysical Journal, Vol. 121, January-May 1955.

From observations of carbon dioxide bands in the spectrum of Mars made by Kuiper, we have redetermined the fraction by volume of this gas in the planet's atmosphere, taking into account the fine structure of the band and the shape of the rotation lines. If the ground-level pressure on Mars is 100 mb, we find that the fraction by volume of carbon dioxide is 50 times greater than in the earth's atmosphere.

61. Greenspan, J. A.
MARS: COMPATIBLE DETERMINATIONS OF SURFACE PRESSURE THROUGH PARTICLE SCATTERING, Science, Vol. 150, 3 September 1965, pp. 1156-1158.

The number of scattering particles required to bring the visual polarimetric and ultraviolet photometric estimates of the surface pressure of Mars into agreement are calculated. Concentrations of 10^8 to 10^9 ice particles, 0.2 micron in diameter, per square-centimeter column are obtained. Based on concentrations of Aitken nuclei in the atmosphere of earth, a layer less than 100 meters thick would contain the required number of particles. The compatible pressures obtained in this manner for various N_2-CO_2 and Ar-CO_2 atmospheric models lie within the range of pressures determined spectroscopically.

62. Gross, S. H., Rasoll, S. I., and McGovern, W. E.
MARS: UPPER ATMOSPHERE, Science, Vol. 151, 11 March 1966, pp. 1216-1221.

The thermal structure of the upper atmosphere of Mars has been theoretically investigated. The atmospheric temperature for a pure CO_2 model atmosphere lies between 400° and 700°K. The origin of the Martian atmosphere is discussed in the light of these results.

63. Guerin, P.
SPECTROPHOTOMETRIC STUDY OF THE REFLECTIVITY OF THE CENTER OF THE MARTIAN DISK AT OPPOSITION, AND THE NATURE OF THE VIOLET LAYER, Planetary and Space Science, Vol. 9, 1962, pp. 81-87.

Spectra of the center of the Martian disk (Arabia region) were compared, wavelength by wavelength, with those of a GO v star. The Martian reflectivity curve was obtained by taking account of the visible and ultraviolet gradients of the star relative to the sun. Mars is red from 6100Å to 3850Å and grey on the average from 3850Å to 3100Å, but in this region of the spectrum, the reflectivity curve presents undulations which perhaps, if real, may be due to packets of absorption bands produced by some organic compound ejected by Martian vegetation.

64. Gustavson, J.
THE RED PLANET, Space Flight Notes, Vol. 27, No. 6, June 1957, p. 706.

This paper discusses the physical data of Mars atmospheric composition, polar caps, dark areas, canals, and an expedition to Mars.

65. Harvard University, Cambridge, Massachusetts
TOTAL REFLECTION SPECTROPHOTOMETRY AND THERMOGRAVIMETRIC ANALYSIS OF SIMULATED MARTIAN SURFACE MATERIALS by C. Sagan, J. P. Phaneuf, and M. Ihnat, 1 December 1964, AD-616 813 (Unclassified Report).

The ultraviolet, visible, and near infrared reflection spectra of the Martian bright areas were compared with the corresponding laboratory reflectivities, measured with an integrating sphere, of a variety of minerals containing ferric

oxides and silicates, as solids and in pulverized form. Except in the ultraviolet, where the effects of the Martian blue haze are prominent, pulverized limonite, a ferric oxide polyhydrate, matches the shape and amplitude of the Martian Russell-Bond albedo within experimental and observational error. Further observational tests of this identification are outlined. If water-rich limonite is a primary constituent of the Martian bright areas, conditions in the earlier history of Mars were probably much more equable than contemporary conditions, and the origin and evolution of life on primitive Mars becomes easier to understand.

66. Hawrylewicz, E. J., Hagen, C. A., and Ehrlich, R. RESPONSE OF MICROORGANISMS TO A SIMULATED MARTIAN ENVIRONMENT, Life Sciences and Space Research, Volume 3; International Space Science Symposium, 5th, Florence, Italy, 12-16 May 1964 (A65-30671 19 04), Amsterdam, Holland, North-Holland Publishing Company; New York, New York, John Wiley and Sons, Incorporated, 1965, pp. 64-73 (A65-30676).

Investigation of the survival of terrestrial microorganisms in a simulated Martian environment. The ultimate objective is to establish whether earth organisms can contaminate Mars. In addition, any demonstration of survival and growth in a simulated Martian environment will provide information relating to the biology of Mars. In the experimental design, exhaustive consideration was given to the duplication of the known and the theoretical environmental parameters of Mars. These included composition of the soil and the atmosphere, barometric pressure, moisture content, solar radiation, and diurnal temperature extremes. Based on these considerations, a simulated Martian summer environment was defined and used in the experiments. One group of microorganisms was selected from culture collections on the basis of their known characteristics. The other group was made of microorganisms isolated from soils. The soil samples were obtained from the Antarctic, from New Mexico and California deserts, and from the Colorado tundra. The studies showed that a number of microoganisms can survive the simulated Martian environment. However, no substantial growth under such conditions could be demonstrated. The ability of microorganisms to form spores as a mechanism for survival is discussed.

67. Heath, A. W., Robinson, J. H., and Firsoff, V. A.
MARS THROUGH COLOR FILTERS, The Journal of the British Astronomical Association, Vol. 69, 1958, pp. 270-272.

The observations on which this report is based have been made with 8-inch, 8½-inch, and 6½-inch mirrors and a 3¾-inch O.G. and color filters, principally the Dufay tricolor set. V.A.F. has used, in addition, monochromatic (narrow-band) Dufay yellow and green and Wratten-70 red, as well as a Kodac "Pola" polarizing screen, with and without filters, and has generally found it helpful in securing better definition and eliminating "ghosts." Observations without filters have likewise been made by all three observers.

68. Hunt, G. R.
INFRARED SPECTRAL EMISSION AND ITS APPLICATION TO THE DETECTION OF ORGANIC MATTER ON MARS, Journal of Geophysical Research, Vol. 70, No. 10, 15 May 1965, pp. 2351-2357.

Infrared spectral emission was obtained for various thicknesses of teflon, mylar, and Dupont film H at temperatures below 100°C. Characteristic data are apparent for samples which exceed the thickness limits imposed by Hovis. The use of an uncooled detector to obtain such characteristic spectral data at long wavelengths (out to 40μ) is demonstrated. Thus, it should be possible to obtain diagnostic spectral emission from the surface of the planet Mars by using proper instruments aboard a Mars probe.

69. Jackson, F. and Moore, P.
LIFE IN THE UNIVERSE, New York, New York, W. W. Norton & Company, Incorporated, 1962.

In some ways, Mars is the most earthlike of our neighbor planets. Moreover, it is closer than any other natural body in the sky apart from the Moon and Venus, and its relatively thin atmosphere results in its surface features appearing clearcut. It is smaller and less massive than the earth.

70. Jackson, F. and Moore P.
POSSIBILITIES OF LIFE ON MARS, Current Aspects of Exobiology, New York, New York, Pergamon Press, Incorporated, 1965, pp. 243-259 (A66-11607).

Study of evidence in favor of the view that organisms of some sort are present on Mars. Life as we know it depends on the availability of water, among other things, and it is only recently that the presence of water vapor in the Martian atmosphere has been conclusively demonstrated. It is probably safe to conclude that the atmosphere of Mars is not likely to be actively toxic to terrestrial-type organisms at the present time. The current physical theory is that the Martian surface consists of crumbled rocks exposed to wide temperature variations and UV flux. The weight of evidence would still seem to favor the view that the changes in the dark areas are signs of biological activity. There is no reason why non-photosynthetic organisms should not exist mingled with the photosynthetic ones, so that a cycling of materials could occur between plantlike and animallike organisms. There is a real possibility that Mars bears indigenous organisms of some kind, based on the following observational arguments:

1) The various colors, including green, exhibited by the dark areas.
2) The seasonal changes in the visual albedo and polarization of the dark areas.
3) The ability of the dark areas to regenerate after an extensive "dust storm."
4) The presence of 2700- to 3000-cm absorption bands, attributed to organic molecules.

71. Jet Propulsion Laboratory, Pasadena, California
ENGINEERING MODELS OF THE MARTIAN ATMOSPHERE AND SURFACE by D. F. Spencer, 1 July 1965, JPL Technical Memorandum No. 33-234 (Unclassified Report).

Engineering models of the Martian atmosphere and surface are developed for application purposes in designing a Mars capsule lander. Models are presented for various surface pressures and an number of low-altitude and stratospheric temperature profiles. An atmospheric surface pressure of 14 mb is suggested for design use. Mean continuous wind velocities of approximately 100 ft/sec at the surface are recommended with a mean vertical gradient of plus

2 ft/sec/1000 ft. A peak design wind velocity of 330 ft/sec is recommen. .d consistent with a 14-mb surface pressure. Models of Mars' surface are developed for the bright areas and the dark areas.

72. Johnson, R. W.
TERRAIN AND SOIL OF MARS, Ninth Annual American Astronautical Society Meeting, Statler Hilton Hotel, Los Angeles, California, 15-17 January 1963, 1962, pp. 406-435.

A brief summary of the physical properties of Mars, especially the atmospheric and crustal composition and structure are presented. From these data discussions of the climate, hydrographic and physiographic features follow. A model of the Martian terrain is developed from soil-forming processes based upon processes active in an earth environment. The surface features of the polar caps and so-called canals are included briefly, particularly from the standpoint of their existence and effect on terrain configuration and soils. The nature and composition of the crust of Mars are discussed in terms of origin and comparison with meteoritic composition. Possible relationships between meteorites and cosmic dust contribution to the surface soils are introduced. Deductive reasoning applied to these data indicates that the surface of Mars is essentially dry and level plain relatively free from either high rises or deep depressions. Occasionally extinct volcanoes may dot the surface, although volcanism as a process is not generally associated with Mars. Crustal warping and cracking are not evident nor hypothesized to any degree. The surface soil is presumed to be fine in texture having a flour-like silt to sand particle size. Winds at velocities up to 30 mph have probably scoured the rises and filled the low depressions. The presence of organic life is discussed briefly.

73. Kaplan, L. D., Munch, G., and Spinrad, H.
AN ANALYSIS OF THE SPECTRUM OF MARS, Liege University, Infrared Spectra of Astronomical Bodies, 1964, pp. 420-423 (N65-10155 01-29, N65-10185).

On a high-dispersion spectrogram of Mars taken at Mount Wilson, rotational lines of H_2O near λ 8300 and CO_2 λ 8700 were detected. Recent laboratory measurements of line strengths were used to determine the amounts of H_2O and CO_2 in the atmosphere of Mars, 14 $\pm 7\mu$ precipitable water and 55 ±20 meter atmospheres CO_2. From the absence of O_2 in the Martian spectra, an upper limit of 70 cm-atmospheres for the O_2 content was set. By suitably combining the CO_2 amount with observations by Sinton of the strongly saturated bands in the 2μ region, a surface pressure of 25 ±15 mb was derived.

74. Kellogg, W. M. and Sagan, C.
THE ATMOSPHERES OF MARS AND VENUS, National Academy of Sciences, National Research Council, Publication 944, Washington, D. C., 1961.

The authors report on the Conference on Planetary Atmospheres held by the Space Science Board of the National Academy of Sciences on 24 June 1960 at Arcadia, California. They discuss the present state of knowledge of planetary atmospheres as known from ground based observations, consider the most important characteristics about which additional information is needed, and discuss space experiments that best promise to yield such information.

75. Kellogg, W. W.
MARS, International Science Technology, No. 26, February 1964, pp. 40-48.

Mars is the one planet in the solar system likely to support life something like the terrestrial kind. But if life exists there, it must accommodate itself to an environment that is extremely harsh by earthly standards. Mean temperatures at the Martian equator, for example, are -35° to -45°C. Furthermore, the Martian atmosphere seems singularly lacking in oxygen (perhaps 0.1 percent by volume) and water vapor (Arizona's desert air is like a Turkish bath by comparison). Nevertheless, changes in color and polarization of Mars' dark areas that coincide with seasonal waxing and waning of the white (ice?) polar caps, persistence of the dark areas through the years, and recent discovery in them of spectral evidence of organic molecules combine to suggest that all of Mars is not as barren of life as its red dusty deserts of limonite seem to be. Fly-by space probes, ingeniously instrumented landing probes, and trained eyes at good telescopes, backed by brains, soon may answer this and a host of equally important geophysical questions.

76. Kellogg, W. W.
THE ENVIRONMENT OF THE PLANETS, Space Exploration, New York, New York, McGraw-Hill Book Company, 1964, pp. 83-96 (A64-80787).

The author presents a summary of the state of knowledge of the planets pertaining to their environments and the possibility of the existence of life. The data include work done until the summer of 1962. Concentrating on Mars and Venus, the author summarizes environmental data gathered by visual, infrared, and radar observations. Observations indicating some form of plant life on Mars are cited. Data from studies of Venus indicate that life probably does not exist there. It is suggested that the one goal of planetary exploration should be to discover the history of the planets, and that only by close inspection shall the complete nature of these environments be determined.

77. Kellogg, W. W.
THE ENVIRONMENT OF THE PLANETS, Space Exploration Lecture Series, California University, Moffett Field, Anaheim, Los Angeles, and San Diego, 1-4 October 1962, p. 2640, N63-19338.

This review discusses the solar system and the limitation of observations from earth optical telescopes, radio telescopes, and space probes. Also included are studies of Mars and Venus atmospheres and surfaces and the possibilities of the existence of life forms on these planets.

78. Kiess, C. C., Corliss, C. H., and Kiess, H. K.
EVIDENCE FOR NITROGEN DIOXIDE IN THE MARTIAN ATMOSPHERE, The Astronomical Journal, Vol. 67, 1962, p. 579.

The authors obtained spectra of Mars and comparison spectra of the moon at a dispersion of 5A/mm. Microphotometer tracings of these spectra show not only the decline of the Martian spectrum toward shorter wavelengths relative to that of the moon, but also numerous features which suggest absorption in the Martian atmosphere. This absorption was found to correspond closely to the absorption spectra of nitrogen peroxide as measured in the laboratory. (Abstract of a paper presented at the August meeting of the American Astronomical Society.)

79. Kiess, C. C., Corliss, C. H., Kiess, H. K., and Corliss, E. L. R.
HIGH-DISPERSION SPECTRA OF MARS, The Astrophysical Journal, n International Review of Spectroscopy and Astronomical Physics, Vol. 125, No. 2, March 1957.

In July 1956, a concave-grating spectrograph was set up at the Slope Observatory of the U. S. Weather Bureau, near the summit of Mauna Loa, Hawaii, for the purpose of photographing spectra of Mars with high dispersion. Several sets of spectrograms with spectra of the moon and Mars in juxtaposition were obtained with dispersions of five and two A/mm. The shortward shift of the spectrum of Mars, due to the Doppler-Fizeau effect, was sufficient to separate Martian lines of O_2 and H_2O in the B and "a" bands from those of terrestrial origin. No such shifted lines were detected. After opposition, our spectrograph was set up again, at the Georgetown College Observatory, and adjusted to cover the spectral range from 5000 to 9000 A. Again, the results were negative. Observations at the National Bureau of Standards on the relative strengths of the water-vapor bands are in agreement with their calculated relative transition probabilities and show that the bands sought thus far in the specturm of Mars are not the ones to use for this purpose. It is suggested that future work be devoted to the bands of H_2O at 1.13 and 1.38μ.

80. Kiess, C. C., Karrer, S., and Kiess, H. K.
A NEW EXPLANATION OF MARTIAN PHENOMENA, Astronomical Journal, Vol. 65, 1960, p. 348.

The existence of water vapor and oxygen in the atmosphere of Mars in amounts too small for spectroscopic detection justifies the assumption that the observed Martian phenomena may be due to the oxides of nitrogen. The polar caps would seem to be solid N_2O_4 and the spread of heavy gaseous N_2O_4 over the dark areas toward the equator would account for the seasonal changes of color. The oxides of nitrogen may exist in both solid and gaseous phases, which could account for the haze and for blue, white, and yellow clouds. Mars may be considered as a gigantic photochemical nitrogen-fixation process. Further, the well known toxic effects of these oxides argue against the existence of living organisms on the planet.

81. Kiess, C. C., Kiess, H. K., and Karrer, S.
PROPOSED EXPLANATION OF MARTIAN PHENOMENA, Sky & Telescope, Vol. 19, June 1960, p. 469.

Oxides of nitrogen are proposed as the principal agents for the surface and atmospheric phenomena observed on Mars. The polar caps may be soild N_2O_4 and the spreading of the heavy gas as the poles melt would cause the seasonal changes in the dark areas. Absorption of light by gaseous NO_2 and N_2O_7 may be responsible for the low albedo, the blue clearing caused by polymerization of NO_2 to N_2O_7, and the yellow clouds caused by increases in NO_2 concentration. This view of Mars would make the presence of life very unlikely because of the toxicity of the oxides of nitrogen.

82. Kopal, Z.
OUR NEIGHBOR MARS, New Scientist, (London), Vol. 1, 22 November 1956, pp. 41-43.

Although nitrogen appears to be the principal constituent of the Martian atmosphere, the only gas whose presence has been established by its power to absorb infrared is carbon dioxide. Evidence for oxygen and water vapor is so far absent. Measurements indicate that the overall Martian temperature is 30° to 40°C cooler than that of the earth. White, blue, or yellow clouds hover near the surface of the planet. Three-quarters of the surface consists of reddish or yellow expanses, probably exposed solid rocks but mostly covered with dust or sand (so-called monotonous deserts). The remaining quarter consists of "dark spots," faint and ill-defined during winter but turning dark with advent of spring. The probable existence of vegetation is also discussed.

83. Koval, I. K.
DEGREE OF SMOOTHNESS OF THE CONTINENTS AND SEAS OF MARS (Foreign Title Not Available), Translated into English in AIAA Journal, Russian Supplement, Vol. 1, 1963, pp. 2433-2437 (Akademiia Nauk SSSR, Astronomicheskii Sovet, Izvestiia po Fizike Planet, No. 1, 1959, pp. 85-92), Vol. 1, October 1963, pp. 2433-2437 (A63-23799).

Study of changes in "land-sea" contrasts from the center to the edge of images of Mars, obtained through IR and red light filters, and also of the positions of brightness maxima on the intensity of the planet. Investigation reveals a decrease in contrast toward the edge of the image and a noncoincidence of the positions of the brightness maxima for the continents and seas of Mars. A previous conclusion that the law of reflection of light is not the same for the averaged continents and seas of Mars is confirmed.

84. Koval, I. K.
DISTRIBUTION OF BRIGHTNESS IN THE EDGE ZONE OF MARS, Life Sciences and Space Research II, A Session of the Fourth International Space Science Symposium, Warsaw, 3-12 June 1963, Amsterdam, Holland, North-Holland Publishing Company, 1964.

It is evident that for successful application of theory to photometric observations of Mars it is necessary to have more precise data on the distribution of brightness along the visible radius of the planet. Moreover, it is especially important to have the corresponding data for the edge zone (up to $\gamma = 0.95\ R°$).

The method of photographic photometry is known not to be sufficiently precise and does not permit us to go beyond $\gamma = 0.80$ or $0.85\ R°$.

During the 1963 opposition, photoelectric observations were made using the 28-inch reflector (30-m cassegrain) at the Main Astronomical Observatory of the Ukrainian Academy of Sciences. The method applied was that of drift-curves in 10 spectral bands in the interval 355-900mμ. Mars was moving over the diaphragm (d = 0.35 inch) because of the diurnal motion. The main part of the material was obtained on 4-5 February 1963.

For each filter, 40-50 drift-curves were obtained. While processing the observations, the diameter of diaphragm was taken into account as well as vibration of the image. Average distributions of brightness along the visible diameter of Mars up to 0.95 R° were obtained. It is shown that the steepness of brightness curves increases from 420 to 600 mμ and remains almost constant for greater wavelengths. For 355 mμ, the steepness is the same as for 600 mμ.

85. Koval, I. K.
MARTIAN CONTINENTS AND SEAS, Izvestiya Akademiya Nauk SSSR, Komis. Fiz. Planet, No. 1, 1959, pp. 85-92 (AID 62-143, N62-16270).

Changes in the continent-sea contrast from the center to the limb of the Martian image were studied on the basis of photos obtained through the use of red and infrared light filters. Results show that the curve-of-brightness change in the Martian sea has less curvature than the curve for the continents. The images of Mars obtained in 1954 are held to be the most satisfactory in determining the light reflection from continents, while those obtained in 1956 are most suitable for studying the seas.

86. Koval, I. K.
STUDY OF OPTICAL PROPERTIES OF THE ATMOSPHERE AND SURFACE OF MARS (K IZUCHENIIU OPTICHESKIKH SVOISTV ATMOSFERY I POVERKHNOSTI MARSA), Translated into English in Physics of the Moon and Planets (Fizika Luny I Planet), 1964, pp. 46-53 (A65-18971).

Study of the problem of brightness distribution along the visible radius of Mars. Results obtained by other authors for narrow regions of the spectrum over a range of 400 to 900 mμ are discussed. It is concluded that, within this range of wavelengths, the Martian atmosphere possesses mainly scattering properties. The darkening of the limb has its maximum at about 650 mμ. A decrease in the limb darkening to the left of this wavelength is due to a scattering similar to that of the molecular type. To the right of this wavelength, this decrease is attributed to the scattering by large dust particles constantly present in larger or smaller quantities in the Martian atmosphere.

87. Kozyrev, N. A.
EXPLANATION OF THE COLOR OF MARS BY THE SPECTRAL PROPERTIES OF ITS ATMOSPHERE (OB'YASNENIE TSVETA MARSA SPEKTRAL'NYMI SVOISTVAMI EGO ATMOSFERY), Translated into English by the American Meteorological Society, Boston, Massachusetts (Akademiya Nauk SSSR, Krymskaya Astrofizicheskaya Observatoriya, Izvestiya, Vol. 15, 1955, pp. 147-152), Report No. AmMetSoc-T-R-428, TT 65-60827, AD-610 116, March 1964 (Contract No. AF19 628 3880).

In the summer of 1954, the 50-inch reflector of the Crimean Astrophysical Observatory was used to obtain spectrograms of Mars, which allowed photometric comparison between the spectra of the surface details of Mars and the solar spectrum. The curves obtained show that the continent and seas of Mars have the same natural color. The observed color difference is due solely to the properties of the Martian atmosphere. Consequently, the albedo of Mars can be determined for different wavelengths. Apparently, the surface of Mars has a natural albedo of approximately 0.45, without any real difference in the visible spectrum, but the large atmospheric dust content in itself causes this neutral surface to appear bright red. The dependence of the optical thickness of Mars on the wavelength, calculated according to this hypothesis, is shown.

88. Kuiper, G. P.
ON THE MARTIAN SURFACE FEATURES, Publications of the Astronomical Society of the Pacific, Vol. 67, October 1955, pp. 271-282.

A description of the surface markings on Mars, their change in form and color, and their probable nature is presented. The historical observations of the canals of Mars are reviewed. The present consensus relegates them to natural surface features. The apparent colors of the Martian maria, which are usually greenish, deteriorate as the seeing improves, often yielding almost the same color as the surrounding deserts. Although volcanic ash deposited by presently active volcanoes has been suggested as the cause of the dark markings, the lack of water on Mars contradicts excessive volcanic action. Plant life still appears to be the most satisfactory explanation for the shades of the markings and their seasonal and secular changes.

89. Kuiper, G. P.
VISUAL OBSERVATIONS OF MARS, Astrophysical Journal, 125:2, March 1957, pp. 307-317.

Visual observations of Mars, made with an 82-inch telescope during one month of nearly continuous observation centered around the time of closest approach in 1956 (September 7), are reported. Emphasis was placed on obtaining dependable determinations of the colors of the Martian dark areas and on the general appearance of the planet, including fine detail. The colors, expected to be green at this season (Martian spring), were found to be neutral gray, with a mere touch of mossgreen in some of the equatorial regions and a touch of brown in the dark border surrounding the south polar cap. A spectacular system of dust storms was observed to develop, eventually enveloping the entire observable planet except the polar zones. Between 6 and 9 September a dense cloud cap formed over the South Pole. This cloud cap had cleared away by September 14 but deposited a new polar cap that has remained largely intact since. It is remarkable that this event occurred shortly before the summer solstice. The bearing of the surface studies on the vegetation hypothesis is discussed.

90. Kurchakov, A. V.
OPTICAL PROPERTIES OF THE ATMOSPHERE AND SURFACE OF THE PLANET MARS, ARS Journal Supplement, March 1962.

Observations of Mars show vastly different details in all parts of the spectrum, excluding the violet part. Besides that, it is known that extinction in the terrestrial atmosphere in the visible spectral range is practically caused only by scattering because true absorption concentrated in the comparatively few and shallow telluric bands, plays an insignificant role in reducing the total light flux. In the visual range of Mars' spectrum, in general, no absorption bands caused by atmosphere of this planet have been detected. Hence, it is considered that the role of absorption in the atmosphere of Mars is still smaller than in the terrestrial.

91. Lebedeva, I. I.
SPECTROPHOTOMETRIC COMPARISON OF THE MARTIAN CONTINENTS WITH RED-COLORED TERRESTRIAL COVERS (SPEKTROFOTOMETRICHESKOE SRAVNENIE MATERIKOV MARSA S KRASNOTSVETNYMI ZEMNYMI POKROVAMI), Translated into English from Leningradskii Gosudarstvennyi Universitet, Astronomicheskaia Observatoriia, Trudy, Vol. 22, 1965, pp. 125-131 (A66-15422).

Comparison of spectral curves of integral Martian radiation in the visual region with similar curves for the continents in the planet's center with curves of spectral reflectivity of red-colored terrestrial rocks. The fair coincidence of these curves is believed to support the theory that the specific color of the Martian surface is due to the presence of limonite dust.

92. Lebedinskii, A. I. and Salova, G. I.
ON THE AMOUNT OF WATER AVAILABLE IN A FREE STATE ON MARS, Soviet Astronomy-A. J., Vol. 6, 1962, pp. 390-397.

The amount of uncombined water on Mars is estimated from data on the degree of atmospheric turbidity and the rate

of evaporation of the polar caps. The two approaches give closely similar results and indicate that the thickness of the polar caps is 0.01 g/cm^2, and the total quantity of free water on Mars is 2.10^{15} g.

93. Lederber, J., and Sagan, C.
MICROENVIRONMENTS FOR LIFE ON MARS, National Academy of Sciences, Vol. 48, 1962, pp. 1473-1475

Deductions as to the habitability of Mars is of great importance in planning for space explorations, and must take account of local variations as well as the harsh, average features of the planet. Substantial moisture may, for example, be frozen in the subsoil, both moisture and warmth being available through localized geothermal activity.

94. Leighton, R. B.
THE PHOTOGRAPHS FROM MARINER IV, Scientific American, Vol. 214, No. 4, April 1966.

This is a review of how the photographs were made and what they show.

95. Leighton, R. B. and Murray, B. C.
BEHAVIOR OF CARBON DIOXIDE AND OTHER VOLATILES ON MARS, Science, Vol. 153, 8 July 1966, pp. 136-144.

A thermal model of the Martian surface suggests that Mars' polar caps are solid carbon dioxide.

96. Ley, W.
THE HISTORY OF THE CONCEPTS ABOUT MARS, Exploration of Mars; Proceedings of the American Astronautical Society Symposium on the Exploration of Mars, Denver, Colorado, 6-7 June 1963, Advances in the Astronautical Sciences, Vol. 15, North Hollywood, California, Western Periodicals Company, 1963, pp. 435-445.

Account of the evolution of man's ideas and concepts about the planet Mars, from the time of the ancient Greeks to the present. The fanciful planetary trip concepts of early and 17th century chroniclers are followed. The astronomical writings which describe the controversies over the "canals" and the existence of life forms on Mars are also examined.

97. Ley, W., Von Braun, W., and Bonestell, C.
THE EXPLORATION OF MARS, New York, New York, The Viking Press, 1956.

The opinions, hypotheses, theories, and exploration of Mars are discussed.

98. Library of Congress, Aerospace Information Division, Washington, D. C.
SURFACE CHARACTERISTICS OF MARS, VENUS, AND THE MOON: ANNOTATED BIBLIOGRAPHY, Author Unknown, 10 February 1964, Report No. AID-U-64-5, TT 65-64280, AD-622 935 (Unclassified Report).

This annotated bibliography of Soviet planetary studies contains data from 1960 to mid-1963. Soviet bloc research of the surface characteristics of Mars, Venus, and the Moon with reference to light polarization and albedo measurement techniques as well as radioastronomical studies are included.

99. Library of Congress, Aerospace Technology Division, Washington, D. C.
SURFACE CHARACTERISTICS OF THE MOON, MARS, AND VENUS, ANNOTATED BIBLIOGRAPHY, Author Unknown, 1 March 1965, Report No. AID-P-65 12, N65-22568, AD-458260 (Unclassified Report).

An annotated bibliography of the surface characteristics of Mars, Venus, and the Moon is presented with emphasis on light polarization and albedo measurement techniques as well as radioastronomical studies. Information on tektites is also presented. The report covers 125 research studies from the years 1960 to mid-1963. More recent findings from about mid-1963 through mid-1964 are included in Appendices A to C.

100. Lippisch, A. M.
VEHICLE DESIGN FOR EXPLORATION OF MARS, Advances in the Astronautical Sciences, American Astronautical Society, Symposium on the Exploration of Mars, 6-7 June 1963, Denver, Colorado, Vol. 15, North Hollywood, California, Western Periodicals Company.

After a definition of the environmental condition on Mars, atmospheric and terrestrial, a critical review of different types of transportation is discussed. While at this stage of our knowledge, it seems difficult to obtain a true picture of the surface conditions on the planet. The atmospheric conditions are at least well enough known so that the requirements for the design of flying vehicles can be predicted. Turning to such design criteria, it can be shown that flight in the vicinity of the surface of Mars will require less power per unit mass than with the same mass on earth. Whether the use of the ground effect concept can be maintained is questionable in the light of the latest information on the surface conditions on Mars.

101. Lipskii, Yu. N.
RESULTS OF OBSERVATIONS OF MARS (REZUL'TATY NABLYUDENII MARS), Translated into English by the American Meteorological Society, Boston, Massachusetts, Report No. AmMetSoc T-R-427, T- 64 11822, AD-602 180, Contract No. AF19 628 3880 (Priroda (USSR) 1957, Vol. 46, No. 4).

Information on the observations of Mars made at Soviet observatories during the opposition of 1956 is presented. Photographs and spectrograms of individual portions of the surface of Mars taken at many observatories through various light filters and polarimetric and micrometric measurements are discussed. Infrared photographs of Mars were obtained with an image translator. Numerous images of the planet were made in total light and through filters. Special electrophotometers were used to compare the brightness of various portions of Mars in different spectral regions.

102. Lowell, P.
MARS AND ITS CANALS, New York, New York, Macmillan, 1907, 393 p.

The phenomenon of a highly complicated system of lines (channels or canals) on the planet Mars forming a network over its surface was first detected by Schiaparelli in 1877. In this book, Lowell presents the interpretation of the phenomenon as representing bands of vegetation along primary irrigation canals, appearing thus in the spring, first near the melting ice caps and following the flow of water toward the equator. The evidence presented is that here is a dry planet and an intelligence of some kind that survives only by utilizing the few remaining sources of water supply. The author is certain that Mars is inhabited by some form of beings. The theory of the existence of intelligent life on Mars may be likened to the atomic theory in chemistry; in both we are led to the belief in units which we are similarly unable to define.

103. McLaughlin, D. B.
CHANGES ON MARS AS EVIDENCE OF WIND DEPOSITION AND VOLCANISM, Astronomical Journal, Vol. 60, 1955, pp. 261-270.

A counter argument is presented for the formation and appearance of the Martian dark areas by volcanic ash deposits rather than by vegetation. Evidence from moving clouds seems to indicate extensive monsoon type winds on Mars. The volcanic hypothesis was developed to explain the greatest temporary changes observed historically. Shifting boundaries of maria are interpreted as due to aeolian deposition of light-colored desert dust or dark volcanic ash accompanied by variable volcanic activity and changes of wind direction. The amounts of ash required for any of the temporary markings are only a few cubic kilometers comparable to the output of major terrestrial eruptions. The patterns of the maria, especially the vertices of the pointed bays, do not support a vegetation theory; since if these points were sources of moisture or fertile dust the concept of volcanoes at these points is strengthened.

104. McLaughlin, D. B.
INTERPRETATION OF SOME MARTIAN FEATURES, Publications of the Astronomical Society of the Pacific, 66:391, August 1954, pp. 161-170.

Numerous dark markings of the Martian surface can be rationally explained in terms of natural mechanisms that are familiar to the inhabitants of the earth. Primarily, the agencies appear to be volcanism and aeolian transportation and sedimentation. This hypothesis accounts for most of the maria and some of the canals.

105. McLaughlin, D. B.
THE VOLCANIC-AEOLIAN HYPOTHESIS OF MARTIAN FEATURES, Publications of the Astronomical Society of the Pacific, Vol. 68, 1956, pp. 211-218.

Arguments that the form of the Martian maria are due to windblown deposits of volcanic ash from an extensive series of active volcanoes are presented. Although vegetation is usually considered the explanation for the dark maria, the volcanic theory and vegetation theory are not mutually exclusive, since the seasonal variation in hue may be due to vegetation growing on areas of deposited volcanic ash and associated moisture. Although the scarcity of water would seem to indicate a similar lack of volcanism, no reliable estimate is yet to be had of the actual available water on Mars. Maps of Mars are very consistent with the concept of flow patterns originating from point sources and curved because of the Coriolis effect. Trade winds carrying ash would produce the dark patterns over large areas of relatively undisturbed flow.

106. Miller, S. L.
THE POSSIBILITY OF LIFE ON MARS, Proceedings of Lunar and Planet, Exploration Colloquium, 3:2, 5 May 1963, pp. 1-7 (NAA Publication 513-W-12, N63-19479).

The primitive earth is believed to have had a reducing atmosphere which was favorable for the evolution of simple organic life. As Mars was formed from the same cosmic dust cloud as the earth, similar conditions might be expected to have existed on that planet. Laboratory experiments demonstrate that certain basic organic compounds necessary to produce "living" matter can be formed in such a favorable environment. Although these data and the polarization and infrared measurements of the Martian surface are not conclusive evidence, the existence of life on Mars is highly probable. The presentation of the paper is followed by an open-forum discussion.

107. Miyamoto, S. and Nakai, Y.
METEOROLOGICAL OBSERVATIONS OF MARS DURING THE 1960-61 OPPOSITION, (Kyoto University Institute of Astrophysics and Kwasan Observatory, Contribution No. 105, pp. 84-151) (N62-15745).

Meteorological phenomena of Martian atmosphere during the 1960-61 opposition secured by the visual and photographic observations at the Kwasan Observatory are described. First two sections are concerned with the general appearance of the surface markings in this opposition. Three dark belts, namely, through Nodus Laocoontis-Sinus Gomer, Nilokeras and Lunae Lacus, and Cerberus and Propontis, connecting the northern and southern hemisphere were remarkably developed.

The remaining parts are concerned with the records and interpretations of the meteorological phenomena. On the blue filtered photographs, it was noticed that both polar regions were almost always covered with white haze, and that a faint white belt of haze extended along the equator. The Martian atmosphere was very cloudy in this season of the year. White clouds were observed almost every night. A yellow cloud of considerable dimension emerged in the Neith and Casius area and drifted eastward. The retreat of the north polar cap has been traced. Evening and morning hazes and a rapid change of the atmospheric transparency were often observed. A peculiar behavior of the stratum of white clouds over Dioscuria and Cydonia and a semipermanent low over Niliacus Lacus suggest the existence of mountain ranges along Dioscuria and Cydonia. Also, the afternoon brightening of white clouds hanging over Hellas suggests that this desert may be a high land.

108. Moore, P.
THE PLANET MARS, Realities of Space Travel, London, England, Putnam, 1957, pp. 313-334.

(This is a reprint of an article which appeared in "Journal of the British Interplanetary Society (London)," 14 (2): 65-84, March-April 1955.) A review is presented of the main features of Mars: its polar caps, canals, dark areas, ochre dust deserts, tracts of vegetation, clouds, meteors, aurorae, and icy polar snows circled by two dwarf moons. The Martian atmosphere, although oxygen-deficient, contains carbon dioxide, argon, and nitrogen. Atmospheric density and pressure are lower than that found on earth.

109. Moore, P.
WHAT WE WANT TO KNOW ABOUT MARS, New Scientist, 16:312, 8 November 1962, pp. 309-311.

Mars presents many problems which remain to be solved. Some of them can hardly be cleared up without the use of probe vehicles. Present impressions, based on visual and spectroscopic studies, indicate an arid world which nevertheless probably supports life of some kind.

110. Moroz, V. I.
RECENT OBSERVATIONS OF THE INFRARED SPECTRA OF MARS AND VENUS IN CONNECTION WITH THE SPACE INVESTIGATIONS PROBLEM, Life Sciences and Space Research II, A Session of the Fourth International Space Science Symposium, Warsaw, 3-12 June 1963 (Sponsored by Committee on Space Research, COSPAR), Amsterdam, Holland, North-Holland Publishing Company, 1964.

The CO absorption band at 2.35 μ (equivalent laboratory absorption approximately four cm) and several unidentified absorption features were found in the infrared spectrum of Venus from the author's observations in 1963. A theoretical model of the Venusian atmosphere in the region of the CO_2 photodissociation was calculated. Observed CO absorption is in rough accordance with that model. Venusian albedo decreases by factor of 20 from 2.5 μ to 2.9 μ. The absorption observed at $\lambda > 3\mu$ seems to create the significant greenhouse effect, which heats the planetary surface. The constituent which produced this absorption is still unidentified (it is not H_2O), but the existence of this strong infrared absorption is established with certainty. New CO_2 bands were also found. The "ice" origin of polar caps and the presence of Sinton's "bands of life" were confirmed on the basis of infrared spectral investigation of Mars. The observed equivalent width of Martian CO_2 bands are lower than those published earlier by Kuiper. Two bands (3.53 and 3.56 μ) were detected instead of the single Sinton's 3.56 μ band.

111. Morozhenko, A. V. and Ianovitskii, E. G.
DETERMINATION OF THE OPTICAL PARAMETERS OF THE MARTIAN ATMOSPHERE AND SURFACE TAKING INTO ACCOUNT ANISOTROPIC SCATTERING (OB OPREDELENII OPTICHESKIKH PARAMETROV ATMOSFERY I POVERKHNOSTI MARSA PRI UCHEIE ANIZOTROPII RASSEIANIIA), Translated into English from Russian in Problems of Astrophysics (Voprosy Astrofiziki), 1965.

Determination of the optical parameters of the Martian atmosphere and surface from absolute photometric data both for spherical and elongated scattering indicatrices. A comparison of the optical parameters for some values of the indicatrices shows a marked increase in optical thickness and slight variations in the surface albedos for the more elongated indicatrices when the albedo of a single scattering event is near unity. Tables of numerical values of the optical parameters are included.

112. Morozhenko, A. V. and Ianovitskii, E. G.
METHODS AND RESULTS OF DETERMINATION OF OPTICAL PARAMETERS OF THE MARTIAN ATMOSPHERE AND SURFACE (METODIKA I RESUL'TATY OPREDELENIIA OPTICHESKIKH PARAMETROV ATMOSFERY I POVERKHNOSTI MARSA), Translated into English from Russian in Physics of the Moon and Planets (Fizika Luny I Planet), 1964, pp. 81-91 (A65-18974).

Presentation of a method for determining the optical parameters of the atmosphere and surface of Mars, based on data from absolute photometry. In particular, the method is shown to make possible a rapid and reliable determination of both the optical thickness and the absorbing power of the atmosphere. On the basis of the results obtained, it is concluded that, in the range of wavelengths from 450 to 840 mμ, the Martian atmosphere is purely diffusive. Beginning with $\lambda \sim 450$ mμ the true absorption increases with a decrease in wavelength. In the range of wavelengths from 360 to 450 mμ, the optical thickness of the Martian atmosphere can vary within very broad limits, frequently exceeding unity. In the infrared and ultraviolet regions of the spectrum, the albedo of the Martian surface varies much more slowly with wavelength than in the visible region.

113. National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, Alabama
THE ATMOSPHERE OF MARS: A DERIVATION OF ENGINEERING AND DESIGN PARAMETERS by W. T. Roberts and G. S. West, 29 June 1966, Technical Memorandum X-53484 (Unclassified Report).

Three model atmospheres have been derived for use in mission planning, aerospace lander design, and Martian orbiter and flyby studies. Atmospheric parameters for these three models have been calculated from the planetary surface to 10,000 kilometers. These three model atmospheres of differing atmospheric composition, surface pressure, and surface temperature are:

1) The upper density model (60 percent CO_2 and 40 percent N_2).
2) The mean density model (100 percent CO_2).
3) The lower density model (80 percent CO_2 and 20 percent Ar).

The general program of Kern and Schilling, with a few revisions, was used; this publication contains the details of the mathematical basis and program routines in considerable depth. The models chosen should provide values which will be of use as guidelines for the engineering and design of orbiting and landing vehicles.

114. National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, Alabama
THE MARTIAN ENVIRONMENT by R. B. Owen, 19 November 1964, Report No. NASA-TM-X-53167 (N65-17995).

An intensive literature survey was made of the present consensus on the surface and atmospheric conditions of Mars. Knowledge of the gross features of the Martian surface appears to be fairly complete, but there is sharp disagreement on the atmospheric conditions. While estimates of the surface temperature are in fairly close agreement and estimates of the surface pressure range from 10 to 150 millibars, other phenomena such as the blue haze are inexplicable. Formal design criteria for entry vehicles cannot yet be finalized because of the wide range of the environmental parameter values.

115. National Aeronautics and Space Administration, Scientific and Technical Information Division, Washington, D. C.
EXTRATERRESTRIAL LIFE, A Bibliography, Part II: Published Literature, December 1965, Report No. NASA SP-7015 (Unclassified Report).

Although this bibliography is primarily concerned with the general subjects of extraterrestrial life and exobiology, its scope also makes provision for several particular topics that are directly pertinent to the search for extraterrestrial life. Included among these are the origin of life on earth, the suitability of other planets for the development of indigenous life, the possibility of intelligent extraterrestrial life forms, techniques and instrumentation for the detection of extraterrestrial life, the chemical basis of life including the synthesis of organic compounds from simple precursors, and terrestrial contamination of spacecraft. Several references, which describe the examination and analysis of meteorites and the relevance of such studies to the subject of extraterrestrial life, are also presented.

Each entry consists of a standard bibliographic citation and an annotation in the form of an abstract or a brief descriptive notation.

116. National Aeronautics and Space Administration, Scientific and Technical Information Division, Washington, D. C.
MARINER IV PRESS CONFERENCE by W. H. Pickering et al, 15 July 1965, CSCL 22A, N65-30565.

A press conference is presented on the Mars photographic experiment of Mariner IV and on the findings of its various scientific data gathering instruments which include the magnetometer, solar plasma probe, cosmic ray telescope, ionization chamber, trapped radiation detector, and cosmic dust detector.

117. National Aeronautics and Space Administration, Scientific and Technical Information Division, Washington, D. C.
NEWS CONFERENCE ON INITIAL SCIENTIFIC INTERPRETATION OF MARINER IV PHOTOGRAPHY, Author Unknown, 29 July 1965, CSCL 22A, N65-29786.

A transcript of the NASA press conference held to interpret 21 of the photographs returned from Mariner IV is presented. Surface details are described in relation to distance, direction of the sun's illumination, and viewing angle. The size of various craters were pointed out and their implications discussed. Details were also given on the data processing of the pictures, the further refinements to be expected, and the camera arrangement. Such topics as temperature, atmosphere, type of surface, and the possibility of life on Mars were discussed in the question and answer period.

118. New Mexico State University, University Park Observatory, New Mexico
GROUND-BASED PHOTOGRAPHY OF THE MARINER IV REGION OF MARS by J. C Robinson, August 1965, Report No. NASA-CR-64468, TN-701-66-10, N65-32884, Grant NsG-142-61 (Unclassified Report).

Observable portions of the path of Mariner IV at central meridian longitudes from 90 to 240 degrees were studied from 251 plates which included ultraviolet, blue, green, red, and near infrared regions. An atmospheric haze appears to have obscured some of the surface details of Mars, but the dark features recorded along the Mariner path are summarized. These include the positions of oases, canals, and a caret. Three of the features were prominent enough for direct positional determination with a Mann measuring engine, but crude determinations were made for the other six features. The approximate areas and positions of regions of clouds or bright haze are also given.

119. New Mexico State University, University Park Observatory, New Mexico
PROVISIONAL TOPOGRAPHIC MAP OF MARS, MARINER 4 REGION by C. W. Tombaugh, July 1965, Report No. NASA-CR-64772, TN-701-66-8, CSCL 03A, N65-33258, Grant NsG-142-61 (Unclassified Report).

A provisional topographic map of the portion of the surface of Mars is presented and explained that the Mariner 4 is expected to photograph. Also included is a summary interpretation of the appearance and nature of the various features of the Mars surface from 37 years of telescopic observations. These interpretations were used as criteria for making a topographic breakdown of the map into 10 levels.

120. Nicks, O. W.
A REVIEW OF THE MARINER IV RESULTS, Prepared for Delivery at the 7th International Space Science Symposium of the Committee on Space Research (COSPAR) at Vienna, Austria, May 1966.

The Mariner IV spacecraft flew close by Mars on 15 July 1965, after a 7½ month journey. It returned useful data from the time of launch in November 1964 until October 1965, when its great distance from the earth and its antenna orientation halted temporarily the signal interpretation. It is known to be functioning, however, and more useful data are expected to be received when Mariner IV returns nearer the earth in September 1967.

A brief description of the spacecraft and mission is presented in this paper, along with some of the more important technological advances to emerge from the program. The selection of the scientific experiments for Mariner IV is discussed, and the key findings, as reported by the experimenters, are summarized.

121. Nourse, A. E.
NINE PLANETS, New York, New York, and Evanston, Illinois, Harper & Row Publishers, 1960.

In this book an attempt to develop step by step a complete, realistic, and stimulating picture of the physical nature of our solar system, the nine known planets, their satellites, and their sun. There is speculation about the things we may reasonably expect to find in the course of the forthcoming exploration of that solar system. An enormous gulf exists between the tables of statistics about the planets and a real understanding of what those statistics may mean to the landing parties going there. Here, an attempt is made to bridge that gulf, both with words and pictures, to try to see the planets and satellites as the landing parties will see them, and to guess what manner of things those landing parties may find.

122. Opik, E. J.
ATMOSPHERE AND SURFACE PROPERTIES OF MARS AND VENUS, Progress in the Astronautical Sciences, Amsterdam, Holland, North-Holland Publishing Company, Vol. 1, 1962, pp. 261-342, Grant No. NsG 58-60.

Critical review of some partly controversial general properties of the surface and atmosphere of Mars and Venus. Two major types of permanent or semipermanent surface formations on Mars are observed, the bright orange-red continents, and the dark grayish maria whose average coloration on an absolute scale is slightly brown or yellow, but by contrast may sometimes give the impression of green or blue. The bright polar caps, regularly varying with the season are undoubtedly composed of a thin layer of water, hoarfrost, or snow. The darkness and coloration of the maria also show regular seasonal variation, in addition to sporadic changes of a more persistent, nonseasonal character. The maria are commonly interpreted as vegetation consisting of primitive plants not containing chlorophyll. The failure to observe topographic irregularities near the Martian terminator is interpreted as indicating the absence of mountain chains or peaks; the upper limit of altitude is set for mountains at 2 to 3 km (Lowell) and for mountain ranges at 0.8 km (Russell). The Martian atmosphere is much thinner than the terrestrial with carbon dioxide the only constituent which has been definitely observed spectroscopically. The bulk of the atmosphere may consist of nitrogen and argon. Oxygen is practically absent. The presence of water vapor is indirectly inferred from the polar caps, but its amount is small. Liquid water surfaces are definitely absent, except perhaps temporarily near the poles.

123. Opik, E. J.
DUST AND THE PLANETS: MARS, Irish Astronomical Journal, Vol. 1, June 1950, pp. 44-47.

The composition of the Martian atmosphere, the physical appearance of the surface, and the nature of the dark areas on the surface are the major problems associated with Mars. The polar caps are most likely snow or hoarfrost, and since CO_2 has definitely been detected and a biologically suitable temperature range occurs, the prerequisites for life certainly exist on Mars. There are apparently no mountain ranges on Mars and wind-blown dust would have provided a featureless pattern if vegetation did not exist. It is likely that the dark areas are somewhat lower and therefore warmer and are also areas of liquid water drainage where vegetation can survive.

124. Opik, E. J.
NEWS AND COMMENTS: MARS, Irish Astronomical Journal, Vol. 5, 1950, pp. 110-111.

A summary is given of recent polarimetric studies of Mars and also the growth of microorganisms under simulated Martian conditions. The surface of Mars may be covered chiefly with a powder of iron oxides. Among the grains of limonite, especially in the maria, are dark grains which could be living organisms such as certain algae, lichens, or mushrooms which show a polarization curve similar to Martian curves. Flowering plants do not show this similarity. Under simulated Martian conditions, populations of microorganisms increased in three samples and decreased in one sample. Yeast and yeast-like organisms gradually disappear.

125. Opik, E. J.
SPECTROSCOPIC EVIDENCE OF VEGETATION ON MARS, Irish Astronomical Journal, Vol. 5, 1958-1959, pp. 12-13.

Theories of the dark areas of Mars are reviewed as well as the latest far-infrared spectroscopic evidence. That the dark areas might be due to volcanic ash or to exposed rock of higher altitude than the light areas is not acceptable as fitting all the observed facts for Martian surface features. The vegetation theory is still favored because terrestrial plants are known to exist such as algae and lichens, which do not show spectrographic absorption or infrared reflection characteristics of chlorophyll-bearing plants. Recent spectroscopic studies of Mars show an absorption band in the far infrared at 3.46 microns which is due to the C-H bond of large molecules which are usually known to be of organic origin. This observation seems to point to the presence of organic material on Mars, most probably of vegetable origin.

126. Opik, E. J.
THE ATMOSPHERE AND HAZE OF MARS, Journal of Geophysical Research, Vol. 65, No. 10, October 1960.

The blue haze is an absorbing smoke, dark as soot in reflection, and red in transmission. Its currently accepted explanation by pure scattering (omnidirectional or forward) is untenable, as it would either increase the surface brightness or fail to obscure the surface details.

The limb darkening of Mars is mainly the result of absorption by the smoke.

The opacity of the Martian atmosphere increases from the red toward the violet. The extinction by the Martian atmosphere is greater than that by the terrestrial at all wavelengths, but only about 20 percent of the Martian extinction is due to scattering.

Dollfus[1] polarimetric estimate, corrected for self-absorption, corresponds to a Martian atmospheric pressure of 87 mm Hg.

The photochemical breakup of carbon dioxide and the escape of oxygen must lead to considerable concentrations of carbon monoxide in the Martian atmosphere.

127. Owen, T. C. and Kuiper, G. P.
A DETERMINATION OF THE COMPOSITION AND SURFACE PRESSURE OF THE MARTIAN ATMOSPHERE, Communications of the Lunar and Planetary Laboratory, Volume 2 (Numbers 31-35), Tucson, Arizona, University of Arizona Press, 1964, pp. 113-132, Grants No. NsG 61-161, NsG 223-61, Nonr (G)-0050-62, ONR-00014-64 (A65-18477).

Calibration of 1 to 2.5 μ Martian spectra using laboratory spectra of pure CO_2 and mixtures containing CO_2, N_2, and Ar. Pathlengths up to 3.6 km are used and pressures down to four mm. With the aid of the total CO_2 content (based on the Mt. Wilson spectrum), preliminary values are derived for the pressure in the Martian atmosphere and the total amount of gases other than CO_2. The values obtained are 17 ±3 mb (13 mm Hg) and $(N_2 + Ar)/CO_2 = 6$. Arguments are given indicating that the Ar/N_2 ratio is probably similar to that for

the earth atmosphere ($\simeq 10^{-2}$) and that the O_2 content is probably less than seven cm-atmosphere.

128. Pickering, W. H.
MARINER 4'S FLIGHT TO MARS, Astronautics & Aeronautics, October 1965, pp. 20-21.

Mariner 4's photographs reveal that the Martian surface is thickly covered with craters very similar to those on the moon. These craters show very little evidence of erosion. Hence, it is unlikely that the planet had a significant atmosphere or significant amounts of free water at any time in its history. Perhaps this would make the evolution of life more difficult, but the only way we can confirm whether it did or did not arise is to land instruments on the surface.

129. Pickering, W. H.
MARS, Harvard Astronomical Station, Jamaica, Boston, Massachusetts, Gorham Press, 1921.

There is little doubt that surface markings are an indication for the presence of vegetation on Mars. Possibly animal life exists there too, but there is still the question of intelligent life. Canals (irrigation ditches) have been the only argument favoring the existence of intelligent beings on Mars. However, there are other theories explaining the occurrence of canals, such as volcanic cracks lying between craterlets. Vegetation growing on the sides is visible by telescope.

130. Rand Corporation, Santa Monica, California
ATMOSPHERES OF THE PLANETS by G. F. Schilling, September 1964, 61p, Report No. P-2964, AD-606 026 (Unclassified Report).

Assumptions, hypotheses, and theory on the planetary atmospheres are reviewed.

131. Rand Corporation, Santa Monica, California
EXTREME MODEL ATMOSPHERES OF MARS by G. F. Schilling, 1951, Report No. RM-2702-JPL (Unclassified Report).

Limits have been calculated for the permissible ranges of temperature, pressure, and density of the Martian atmosphere. An unusual conjectural model of the Martian atmosphere is based in part on the supposition that a small amount of ozone is present to produce appreciable amounts of stratospheric heating.

132. Rand Corporation, Santa Monica, California
LIMITING MODEL ATMOSPHERES OF MARS by G. F. Schilling, 1962, Report No. R-402-JPL (Unclassified Report).

From factual observational knowledge, realistic upper and lower limits were calculated for the permissible ranges of temperature, pressure, and density of the Martian atmosphere. The results are presented here in the form of two model atmospheres. Model I is in convective equilibrium throughout. Model II, more realistically, assumes convective equilibrium to a tropopause level, then conductive equilibrium up to an altitude of 30 kilometers. These two numerical models show that Martian atmospheric parameters still range widely in possible extreme values. Therefore, with certain speculative assumptions, the author tried to form a new, more coherent picture. The result is a conjectural Model III, reaching to 200 km in altitude. It was based partly on the supposition that even a relatively small amount of oxygen would give rise to some ozone and, hence, to appreciable amounts of stratospheric heating. Though conjectural, this model atmosphere has some surprising and potentially important meteorological characteristics. A combination of these three models allows us to predict with reasonable confidence ranges of Martian atmospheric conditions for specific heights up to 180 km over middle and low latitudes, regardless of season or time of day. The parameters of the Martian atmosphere are compared graphically, for practical use, with those of the earth's.

133. Rand Corporation, Santa Monica, California
NOTE ON THERMAL PROPERTIES OF MARS by C. Leovy, April 1965, Report No. NASA-CR-63278, RM-4551-NASA, N65-26075, Contract No. NASr-21(07).

As measured by Sinton and Strong the variation of infrared emission from the surface of Mars with local time on Mars is here interpreted in terms of a simplified theory of diurnal temperature variations, in which the effect of the atmosphere is included. The results suggest a very low thermal conductivity for the upper few centimeters of the Martian ground. Such low conductivities appear to be possible only if the material composing these layers is very fine powder having a characteristic size of not more than a few microns. If a linear relationship is assumed between convective heat transfer and surface temperature, the appropriate constant of proportionality is on the order of 10^{-4} cal per cm^2 sec deg.

134. Rand Corporation, Santa Monica, California
PROBLEMS AND CONCEPTS OF GENERAL PLANETOLOGY by S. H. Dole, 15 April 1960, Report No. P-1970, AD-616 651 (Unclassified Report).

The concept of treating planets as members of a general class of non-self luminous objects is introduced. Planets are shown to occupy the mass range roughly between 0.00001 to 10,000 earth masses (10 to the 23rd to 32nd grams), objects above this mass range being stars and below this mass range being classified as meteoroids or asteroids. Planets are further classified into types as airless bodies, planets with light atmospheres, and planets with massive atmospheres, the type being dependent on surface escape velocity and exosphere temperature. Some relationships among fundamental properties of planets are discussed: mean density versus radius, atmospheric composition as a function of exosphere temperature and velocity of escape, and oblateness as a function of rotational velocity, mean density, and internal density distribution. Some unresolved problem areas of general planetology are indicated.

135. Rea, D. G.
EVIDENCE FOR LIFE ON MARS, Nature, Vol. 200, 12 October 1963, p. 114.

The question of life on Mars has intrigued scientists for decades. Owing to the possibility of being able to verify directly the life hypothesis in the very near future it is becoming a subject of widespread study. One approach is to determine if certain terrestrial organisms can exist, perhaps in a modified form, in the Martian environment. Workers in this field have been encouraged by the recent positive identification of water vapor in the Martian atmosphere.

136. Rea, D. G.
THE DARKENING WAVE ON MARS, Nature, Vol. 201, 7 March 1964, pp. 1014-1015, A65-15140, NASA Grant NsG 101-61.

Paper dealing with a recent communication of the author concerning the evidence for life on Mars and, in particular, the seasonal wave of darkening and associated changes in the polarization of the dark areas. An improved rationale for a previous model (the principal feature of which is the seasonal transport of dust on and off the dark areas) explaining these phenomena is proposed.

137. Rea, D. G.
THE ROLE OF INFRARED SPECTROSCOPY IN THE BIOLOGICAL EXPLORATION OF MARS, International Symposium on Basic Environmental Problems of Man in Space, 2nd, Paris, France, 14-18 June 1965, Preprint No. 9 (Symposium Sponsored by the International Astronautical Federation, International Academy of Astronautics, UNESCO, International Atomic Energy Agency, International Telecommunication Union, World Health Organization, and World Meteorological Organization) (Grant No. NsG 101-61, Contract No. NASr-220,A65-26729).

Discussion of the theory underlying infrared spectroscopy and summary of the remote infrared observations made of Mars. The emission and absorption characteristics of liquids, solids, and gases resulting from the electromagnetic dipole, rotational, and vibrational properties of their molecules are outlined. Infrared spectroscopy has provided information on the atmospheric composition, pressure, and other parameters which are vital in the designing of a lander to explore the surface of Mars for evidence of life. Infrared radiometry has been used to measure the surface temperatures for the entire disk during the various seasons. The possibilities afforded by a spacecraft orbiting Mars and by a landed vehicle in the search for life on that planet are detailed.

138. Richardson, R. S. and Bonestell, C.
MARS, New York, New York, Harcourt, Brace & World, Incorporated, 1964.

If there is extraterrestrial life in the solar system, Mars is the only planet for which we have the slightest evidence of it.

139. Ryan, J. A.
NOTES ON THE MARTIAN YELLOW CLOUDS, Journal of Geophysical Research, Vol. 69, No. 18, 15 September 1964, pp. 3759-3770.

The so-called yellow clouds which occur in the Martian atmosphere are generally believed to consist of granular material which has been swept from the surface by atmospheric winds. Three questions relating to these clouds are considered in this paper, and are as follows:

1) The surface winds required to initiate grain motion.
2) The particle grain sizes which may be primarily responsible for the surface obscuration.
3) The effects such material movement may have on the surface.

It is found that unless the Martian surface is extremely rough, which appears unlikely, the wind velocities necessary to initiate grain movement are considerably greater than on the earth. If the surface atmospheric pressure is 80 mb, the required velocities do not generally exceed those observed. This is not the case if the surface pressure is 25 mb. Compatibility, for 25 mb, can be achieved, however, if the required high-velocity winds are of such short duration as to have escaped detection or if they are associated with relatively small cyclonic disturbances. It is also found that the vertical wind velocities required to maintain particles aloft are less than those required in the terrestrial atmosphere over a rather large grain size range (1 to 300 μ for 80 mb; 4 to 200 μ for 25 mb) and that particles significantly larger than generally quoted in the literature could be responsible for most surface observations. The possible effects of yellow cloud formation on the surface are noted. In particular, the presence on absence of dune formations can be used as an indirect indication of the surface grain size.

140. Sagan, C.
IS THE MARTIAN BLUE HAZE PRODUCED BY SOLAR PROTONS? Icarus, Vol. 1, 1962, pp. 70-74.

The hypothesis that solar protons produce the Martian blue haze is examined. To reach the atmospheric depth at which the observed haze layer is localized, proton energies in excess of two Mev are required. To produce sufficient molecular ionization to obscure surface detail in the blue, the proton fluxes must be greater than 10^{11} cm^{-2} sec^{-1} at Mars. So that magnetic deflection of solar protons by the terrestrial magnetic field can explain the clearing of the blue haze which is observed at opposition, the interplanetary magnetic field strength must be less than 10^{-8} gauss. Recent observations argue strongly against these required interplanetary magnetic field strengths, solar proton energies, and fluxes. Several further observational tests are suggested, but at the present time it appears that this hypothesis should be rejected.

141. Sagan, C.
MARINER IV OBSERVATIONS AND THE POSSIBILITY OF IRON OXIDES ON THE MARTIAN SURFACE, Icarus, Vol. 5, January 1966, pp. 102-103 (A66-21211).

Discussion of the results produced from the flight of Mariner IV past Mars and their indirect bearing on the study of the composition of the Martian surface. The results showed that there was no detectable magnetic field or related radiation belts, and that the surface was heavily cratered. The first result suggests that a migration of iron to the core has not occurred and that, consequently, there may be more iron on the Martian surface than on the terrestrial surface. The craters may be attributed to asteriod impact, indicating the possibility of meteoric iron on the surface. Original iron and subsequent meteoric iron may have oxidized as a consequence of the photodissociation of water vapor in the Martian atmosphere and the preferential escape of hydrogen.

142. Sagan, C., Hanst, P. L., and Young A. T.
NITROGEN OXIDES ON MARS, Planetary and Space Science, Vol. 13, January 1965, pp. 73-88 (A65-17992)

Comprehensive analysis of the case for the presence of nitrogen oxides on Mars. Analyses of observations at a variety of wavelengths place a firm upper limit on the Martian NO_2 abundance of one mm-atmosphere. Nitrogen dioxide is a highly photolabile gas and will be photodissociated by visible and ultraviolet radiation on Mars. The photochemical equilibria of nitrogen oxides on Mars have been computed from the observational upper limits on the NO and O_2 abundances. The same procedure gives consistent results for the earth at locales free from urban pollution. The corresponding theoretical upper limit to the abundance of NO_2 on Mars is one-mm atmosphere when reactions with water are neglected. When reactions with water are considered, the NO_2 abundance is further diminished. These low abundances are regarded as inadequate to account for the Martian observables discussed by Kiess et al. The one Martian phenomenon in which it is suggested that nitrogen peroxide may play a role is the blue haze, where one-mm atmosphere may help to explain not only the general blue and violet opacity, but also the dependence of the opacity on time and position. The required abundance of NO must then be > 50-cm atmosphere.

143. Sagan, C.
REPORT ON THE NASA INTERNATIONAL CONFERENCE ON REMOTE INVESTIGATIONS OF MARTIAN BIOLOGY, January 1964.

A conference with the above title was held in Cambridge, Massachusetts, in January 1964 by the American Institute of Biological Sciences with support from the National Aeronautics and Space Administration. Participating were 35 scientists, including astronomers, biologists, physicists, chemists, meteorologists, spacecraft engineers, and specialists in the psychology and physiology of vision. The conference was held to evaluate observations suggesting that life exists on Mars, to discuss theoretical constructs proposed to explain these observations, and to recommend future avenues for Martian research from the earth, from balloons, from earth-orbiting spacecraft, and from Mars fly-bys and orbiters. The purview of the conference explicitly excluded experiments performed from Mars landing vehicles. Particular attention was paid to the Martian wave of darkening, secular changes in the Martian dark areas, polarimetric observations of seasonal changes, and infrared observations of organic matter in the Martian maria. Only by postulating an extensive coverage of living organisms on the planet could the participants come to any unified hypothesis explaining these and other observations on Mars. The proceedings of this conference will be published separately in book form.

144. Sagan, C.
THE ABUNDANCE OF WATER VAPOR ON MARS, Astronomical Journal, Vol. 66, 1961, p. 52.

The water vapor required in addition to carbon dioxide in the Martian atmosphere to explain the green house effects is between 2 x 10^{-2} and 2 x 10^{-3} g/cm^2. The corresponding maximum thickness of polar cap is one-mm.

145. Salisbury, F. B.
A DISCUSSION OF SOME CURRENT THEORIES REGARDING THE MARKINGS ON MARS, Publications of the Astronomical Society of the Pacific, Vol. 69, 1957, pp. 396-397.

Arguments are advanced against theories of vegetation on Mars composed of earth-like crustose lichens. Lichens do not exhibit seasonal color changes, are very slow growing, would not appear quickly after dust storms, and could hardly be expected to cover large areas without adequate water. The ecological aspects of Mars would be very inimical to earth-like lichens. Gaseous exchange mechanisms with the limited O_2 available present another problem. Two biological possibilities remain. Life, as we know it, has become adapted somehow to the conditions on Mars or that another form of life unknown to us-a parabiology-accounts for the markings on Mars.

146. Salisbury, F. B.
MARTIAN BIOLOGY, Science, Vol. 136, 1962, pp. 17-26.

The author demonstrates that, of all the proposals put forth to account for the dark areas on the Martian surface, the idea of a biological origin seems to be the most tenable. If such is the case, this life (evidently vegetation) is very well adapted and flourishing. Suggested criteria seem to eliminate all known terrestrial life forms, but a higher plant would require the least modification to meet the criteria. Mobile and even intelligent Martian life forms are a possibility which cannot be ignored.

147. Shachovskoy, A. M.
RADAR OBSERVATIONS OF THE PLANET MARS IN THE SOVIET UNION, Life Sciences and Space Research II, A Session of the Fourth International Space Science Symposium, Warsaw, 3-12 June 1963, Amsterdam, Holland, North-Holland Publishing Company, 1964.

Radar observations of Mars were conducted in the Soviet Union at the beginning of February 1963, when the planet was in opposition. During the observation, the distance between the earth and Mars was 100 to 101 million km, and the used frequencies were near 700 MHz.

148. Sharonov, V. V.
A LITHOLOGICAL INTERPRETATION OF THE PHOTOMETRIC AND COLORIMETRIC STUDIES OF MARS, Soviet Astronomy-A. J., Vol. 5, 1961, pp. 199-202.

Results of visual photometric and colorimetric observations of the surface of Mars were compared with data of a study of terrestrial rocks. According to the mean values of the albedo Ω and the color excess D, sand, desert coverings, red Permian rocks, and dense varieties of limonite are not similar to the continents of Mars. Only the earthy varieties of limonite approximate the more saturated color of Mars. It is proposed that the surface of the Martian continents is covered with silt of limonite particles. The orange haze is caused by these particles ascending into the atmosphere.

149. Sharonov, V. V.
DUST COVERS ON THE SURFACE OF PLANETS AND SATELLITES, Life Sciences and Space Research II, A Session of the Fourth International Space Science Symposium, Warsaw, 3-12 June 1963, Amsterdam, Holland, North-Holland Publishing Company, 1964.

The problem of the presence or absence of extensive dust covers on the Moon, Mars, and other planets is the subject of many investigations and hypotheses.

The existence of a dust layer signifies firstly, that the processes transforming rocks into a finely dispersed material are active on the given celestial body, and secondly, that the factors leading to the cementation of such a powdery material are absent.

There are two pieces of observational evidence that the dust probably covers the planets:

1) The appearance of dust clouds or mist in the atmosphere of the planet.
2) The reflection of light from the surface is of the orthotrope type, i.e., according to Lambert's cosine law.

Numerous investigations of the reflection diagrams of terrestrial rocks and some kinds of terrestrial landscapes lead us to the conclusion that the reflection of light according to an orthotropic law occurs very rarely for massive rocks. It is on a flat stone surface that fairly regular reflection is generally observed. For rough surfaces, the diagram of reflection is typically elongated in the direction of the source of light. Only powdery materials, such as dust or volcanic ash, demonstrate a reflection similar to the orthotropic one.

Taking into consideration the nature of volcanic districts, one may see that the fall of a considerable amount of volcanic ash results in the flattening of the very fragmented surface of lava flows and as a consequence the reflectivity diagram becomes more nearly orthotropic.

As it is generally known, photometric observations of the moon give a reflectivity diagram, sharply elongated towards the sun. As a powdery material cannot possess such a diagram, the existence of extensive dust cover on the moon is unlikely. We are forced to assume the hypotheses that the lunar surface throughout consists not of dust, but of a slag-like material, which has recently been confirmed as a result of the analysis of radioastronomical observations. It is quite probable that this slaggy material has been formed as a result of the impacts of meteor particles of various sizes.

The surface of Mercury should resemble that of the moon and, therefore, there is no reason to suppose that there are dust covers on it.

As to Mars, photometric data indicate that the reflectivity is nearly orthotropic. Besides, orange or reddish dust mist or fog is observed in the planet's atmosphere. This allows us to suppose that the surface of the planet is mostly covered with dust, which on account of its color, in all probability consists of powdery limonite or ochre. That this material remains uncemented is a result of the lack of moisture.

Thus, the conditions under which extensive dust covers may arise are as follows:

1) The presence of an atmosphere, protecting the surface from the meteor impacts.
2) The absence of water or other agents causing cementation of clastic materials.

150. Sharonov, V. V.
THE NATURE OF THE MARS SURFACE AND ATMOSPHERE ACCORDING TO PHOTOMETRIC AND COLORIMETRIC DATA (LA NATURE DE LA SURFACE ET DE L'ATMOSPHERE DE LA PLANETE MARS D'APRES LES DONNEES PHOTOMETRIQUES ET COLORIMETRIQUES), Translated into English from French in Société Royale des Sciences de Liège, Mémoires, Cinquième Série, Tome 7, 1963, Physics of Planets, Proceedings of the Eleventh International Astrophysical Symposium. Liege, Belgium, 9-12 July 1962. University of Liege and USAF. Institut d'Astrophysique, Liege, Belgium, 1963, pp. 386-392 (A63-25359).

Conclusions on the nature of the surface and atmosphere of Mars derived from visual and photographic observations. The data on the albedo and color of objects on the earth and on Mars are tabulated. The photometric observations show that the light reflection from the soil of bright regions occurs in accordance with the Lambert law. The simplest explanation is that the external layer of the Mars surface consists of powder or powders colored orange by limonite.

151. Sinton, W. M.
AN UPPER LIMIT TO THE CONCENTRATION OF NO_2 AND N_2O_4 IN THE MARTIAN ATMOSPHERE, Publications of the Astronomical Society of the Pacific, Vol. 73, 1961, pp. 125-126.

The author offers evidence to disprove the theory of Kiess, Karrer, and Kiess (1960) that there is a high (1600 meter-atmospheres)concentration of NO_2 and NO_4 in the Martian atmosphere. A value of 2.2-mm atmospheres is given as the upper limit.

152. Sinton, W. M.
EVIDENCE OF THE EXISTENCE OF LIFE ON MARS, Advances in the Astronautical Sciences, Recent Astronomical Data on Mars and Evidences of Life, Proceedings of the AAS Symposium on The Exploration of Mars, Denver, Colorado, 6-7 June 1963, Vol. 15, Part 7, pp. 543-551 (A64-10167).

The observational evidence that bears on the supposed existence of vegetation in the dark regions of the planet Mars is discussed. Perhaps the oldest evidence which is sometimes cited is that the dark areas are green. In truth, these areas may not be green. The oldest valid evidence is the marked seasonal intensity variation of the dark regions. Another line of evidence follows from the failure of the dark areas to be covered up as a result of the dust storms. Recently, it has been found that the polarization properties of the dark regions vary regularly with the season, and from this variation it is concluded that the microscopic character of the dark material varies. Recently, too, it was learned that the characteristic infrared absorptions of organic matter are present in the dark regions, which observation considerably strengthens the hypothesis of vegetation. The temperature measurements of Mars are presented because, although they do not give any direct support to the existence of vegetation, they do have a bearing on the nature of the vegetation, if such is present. From the temperature observations it is concluded that plants are likely to be like cactus.

153. Si ter, A. E
THE VOLCANIC THEORY OF MARTIAN GREEN AREAS, Journal of British Interplanetary Society, Vol. 14, November 1955, pp. 319-323.

A review of the volcanic theory proposed by McLaughlin for the dark areas of Mars is presented. A trade wind system on Mars seems plausible, although observers have not noticed certain convergence zones of heavy cloud formation, as is the case on earth. Some parts of the descriptions of the dark areas seem consistent with the idea of a point source and occasional limited changes in wind direction. However, in areas of weak winds there should be a greater concentration of matter around each major source, and again there is no observational evidence for this. It is suggested that the seasonal change in intensity of the dark areas may be due to a combination of factors:

1) Volcanism, which ejects moisture and ash.
2) The seasonal growth of vegetation which depends on moisture from volcanoes and the melting polar cap.

154. Slipher, E. C.
A PHOTOGRAPHIC STUDY OF THE BRIGHTER PLANETS, Flagstaff, Arizona, Lowell Observatory, and Washington, D. C. National Geographic Society, 1964.

This unique collection of photographs, taken during an interval of early sixty years, should record the entire gamut of change that any planet may undergo in a very long time. Many of the photographs record interesting changes on Mars: seasonal changes in the snow caps and the darkening of the dark regions; Martian clouds and atmospheric phenomena, secular changes and temporary dark areas, and the problem of the Martian blue haze and blue clearing.

155. Slipher, E. C.
ATMOSPHERIC AND SURFACE PHENOMENA ON MARS, Publications of the Astronomical Society of the Pacific, Vol. 39, 1907, pp. 209-216.

Descriptions are given of cloud and haze formations in the Martian atmosphere and the changes in form and color of the surface maria. The meteorology of the atmosphere shows a sluggish circulation, although apparently changes can occur quickly in atmospheric clearing over extremely wide areas. Photographs show an extensive atmosphere, and spectrographic confirmation of oxygen and water vapor has been obtained. From the extent of the polar caps, a temperature fairly similar to earth's is inferred. It is apparent that the dark markings on Mars are all due to the same cause and obey the same law of change. Seasonal variation, color, and appearance of the dark area all obey the law of change expected of vegetation.

156. Slipher, E. C.
THE PHOTOGRAPHIC STORY OF MARS, Cambridge, Massachusetts, Sky Publishing Corporation, Flagstaff, Arizona, Northland Press, 1962.

The background information contained in the opening chapters of this book should provide the general reader with sufficient information to appreciate the photographs, understand their descriptions, and evaluate the author's conclusions. Otherwise, both astronomers and scientists in crossed disciplines who are interested in space research should find food for thought not only in the photographs and the general conclusions, but in the many technical details which must be considered before accurate conclusions can be drawn. The description of the changes in the Martian seasons, by one who has witnessed so many, should interest everyone with some measure of curiosity about Mars.

157. Sloan, R. K.
THE SCIENTIFIC EXPERIMENTS OF MARINER IV, Scientific American, Vol. 214, No. 5, May 1966, pp. 62-75.

The highly successful Mariner IV spacecraft provided new information on Mars and on the fields and particles in planetary space.

158. Smoluchowski, R.
TITLE UNKNOWN, Science, Vol. 148, 14 May 1965, pp. 946-947 (A65-24293).

An investigation of the phenomena associated with the effect of radiation flux on certain Martian minerals as an inorganic explanation for some of the seasonal color changes observed on that planet. At least some of the changes in the color of Mars at different seasons are caused by color centers produced by electromagnetic and corpuscular solar radiation in solids on the surface. Calculated radiation flux, at appropriate energies and known temperature variation, could account for seasonal formation of color centers and bleaching, if a simple trap model is assumed. It can be assumed that there are a large number of shallow electron traps which are easily ionized during summer but are mostly occupied during winter. This leads to a depletion of electrons from the color centers during winter and to an increased occupation during the summer. In certain kinds of rhyolite (SiO_2, $NaAlSi_3O_8$), which has been suggested as one of the possible constituents of the Martian surface, color centers can be produced. No color centers are expected in limonite, $Fe_2C_3 \cdot 3H_2O$, the other likely constituent.

159. Spinrad, H.
THE ATMOSPHERE AND SURFACE FEATURES OF MARS, Virginia Polytechnic Institute, Conference on Artificial Satellites, Part B, August 1964, 20 p., N65-15488 06-31, N65-15491.

A review is presented of earthbound observations of Mars. An up-to-date description of the Martian surface is included, and it covers discussions of polar caps, dark areas, vibration absorptions in the infrared specturm, color, mountain areas, canals, wave of darkening, propagation velocity, surface temperature, and the equatorial temperature. The molecular atmosphere of Mars reveals only two positively identified gases - carbon dioxide and water vapor. A study of the estimates of these gases is presented. The cloud and blue haze patterns are discussedin terms of absorption with photometric evidence.

160. Stone, L.
MARINER DATA MAY LIMIT VOYAGER PAYLOAD, Aviation Week & Space Technology, 2 August 1965, pp. 55-60.

Largest single factor which may limit the payload capacity of the Voyager capsule, projected for letdown on Mars in 1971, is the Mariner 4 data indicating a thin atmosphere of only 10 to 20 millibars rather than the 20 to 40 millibars estimated previously from earthbased spectroscopic studies.

161. Strughold, H.
IS MARS COVERED WITH ICE? (IST MARS MIT EIS BEDEKT?), International Science and Technology, No. 30, June 1964, pp. 11-12.

A brief description is given of a theory revived and developed by Davydov which postulates the existence of a subsurface frozen hydrosphere on Mars. The possibility of a biosphere in this region is briefly considered. The entire matter is highly hypothetical, but it should not be ignored.

162. Sytinskaya, N. N.
PROBABLE DIMENSIONS OF MICROFEATURES OF THE LUNAR SURFACE, Bulletin of Commission of Physics of Planets, Academy of Sciences USSR, Astronomical Council, No. 1, 1959, pp. 81-84.

The unevenness of the lunar surface is estimated by comparing the nature of light reflection from the surface in the optical region (strong roughness) in the decimeter range (mirror characteristics). The mean dimension of the microfeatures appears to be of the order of several millimeters to several centimeters.

163. Tolbert, C. W.
OBSERVED MILLIMETER WAVELENGTH BRIGHTNESS TEMPERATURES OF MARS, JUPITER, AND SATURN, The Astronomical Journal, Vol. 71, No. 1, February 1966.

Analyses of observations of 35, 70, and 94 Gc radiation from Mars, Jupiter, and Saturn made with a 16-ft antenna yield brightness temperatures for Mars of 230 (+42, -42)°K and 240(+72, -48)°K at 35 and 94 Gc, respectively; for Jupiter, 113(+11, -11)°K, 105(+18, -12)°K and 111(+22, -11)°K at 35, 70, and 94 Gc, respectively; and for Saturn, 116(+30, -30)°K, 103(+70, -64)°K and 97(+52, -42)°K at 35, 70, and 94 Gc, respectively. The antenna temperatures from which the brightness temperatures were calculated were obtained by averaging the responses of right ascension scans of the antenna beam across the planets. The observing and data reducing techniques are herein described and the averaged antenna temperatures shown.

164. Tombaugh, C. W.
EVIDENCE OF FAULTING IN THE CRUST OF MARS, PART I, GRABENS, The Astronomical Journal, Vol. 68, No. 8, 1963, pp. 533-547.

This is one of a series on the geology of Mars. Since the methods of measurement of relief on the moon are not practical for Mars, an indirect approach was sought.

165. Tombaugh, C. W.
GEOLOGICAL INTERPRETATIONS OF THE MARKINGS OF MARS, The Astronomical Journal, Vol. 55, December 1949-February 1951, p. 184

The formation of the various markings on Mars by geological processes, asteroid impact, and association with hardy seasonal vegetation is discussed. Low temperatures would greatly retard oxidation of surface minerals. The deserts may consist of relatively unaltered rhyolitic igneous rock due to a lack of water erosion and minimal sand erosion. The round oases are sites of impact craters caused by collisions of small asteroids filled by vegetation similar to lichens which find a favorable environment in the pulverized igneous rock and shelter offered by the crater. Previous civilizations capable of building the canals are ruled out by consideration of available natural resources. The canals may be fracture zones caused by asteroid impact which give haven to vegetation capable of absorbing slight atmospheric moisture.

166. Tombaugh, C. W.
LIFE ON MARS, Space World, 2:2, January 1962, pp. 36-37, 58, and 61-62.

The controversial question of whether or not life exists on Mars is discussed. Observations and theories concerning the planet's atmosphere, surface features, and natural satellites are related.

167. Tombaugh, C. W.
MARS A WORLD FOR EXPLORATION, Astronautics, 4:1, January 1959, pp. 30-31, 86-93.

The atmosphere and climate of Mars is discussed. The shrinking and reforming of the polar caps are cited as evidence of an atmosphere which is estimated at one tenth that of earth. Spectrographic observation has failed to disclose free oxygen; CO_2 and some argon are present. The solar radiation received on Mars is only from 53[2] to 36 percent of that received on earth. Mars' seasons are of unequal length, and the highest noon temperatures are only a few degrees above freezing with a diurnal variation of over 200°F. The southern marias exhibit the fullest range of seasonal color change. New spectrographic evidence indicates that organic matter exists on Mars, but water would be required in the atmosphere for this matter to have life. No ozone or sulfur dioxide layer, which would protect the surface from ultra-violet radiation, has been discovered. However, vegetation may shield itself by changing color. The canals (asteroid scars) and the oases (impact craters) may be havens for vegetation. Martian geology shows a lack of sedimentary rock, erosion carving, and metamorphic rocks.

168. Urey, H. C.
ON THE ESCAPE OF WATER FROM MARS, Publications of the Astronomical Society of the Pacific, Vol. 68, 1956, p. 220.

Not Abstracted.

169. Van Tassel, R. A. and Salisbury, J. W.
THE COMPOSITION OF THE MARTIAN SURFACE, Icarus, Vol. 3, 1964, pp. 264-269.

It is generally believed that the desert areas of Mars are composed of limonite. This model of the surface, while based upon polarmetric, spectrometric, color, and albedo measurements, contradicts a reasonable geologic model. An examination of the evidence of limonite on Mars shows that the above measurements are ambiguous. Laboratory experiments demonstrate, in particular, that the lack of the characteristic infrared emission spectra of minerals can be a result of small grain size. Finely powdered minerals have infrared emission characteristic of a graybody and yield very little spectral information. Thus, the Martian surface materials could be composed primarily of fine-grained silicates, or of coarse-grained silicates coated with finely divided limonite, without their presence being revealed spectrometrically.

170. Vishniac, W.
BACTERIAL ECOLOGIES IN LIMONITE, Life Sciences and Space Research, Volume 3, International Space Science Symposium, 5th, Florence, Italy, 12-16 May 1964, Amsterdam, Holland, North-Holland Publishing Company, New York, New York, John Wiley and Sons, Incorporated, 1965, pp. 64-73 (A65-30671 19-04).

Limonite ($Fe_2O_3 \cdot nH_2O$) may be a constituent of the Martian surface. We have prepared culture media with ferric hydroxide as an electron acceptor. One medium contained ethanol, another contained gaseous hydrogen and carbon dioxide. Bacterial growth without light and oxygen suggests that ferric iron serves as a terminal respiratory electron acceptor. The oxidation of ferrous hydroxide may be carried out by photosynthetic bacteria. A ferrous-ferric couple may thus support bacterial respiration and photosynthesis in the absence of oxygen. This cycle may account for the dark markings of Mars.

171. Wells, R. A.
EVIDENCE THAT THE DARK AREAS ON MARS ARE ELEVATED MOUNTAIN RANGES, Nature, Vol. 207, 14 August 1965, pp. 735-736 (A65-32615).

Discussion of evidence regarding the existence of elevated mountain ranges on Mars which appear as dark areas when observed by telescope. A statistical survey of the occurrence of localized white and yellow Martian clouds has indicated that many white clouds are observed to form over the bright desert regions along dark areas and to remain stationary for sometime. Notable areas for such occurrences have been recorded by Focas and Dollfus for the "Edom" region to the north of Sabaeus Sinus. For polarization investigations, Dollfus has interpreted the curves for white clouds to be identical with that observed for ice crystal clouds. Scorer's theory of the formation of standing waves to the lee side of mountain ridges is used to explain this phenomenon. A mathematical analysis of this theory is then given, corroborated by terrestrial observations on Alpine Föhn winds. The hypothesis is made that the observed Martian white cloud formations are physical evidence of the presence of mountain ranges on Mars, confirmed by telescopic observations of dark areas.

172. Whipple, F. L.
EARTH, MOON AND PLANETS, New York, New York, Grosset & Dunlap, Publishers, 1958.

Not Abstracted.

173. Young, R. S.
BACTERIA UNDER SIMULATED MARTIAN CONDITIONS, Space World, Vol. A-2, November - December 1963, pp. 36-39 (A64-18258).

Discussion of a new technique for the simulation of known parameters of the Martian evironment along with possible biological implications. The response of bacteria to such simulation is demonstrated in terms of survival and growth, showing that certain bacteria will not only survive but grow during simulated Martian freeze-thaw cycling if water is present. How water could be present on Mars although not detectable with current technology is demonstrated, and plans for future experimentation are discussed.

174. Young, R. S., Ponnamperuma, C., and McCaw, B. K.
ABIOGENIC SYNTHESIS ON MARS, Life Sciences and Space Research, Volume 3, International Space Science Symposium, 5th, Florence, Italy, 12-16 May 1964, Amsterdam, Holland, North-Holland Publishing Company, New York, New York, John Wiley and Sons, Incorporated, 1965, pp. 64-73 (A65-30671 19-04).

Atmospheres capable of producing organic compounds under primitive conditions are discussed in the light of recent experimental evidence. The atmosphere of Mars is discussed, in particular, the observations of Sinton of reflection spectra with features at 3.45, 3.58, and 3.69, which are attributed to C-H bands and the presence of organic molecules. Colthup interprets these features as being representative of organic aldehydes and suggests specifically, acetaldehyde. Many works have considered these observations as being indicative of life on Mars. Rea has offered alternative hypotheses. This paper presents experimental evidence of yet another possible explanation; that organic compounds are being produced in the Martian atmosphere and may be responsible for Sinton's observations. The influence of such syntheses on possible Martian organisms is discussed. Various possible Martian atmospheres have been irradiated with ultraviolet

light as well as other possible energy sources, and a variety of organic end products have been identified. Martian atmospheres plus acetaldehyde as a starting point have also been used and end products analyzed. Possible abiogenic pathways for Mars are discussed.

175. Zhukova, A. I. and Kondratyev, I. I.
ON ARTIFICIAL MARTIAN CONDITIONS REPRODUCED FOR MICROBIOLOGICAL RESEARCH, Life Sciences and Space Research, Volume 3, International Space Science Symposium, 5th, Florence, Italy, 12-16 May 1964, Amsterdam, Holland, North-Holland Publishing Company, New York, New York, John Wiley and Sons, Incorporated, 1965, pp. 64-73 (A65-30671 19-04).

It is of interest to investigate the behaviour of the terrestrial microorganisms under artificial Martian conditions. This will help to verify the hypothesis concerning a possibility of life on this planet.

An artificial climate chamber enables one to expose microbial cells to a simultaneous effect of such factors as temperature, pressure, gas composition,and insolation as follows:

1) Temperature regime is maintained automatically by means of an electronic-mechanical program device.
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3) The spectral composition of light source is close to that of the sun spectrum.
4) The chamber enables to expose microorganisms on membrane filters with diameter of 23 mm or in special quartz cells of the same diameter size.

The preliminary experiments have shown that not all the terrestial forms of microorganisms survive under artificial conditions of the Martian summer.

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13. ABSTRACT

This summary and annotated bibliography is a selection of the more accepted literature from the enormous quantity which covers the range of hypotheses as to Mars surface formation, surface material, and terrain. Various hypotheses and the few generally accepted facts are discussed. Included is a selected bibliography, author index, and subject index.

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