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Significant Achievements in the Planetary Geology Program, 1980

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Significant Achievements in the Planetary Geology Program, 1980

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INTRODUCTION

The purpose of this publication is to summarize the research conducted by NASA's Planetary Geology Program Principal Investigators (PGPI) and Mars Data Analysis Program (MDAP) Geology Principal Investigators. The summaries in this document are based on presentations at the eleventh PGPI meeting held at Arizona State University, January 14-16, 1980 and are a digest of the 1980 meeting abstract document. (Report of Planetary Geology Program, 1979-1980, NASA TM81776). Important developments are summarized under the broad headings as listed in the Table of Contents.

The accomplishments of any science program are a reflection of the people who take part in it. The contents of this document is a testimony to the PGPI's who have produced significant advances in the exploration of space. They represent a group of people dedicated to advancing the frontiers of geology past the traditional limitation of the planet earth.

This document is based on summaries prepared by session chairmen at the annual meeting. These contributing authors are listed below.

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GEOPHYSICS AND TECTONICS OF MARS

The global-scale geophysical characteristics of Mars that are relevant to tectonic synthesis were presented (Phillips; Davies) and followed by two more or less conflicting presentations attempting to constrain geophysical models of the martian interior and its evolution using the entire spectrum of structural, stratigraphic, geophysical and cratering studies (Solomon and Head; Wise). The final report was a more detailed discussion of the tectonic significance of the Coprates region (Saunders, Roth, Downs, and Schubert).

R.J. Phillips (LPI) compared the gravitational power spectrum of Mars with that of the Earth. The unique long-wavelength anomaly of the Mars spectrum is related to the Tharsis bulge; otherwise, the slope of the power-vs.-sperical-harmonic-index curve is roughly parallel to that for the Earth up to the middle harmonics for which the Mars curve has been determined. Phillips suggested that the Tharsis region may be somewhat analogous to the North African gravity low -- perhaps an incipient rift (?).

G.F. Davies (Washington U) discussed models for the thermal evolution of Mars that consider a multiplicity of heat sources and that assume convective heat transport. The initial temperature assumed is the primary control on the timing of peak heat flux; core formation will exert only a secondary influence on this timing. If T_o is on the order of 20-50% of present T, then peak heat flux would occur $< 2 \times 10^9$ years ago, whereas if T_o is $> 80\%$ of present T, peak heat flux would be expected $> 3.5 \times 10^9$ years ago. Early peak heat flux is strongly favored by evidence derived from cratering chronologies for widespread resurfacing $> 3.5 \times 10^9$ years ago. The peak heat flux on Mars very likely was close to current Earth ocean-basin flux, raising some interesting questions about the operation or non-operation of plate tectonics on Mars $\sim 3.5 \times 10^9$ years ago.

S.C. Solomon (MIT) and J.W. Head (Brown) presented an alternate view of the tectonic history of the Tharsis region. They pointed out that the tacit assumption of some workers that the heavily cratered materials incorporated in the Tharsis uplift are primordial crust need not be true, but that these materials could just as easily be very old volcanics formed just before the end of early bombardment. Thus they argued that the entire "uplift" could be constructional. If so, it is not necessary to postulate unique, ad hoc internal events to explain the large and unique crustal feature Tharsis. They postulated a strictly constructional Tharsis supported by a regionally thick lithosphere; a lithosphere with local thin spots that concentrate global stresses (and thus control fracturing) and that also concentrate volcanic activity. The heat of volcanism would tend to preserve the local thin spots in the lithosphere, favoring long-continued tectonic and volcanic activity in the same places.

D.U. Wise (U Mass) summarized structural, stratigraphic, and cratering evidence bearing on the tectonic evolution of the Tharsis region and Mars. The historical evidence points to relatively fast, unique events early in martian history -- resurfacing of 1/3 of the planet, and formation of the Tharsis uplift -- a history that does not seem consistent with models based on continuous operation of the same volcanic and tectonic processes. These unique events can be explained by a model for the tectonic development of Mars that begins with planet-wide convection and foundering of the northern third of the primordial crust; this was follwed by core formation, a rapid event that liberated the heat required for the Tharsis uplift and the long-lived volcanic activity. The highland-lowland boundary acted as a zone of weakness controlling the location of Tharsis.

R.S. Saunders, et al. (JPL) and G. Schubert (UCLA) reported on a study of a region south of Coprates Chasma that coincides with the crest of topographic high, recently defined by Earth-based radar scans. The high region is embayed by materials of Ridged Plains, so it existed as a topographic elevation before the formation of these materials. There is photogeologic evidence that the lavas forming the Ridged Plains have, at least in part, come from sources on this topographic high. Of even greater interest, however, is the presence of flatiron-like features along the flanks of the high region. By analogy to similar features on Earth, the authors interpret these flatirons to represent the upturned and eroded edges of layers dipping away from the high region, an interpretation implying that the elevated region is tectonic rather than constructional.

MARTIAN CRATERING

The role of impact cratering on Mars was reviewed by J. Head (Brown). The unique character of martian fluidized ejecta craters (rampart, "splosh" or pedestal craters) was discussed in context with the inferred cratering mechanisms responsible for the production of lunar and terrestrial craters. Latitude, altitude and target material were shown to influence martian crater morphology and the areal extent of the ejecta deposits, but the exact mode of formation of these craters remains unresolved. Target characteristics (a combination of pre-existing particle size, stratification and volatile content) at the time of the cratering event were identified as the most likely causative factor for the production of fluidized ejecta, but atmospheric effects were also considered. Detailed geological mapping of large martian craters and the application of lines of future research to help resolve some of the processes responsible for the striking morphological differences bewteen martian craters and their lunar and mercurian counterparts.

The use of crater size/frequency curves to derive estimates for a martian chronology was discussed by K. Hiller and G.

Neukum (Ludwig-Maximilian U, W. Germany). A compilation of published crater counts suggests that on the basis of their cratering curve, the production of the volcanic constructs and the major erosional episodes on Mars were restricted to the early history of the planet. Exceptions to this time frame are the relatively recent formation (0.5 b.y. B.P.) of the Tharsis shield volcanoes and the floor material of channels such as Kasei Vallis.

Viking Lander images were employed by R. Arvidson (Washington U) to calculate the resurfacing history of Mars. The high degree of crater preservation at VL-1 suggests that rock breakdown and removal rates are much less than 1 mm/yr. Cumulative crater frequency curves for parts of the high northern latitude plains indicate that a "bulbous terrain" material is equivalent in age to the oldest extensive plains units in the equatorial region. Dust mantling on this unit may be occurring at about 1 mm/yr if such plains materials are $3 - 4 \times 10^9$ years old. This deposition rate is similar to that inferred for the higher northern plains and is not considered to require any drastic change in martian climate. Arvidson estimates from crater counts that $\sim$75% of the planet's surface area formed between 3.5 - 4.0 b.y. ago, which he notes is inconsistent with current evolution models for Mars.

Three papers dealt specifically with aspects of martian crater morphology. K. Blasius and coworkers (PSI) outlined a project designed to provide a global survey of crater ejecta morphology, and presented footprints for the medium resolution Viking images that they intend to use as their data base.

A. Woronow and P. Mutch (UA) described their measurements of crater size vs. ejecta surface area for craters lying in quads. MC-17 and MC-18. They applied a variety of theoretical models to their data base to conclude that discrete crater types (pedestal, lobate, and multi-lobate) exist on Mars, instead of a continuum of ejecta blanket morphologies. Distinct and different physical properties of the target and/or projectile were inferred to produce these different crater types. A ballistic mode of ejecta emplacement was rejected by employing empirical as well as observational data. The formation of each ejecta lobe was attributed to internal failure of rim material, which was initiated by the maximum thickness of the ejecta exceeding the loading strength of the material. Successive episodes of failure were proposed as a possible mechanism for the formation of multi-lobate crater ejecta deposits.

Aspects of ejecta emplacement were also considered by P. Mouginis-Mark (Brown). A global study of craters possessing single (Type 1) and double (Type 2) continuous ejecta deposits revealed that neither latitude, altitude nor target material were solely responsible for the distribution of these crater types. A disparity of ejecta travel distances was identified but remains unexplained: Type 2 ejecta deposits consistently travelled 0.8 crater radii further from the crater rim than comparable ejecta around Type 1 craters. Volume estimates for the ejecta and crater cavity indicate that considerable quantities of locally derived material beyond the crater may have to be incorporated within the ejecta lobes to explain the observed thicknesses of these deposits. Ries Crater was suggested as a possible terrestrial analogue for this martian process, since the German crater exhibits a similar increasing proportion of locally derived material with increasing distance from the parent crater and radial scouring of bedrock beyond the rim deposits.

MARTIAN VOLCANISM

A review of the major volcanic provinces and processes currently identified on Mars was ably presented by Ronald Greely (ASU), providing a framework for subsequent papers. Greeley summarized the distribution of volcanism in space and time, concluding that plateau plains are the oldest volcanic units, the large shields and flood lavas surrounding them are the youngest.

Small volcanic constructional features of the Tempe Plateau were discussed by Carroll Ann Hodges (USGS) and Jeff B. Plescia (USC, JPL), both of whom drew analogy with low shields of the Snake River Plain. The Tempe Plateau region surveyed covers about 200,000 km^2, as represented on Viking images obtained during rev 627A, frames 01 through 58. The area includes two major terrain units: an intensely fractured upland plateau remnant and an embaying lowland clearly made up of a sequence of lava flows; the vents occur predominantly, but not exclusively, in the lowland, and appear to be localized along fractures trending N 50°-60° E. The fracture trend in the upland is predominantly N 30°-40° E; scattered N 50°-60° E fractures in the upland appear transected by the N 30°-40° E set, which is absent from the volcanic lowlands.

Hodges concluded that the vents (numbering perhaps 26 to 30) of the Tempe-Mareotis region were decidedly the most convincing of all the "lesser volcanic provinces" thus far postulated; the dimensions are within the same order of magnitude as those of similar small terrestrial shields, and dimensionless ratios, insofar as these can be determined (height/base; summit crater width/basal diameter of shield), are essentially identical to those of low shields (Icelandic shields), and steep shields (including Mauna Ulu in Hawaii). Fissure vents also appear to occur in this province.

Plescia compiled crater statistics showing that the shields and lava plains were contemporaneous, having 1-km-crater densities of about 1100 ± 35 per $10^6 km^2$. These vents are older than the large Tharsis shields but essentially contemporaneous with the smaller shields (Uranius Patera, Uranius Tholus, Ceraunius Tholus) that are aligned with the large shields and localized between them and the Tempe area.

A major problem seems to be explaining the truncated development of the small Tempe shields and their occurrence at the fringe of the province of very large shields. Greeley (ASU) earlier raised the same question of development with respect to the shields of the Smake River Plain. Hypotheses to account for this type of basaltic eruption style must consider both martian and terrestrial geologic environments of localization.

Gerald Schaber (USGS) discussed the radar, visual, and thermal characteristics of lava flows in the Tharsis-Memnonia-Amazonis region of Mars. High resolution (10-25 m/pixel) Viking orbiter images permit visual assessment of Earth-based radar analyses of rms slopes at 1 to 30 m lateral scale. Variable but generally high rms slopes predicted for the Tharsis-Memnonia-Amazonis volcanic plains from radar data are qualitatively confirmed by the Viking image data. Among the roughest planar surfaces on the planet (at lateral scales of 1 to several 100 m) is in southern Elysium Plainitia where the existence of yardangs is indicated by the Viking images.

The high resolution images also offer clues to interpretations of pre-dawn temperature residuals and the thermal inertia data. Thermal contacts that outline low-temperature regions on Mars (Tharsis-Memnonia-Amazonis, Arabia, Elysium Mons) apparently mark the boundaries of stable and unstable eolian mantles. Surfaces with pre-dawn temperature residuals below about -10^{o}K or thermal inertia below about 4 south and west of Arsia Mons may have received either a continuous deposition of fine-grained (10 to 100 microns) material or an older accumulation of similar material that somehow has been stabilized.

The correlations between Earth-based radar and martian landforms images by the Viking orbiters were further discussed by Peter Mouginis-Mark (Brown) in a paper co-authored with S. H. Zisk (Haystack) and G. H. Pettengill (MIT). Surfaces characterized by high rms values in the radar return appear to be rugged or hilly units in the Viking images. The authors noted the ability of radar sensors to distinguish lava types on the basis of physical properties (e.g. highly vesicular or rugged surfaces) and/or the degree to which surfaces are mantled. The authors contended that radar data confirm the anomalous character of Solis Lacus (20°S, 85°W), an area having exceptionally high reflectivity and smoothness values, and that the observed seasonal variations in the radar return can be explained only by the presence of small amounts of liquid water at the surface of Solis Lacus during local summer. This conclusion generated considerable controversy in the ensuing discussion.

Alex Woronow (LPL) described small constructional features in western Utopia Planitia according to measurements of their base or total ejecta areas as related to the areas of the central craters and concluded that the ratios between these parameters dictated a pyroclastic volcanic origin. He determined that both the size distribution and the extensive size of individual features precluded their origin by impact. Factoring in the effects of gravitational and atmospheric differences between Mars and Earth, Worow concluded that the Utopian features were most nearly analogous to terrestrial cinder cones.

MARTIAN ATMOSPHERE-LITHOSPHERE

A summary of probable martian atmosphere-lithosphere interactions was presented by J.B. Pollack (ARC). Proposed volatile inventories of Mars, the Earth, and Venus were compared, and it was argued that the volatiles were probably derived primarily from gases trapped in material that formed the planet. Gases captured from the solar wind or the primordial nebula subsequent to planet formation, and gases derived from impact of asteroids and comets were suggested not to be principal sources of volatiles. The differences in volatile inventories bewteen Mars, Earth, and Venus were attributed to a large pressure gradient but small temperature gradient in the solar nebula as well as to differences in the efficiencies of outgassing. An early epoch of outgassing during the first billion years was proposed, followed by episodic releases of juvenile volatiles associated with major igneous events. It was argued that the martian atmospheric pressure may have declined more or less monotonically with time through chemical and physical interaction with the regolith since, unlike Earth, there has apparently been little atmosphere-crust volatile recycling. Possible effects of periodic obliquity-driven atmosphere-regolith volatile exchanges on Mars were also reviewed, including channel formation, strong modulations of dust storm activity, and the formation of polar layered terrain.

R. S. Saunders, F. P. Fanale, and J. B. Stephens (JPL) presented results from and a description of their Mars Atmosphere-Regolith Simulation (MARS) experiment. They reported the successful design, fabrication, and testing of the MARS chamber and the Aeolian Clay (air) Classifier atmosphere-regolith exchange and gas permeation processes. They plan to study the rate at which CO_2 penetrates the regolith in response to variations in atmospheric pressure in order to determine whether or not the regolith could buffer the atmospheric variations in pressure on a seasonal time scale. They also intend to study analogous processes with inert gases and H_2O vapor. Initial testing with evacuated and dried 1-10 um montmorillonite showed that the system can detect a pressure wave of N_2 as the gas flows through the clay under a pressure difference of 5 mm to 20 mm (at the surface of the clay).

R. V. Morris (USC) and H. V. Lauer, Jr. (Lockheed Electronics Co.) reported results from an experiment in which natural and synthetic magnetite samples were exposed to unfiltered UV-VIS-IR radiation or to filtered UV, VIS, and (or) NIR radiation at 0.8 w/cm^2 in the near-UV. Most irradiations were carried out in 100 torr pure O_2 atmospheres, while some were carried out in dry air or laboratory air in a closed circulating gas system. Depending on whether or not filters were used, sample temperatures were $\lesssim 80^{\circ}C$ or $\lesssim 540^{\circ}C$, monitored with a thermocouple in intimate contact with the magnetite. Samples were irradiated for up to $\sim$300 hr and they were analyzed for possible oxidation by searching for changes in saturation magnetization (J_s) with a vibrating sample magnetometer. The unfiltered radiation (producing $\lesssim 540^{\circ}C$ temperatures) produced measurable oxidation, while all but one sample irradiated with filtered light showed no detectable change in J_s. Since the unfiltered samples ($\gtrsim 80^{\circ}C$) produced no perceptible changes in J_s, they deduced that all of the observed oxidation was probably due to thermal oxidation rather than photooxidation. They suggested that the results of earlier experiments by R. L. Huguenin may also have been due to thermal oxidation, and that there is not the experimental basis for inferring that UV photostimulated oxidation occurs naturally on the surface of Mars.

R. L. Huguenin, J. Danielson, and S. Clifford (U Mass) reported additional laboratory evidence that UV photostimulated oxidation of magnetite should occur on Mars. In contrast to the results of Morris and Lauer, unfiltered UV-VIS-IR illumination at fluxes as low as 1.7 x 10^{12} photons cm^{-2}s^{-1}A^{-1} at 1950A produced oxidation after 240 hrs at sample temperatures of 50-65°C in laboratory air. Sample temperatures were measured using (1) embedded or thinly coated (with magnetite) thermocouple and thermistor probes in a variety of configurations; and (2) a series of magnetite coated and (or) embedded standardized melting point substances. Relative humidities were maintained above the critical 1-5% level at 50-54°C, which is required in order for photooxidation to occur. When humidities were lower than the critical threshold, photooxidation did not occur (as reported in the earlier experiments). This might account for the results of Morris and Lauer, who used dry atmospheres. Humidity is not required for oxidation of magnetite at $T = 580^{o}C$, which is also consistent with the results of Morris and Lauer. Huguenin et al also reported experimental confirmation that UV illumination produces photoemission from magnetite with a work function of $3.9 \pm .1$ eV and a quantum yield of 0.1 - 1 at 1950Å in 10^{-6} torr O_2, as predicted by the earlier photooxidation experiments. Also reported was an error in the earlier UV flux estimates, which indicates that photooxidation may be occurring by a factor of 10^3 faster on Mars than previously estimated. It was suggested that the rate is probably severely inhibited by surface coatings, however, and that freshly abraded rock surfaces may form surface coatings on a much faster time scale than previously estimated.

S. D. Wall (JPL) reported the observation of a white surface condensate at the Viking 2 lander site during both of its two winters. In each case the condensate appeared near L_s = 235^{o} and remained for approximately 200 sols. Dust storms over the lander accompanied the appearance both years. Data acquired included photometric function, spectral albedo, temperature and pressure. A $CO_2(s)$ composition was indicated, but $H_2O(s)$ may be required to explain the slow removal period. Thickness of the condensate could not be accurately measured but it was bounded by $\sim$1 μm at the low end and $\sim$1 mm at the high end.

S. M. Clifford and R. L. Huguenin (U Mass) discussed the H_2O mass balance on Mars and proposed that a global subpermafrost groundwater flow system may be indicated. Annual polar deposition rates (poleward of 60^{o} N) and equatorial evaporation/outgassing rates are both apparently $\gtrsim 10^{15}$ g/yr. If these rates are typical of the martian norm, an amount of H_2O equivalent to that believed to be contained in the North Polar Cap would accumulate in less than 10^5 years and the entire theoretical global inventory of H_2O on Mars could be cold-trapped at the poles in 10^7 years. Since such accumulations have not been observed and since enough time has elapsed for this process to have been repeated several hundred times, it was proposed that some efficient means for removal of H_2O from the poles and replenishment of equatorial regolith H_2O probably exists. Purely atmospheric models of replenishment (preferential adsorption and burial of condensates) were reviewed and they appear to be too inefficient. It was proposed that the deposition of atmospheric H_2O in the polar regions may be balanced by the release of geothermally melted H_2O from the base of the cap into a global interconnected groundwater flow system beneath the martian permafrost. Evaporation of brines and ice from the top of the permafrost at equatorial and midlatitudes could then be balanced by the flow of subpermafrost melt water into these regions, completing the cycle. They proposed that the cycle may not be continual on a short term; instead the system may periodically discharge and recharge in response to climatic variations.

MARTIAN CHANNELS

A summary talk by M. H. Carr (USGS) stressed the great improvement in resolution of channel detail acquired during the Viking missions. The recognition of widespread small channels of apparently quite old age is taken to indicate a distinctly different climate in early Martian time. These small channels probably played a significant role in the exchange of water between the Martian regolith and atmosphere. A range of proposed mechanisms were responsible for different channels. Criteria diagnostic of various mechanisms should be further developed.

D. E. Thompson (JPL) found that recent theoretical analysis on the flow stability and erosion by debris flows had pointed to the need for better understanding of sediment transport mechanisms in catastrophic floods, especially in terms of the formation of specific enchannel fluvial features. Thompson has initiated a field program in two areas of catastrophic flooding in the St. Elias Mountains, Yukon. Here, glaciers periodically dam major rivers. The resulting lakes are drained either by tunneling under the ice or breaking the ice dam. The features formed during the flooding are analogous to those in the Channeled Scabland and in selected outflow channels on Mars.

Bedform profiling and gravel size analysis are carried out in the field. Size-dependent sediment transport models are then developed to predict the observed profiles and grain sizes. These models are created both in terms of kinematic wave response of dune height to instantaneous changes in discharge, and in terms of shock propagation of changes in fluid rheology, and hence erosion potential, due to hyper-concentration of debris during flooding.

H. Masursky (USGS) reported on recent progress in determination of crater-frequency ages of the sequence of events that lead to the formation of the large channels which flow into Chryse Planitia. The creater frequencies confirm an extended history of water flow in the channels. The lack of resolvable shorelines suggest that the individual flood events were widely separated in time and that no accumulation of ponded water occurred.

D. Pieri, M. Malin and J. Laity (JPL) reported on further analysis and classification of the small channels or valley-systems. They have found that the morphologic heterogeneity of the small channels is at least as great as that of the large channels previously classified by Sharp and Malin. They have developed a classification scheme consisting of seven network patterns. Notably, in spite of the common reference to this channel as "dendritic", none of the systems display dendritic network patterns.

Available qualitative and quantitive evidence, gathered by a survey of martian valleys both from the Mariner 9 and Viking

Orbiter data sets, seems to discount the hypothesis of a rainfall origin. Instead, the data seem to favor an origin through groundwater or groundice (sublimative) sapping.

This hypothesis by Pieri and co-workers is, if verified, quite significant. It has previously been suggested that the small channels reflect the initial process of acquifer recharge. If, on the other hand, the channels reflect groundwater sapping then there must have been an earlier event of recharge; and event with one, as of yet, unrecognized morphological imprint.

D. Nummedal (LSU) presented a debris flow-debris avalanche model to account for the down-channel changes in morphology of the large channels of the southern Chryse Basin. The model calls for initial liquefaction and collapse of unstable volcano-clastic sediments within the chaotic terrains followed by a slow pseudolaminar flow of debris out of the chaos. By progressive viscosity decrease this debris can be accelerated into a catastrophic turbulent debris-avalanche at the channel debouchment area. This down channel transformation of fluid properties is consistent with observed changes in channel morphology. Stable islands near the channel source are evidence of laminar shear flow, whereas streamlined remnants in the debouchment area suggests the action of a violent turbulent flow.

MARTIAN POLAR AND PERIGLACIAL PROCESSES

B. K. Lucchitta (USGS) reviewed the status of investigations into Martian periglacial features. Various types of patterned ground and their relationship to possible freeze-thaw phenomena were discussed. A new hypothesis was presented on the origin of outflow channels, namely that these features were produced by glacial scour. Lucchitta also suggested that the circumferential ridges on the flanks of Arsia Mons and other Tharsis shield volcanoes might also be of glacial origin. These unusual ridge structures are not deflected by pre-existing topography in the way that the terminal ridges of ejecta flows and land slide tongues have been deviated by crater rims. Lucchitta suggests that moraine-like debris accumulations were lowered down on the subjacent terrain as the ice ablated.

M. C. Malin (ASU) described studies of the sapping process using the Earth as an analog for features on Mars. Sapping, the headward erosion by undermining of basal support and subsequent collapse, has been invoked as one possible mechanism formation of valleys and canyons on Mars. The role of multiple processes of weathering and transport in forming these features on Mars was stressed. Malin has studied sapping processes in the field in Utah (Navajo and Wingate sandstones) and Iceland (hydroclastic moberg deposits and basaltic tephra) with the objective of developing a more detailed understanding of sapping, and has recognized the importance of wall mass movements related to exfoliation.

In a paper that was not presented at the meeting, H. Masursky (USGS) reported on research into the inventory of permanent polar ice in the north polar region. Preliminary photogrammetric measurements of the topography of the north polar region and a new map of the extent of perennial ice have been compiled. These measurements are interpreted to imply a polar ice thickness of 2.2 km and a volume of 2×10^6 km^3. Additional work is planned in order to refine these estimates.

A. D. Howard (UVA) described the status of his investigations into the polar layered deposits. Two areas of investigation are being stressed: the detailed description of the geometrical relationships of layered slopes and perennial ice throughout the polar region, and detailed descriptions of limited areas using photoclinometric techniques.

J. A. Cutts (PSI) described the simulation of sequences of layered strata in the polar region. Polar layered thicknesses are related to global dust storms occurrences, which is assumed to be controlled by long-term climate variation. The climate variations are related to long-term quasiperiodic variations in the orbital eccentricity and axial obliquity of Mars. Preliminary results suggest that obliquity control of dust storm occurrence results in regularly spaced layers. More detailed modelling efforts in which the physical processes involved in polar layer formation were investigated in depth were briefly referred to.

J. E. Guest (U London) described work on the origin of the Nix olympica aureole. The aureole is considered to be a massive slide feature which separated from the Nix Olympica scarp. Measurements of the volumes of material in the aureole and comparison with the material lost from the scarp are permissive of this model.

MARTIAN EOLIAN PROCESSES AND LANDFORMS

J. F. McCauley (USGS) gave a review of the "typical" eolian landforms of Mars (dunes, yardangs, and "streaks") and the equatorward surficial wind circulation shown by most of these landforms. Two outstanding problems in martian eolian geology are the nature of the pitted rocks at both Viking lander sites and the source for the "sand" in the north polar erg. From his field and laboratory works, McCauley considers that many of the rocks visible at the surface may not be vesicular specimens, but instead may be originally massive rocks now severely pitted by wind erosion. As for the sand source for the dune field near the north pole, rivers as on Earth may have made available substantial amounts of sediment for wind transport. In the Mars case, north-flowing rivers from the equatorial canyons and the northerly fretted terrain may have debouched in the mid- and high-latitude regions, providing sediment to an active wind regime.

Peter Thomas and Joseph Veverka (Cornell) continue their work on martian streaks. One of their new ideas is that many regions on Mars are kept free of dust deposition by actively saltating particles, both in dunes and sand sheets. This implies that, although significant sand-moving winds have not been recorded by the landers, nor have sand particles or changes in wind features been observed, many regions of Mars experience active eolian deposition and erosion of sandsized sediment.

Thomas and Veverka also observe that strong katabatic winds occur on the Tharsis volcanoes. Dust on the volcanoes can be moved during most seasons by slope winds.

E. C. Morris (USGS) has been studying the Tharsis region and considers much of the Olympus Mons aureole to be wind-eroded rocks, probably ignimbrite deposits. He reported on twelve dark, irregularly shaped patches occurring in a straight line in part of the aureole. Morris considers these patches to be due to fluids or gasses from subsurface deposits. The fluids or gasses probably would be volcanic in origin and perhaps (if fluids) enriched in iron and sulfur minerals. Furthermore, because the patches formed on some of the youngest surface units, they may be very recent features.

C. S. Breed, A. W. Ward, J. F. McCauley, N. Witbeck, and M. Weisman (USGS) presented a progress report on the Atlas of Martian Eolian Features, due to be published during 1980. The atlas is designed as a "user's guide" to martian eolian landforms and contains photographs of features such as dunes, yardangs, sand sheets, and deflation hollows, plus quadrangle maps showing the distributions, orientations, and variabilities of the wind features. Much of the work will be taken from the Ph.D. thesis of Ward (1978) and the maps will be digitized and placed in the Mars Data Bank.

"Zig-zag" dunes on Mars and Earth were discussed by R. S. U. Smith (U Houston). Zig-zag (irregular) transverse dunes are common in the north-polar erg on Mars, but uncommon on Earth. The martian dunes are made of nearly straight segments joined at acute angles into transverse ridges. Similar (but smaller) dunes occur in northern Death Valley, California. There, winds are channelled along the valley yet reverse seasonally, yielding little net migration of the dunes. If this terrestrial example is a valid indicator, balanced, reversing wind regimes may exist on Mars.

Two papers were presented on dunes and topographic obstacles that control them. The first, by H. Tsoar and R. Greeley (ASU), reports on a few martian examples, laboratory modeling, and field studies. Their work is concerned with "echo" dunes, dunes that are formed partly by winds bouncing off downwind obstacles, and locally flowing upwind. On Mars, many dune fields occur within craters. Many of these intracrater dune fields have deep moats or troughs between the periferal dunes and the interior crater wall. Tsoar and Greeley consider that the position of the trough around the field may indicate the last strong wind direction, which may not be recorded by dune orientation.

C. K. McCauley and W. J. Breed (Museum NA) reported on climbing dunes in northern Arizona. Their study is of barchan dunes reaching an escarpment, the resultant echo effect, and portions of the dunes elongating to become linear dunes that can migrate up the notches in the cliff faces. They have installed meteorological equipment and have sampled the dunes. Future tasks include installing traps to measure sand flow.

MARS GENERAL

The 1:15,000,000 scale Mars geologic map was highlighted by D. H. Scott (USGS). Geologic mapping at 1:15 million scale in the western equatorial region of Mars shows the stratigraphic succession of many different rock types, including 20 volcanic flows within the Tharsis volcanic province. Major volcanic and tectonic episodes are correlated with the stratigraphic units and the absolute ages of these events estimated using two time-crater frequency distribution models. Relations between geologic units and remote sensing data such as infrared thermal maps, color variations, and gravity anomalies are being studied. This new geologic map of Mars made from Viking images could be the single most detailed source of geologic information about the planet until future missions are accomplished.

L. Albee (JPL) discussed the Future of Mars Exploration in the context of present financial constraints. Part of this future includes the continuing Viking Orbiter and Viking Lander missions. Viking Lander 1 will be supported as long as the spacecraft is operational. Earthbased observations - telescopic and radar - will increasingly become an important tool in the continued studies of the planet Mars.

The ongoing Viking Lander missions was presented by K. L. Jones (JPL). VL-2 has acquired a wealth of data during its second complete Mars year including observations of an additional dust layer and a repeat performance of a condensate accumulation. VL-1 observed a new small-scale landslide slump. The repeatability of the year-to-year observations suggests that we have observed "typical" mars years. However, the dust accumulation seen at both sites requires that with observable frequency (10 years), the landing sites are swept with winds of sufficient strength to remove this thin dust layer. VL-2 will return its final data in late spring, 1980. VL-1 continues to operate and data return is currently planned through 1990.

Nancy Evans (JPL) discussed the ongoing Viking Orbiter Survey Mission. Medium resolution mosaics of extensive regions in the ancient cratered terrain reveal numerous fascinating land-forms, many of which invite a variety of interpretations. Ms. Evans unrolled an impressive mosaic of Survey Mission images that testified to the importance of continuing the imaging mission as long as the orbiter remained functional. Cataloging and mosaicking of Survey Mission images is continuing but possibly will be extended over the next few years.

R. W. Wolfe (NASM) described a method of applying optical power spectrum analysis techniques to Mars terrains. These techniques are a quantitative tool that can be used to classify various terrain types and obtain information useful to photogeologists.

S. Liebes and E. C. Levinthal (Stanford) reported on their accomplishments and prospects using Viking Lander Interactive Computerized Video Stereophotogrammetry. They are producing a variety of data products ranging from detailed studies of specific features (sampler arm, trenches, etc.) to systematic contour and profile coverage of the area out to 100 meters from each spacecraft. Specific products include contour map sheets in a variety of scales appropriate to the distance from each lander. Additionally described were a multitude of imaging photoproducts derived from high-resolution imaging mosaics. These include 8" x 10" photoproducts, 42" x 42" lithograph sheets, stereoscopic imaging pairs, and other geometric transformations.

D. W. G. Arthur (USGS) discussed the ability to measure Mars topographic relative altitudes using shadow measurements. However, instead of the usual measurements of shadow length by pixel counts, it is possible to use a relative photometric determination on shadows of less than 2 pixels width. This method is influenced by atmospheric conditions and nearby area of known photometric properties is required. This method has proven effective in measuring the relative height of a few meters.

R. M. Batson (USGS) outlined the continuing Mars Cartographic Program. The Mars 1:15 million map and the Chryse Basin map are behind schedule, but progress is now well underway and no additional problems anticipated. Revision of the 1 km planetwide contour map on the 1:150,000,000 base will be completed, as well as six 1:5,000,000 airbrush maps will be completed by October 1980. Of twenty-two 1:2,000,000 photomosaics, 6 are in press and 15 are in preparation. Contour overlays for 14 1:2,000,000 are in preparation. Ten to twenty Viking orbiter color mosaics, and contour maps with orthophoto bases for Olympus Mons, Arsia Mons, and Tithonius Chasma will be completed by October 1980.

SMALL BODIES AND GALILIAN SATELLITES

Possible effects of meteoroid impacts into short-period comet nuclei was discussed by M. Cintala (Brown). If the physical properties of comet nuclei are similar to those of H_2O snow, then significant quantities of meteoroid debris could be absorbed by the nucleus of a short period comet during its passage through the asteroid belt. Numerous experiments designed to study the phenomenology of fragment impact into snow have been performed, revealing that little lateral excavation occurs, with the projectile ultimately located at or near the apex of the crater. As cometary devolatilization continues, this asteroidal debris would be concentrated in the outermost layers of the nucleus. Continued low velocity impacts into a regolith covered comet nucleus could produce shock lithification of the variegated target, producing polymict breccias. Reflectance spectra of such bodies might be complex, and still-active comets might eject polymict breccia fragments into Earth-crossing orbits during bursts of devolatilization.

F. Whipple and Z. Sekanina (SIAO) reported on the precession of the spin axis and apparent sublimation of Comet Encke from observations made during 59 perihelion passages over the past 200 years. The data suggest that the rotation axis was essentially fixed for hundreds of revolutions before 1700 A.D., but the calculated spin axis moved more than 100° in longitude and almost 30° in latitude between 1786 and 1977. The tentative rotation period about 1900 A.D. was 6h 33 m and the possible spinup rate is some 21 minutes per century. The required mass loss by sublimation is about 0.09 percent per revolution, and the mass and oblateness of the nucleus are estimated at 10^{16} grams and less than 4 percent, respectively.

The search for planet-crossing asteroids by the team of E. Shoemaker and E. Helin (CIT) has continued with the Palomar 122 cm Schmidt camera. Preliminary studies of eight plates taken during November 1978 revealed position data for a total of 232 asteroids. New orbits were calculated for 145 asteroids based on the 25 day arcs, and their apparent visual magnitudes were in the range of 15 to 21. Although 13 asteroids were considered to be possible Mars crossers, only 2 objects could be positively identified to cross Mars orbit. About 1 percent of the new asteroids found are members of the EROS family, about 4 percent are members of the Coronis family and 5 percent are members of the Themis family.

Donald Davis, et al. (PSI and LPI), described dynamical studies pertinent to groove origin on Phobos, together with the unusual ejecta trajectories calculated for the dynamical environment that exists on Phobos. Previous hypotheses proposed to account for the Phobos grooves include (a) tidal stresses due to Mars, (b) aerodynamic drag stress during capture of Phobos, (c) fractures from the Stickney crater forming event and (d) secondary cratering chains. While these hypotheses may explain some groove features, it appears necessary to seek other mechanisms to understand all groove orientations. A recent model by S. Weidenschilling proposed a modification of the impact hypothesis for groove origin. In this scenario the Stickney impact broke the synchronous rotational lock and started Phobos rotating about a randon axis. The non-synchronous rotation coupled with Phobos' irregular shape, generated varying tidal stresses that eventually produced grooves. This model assumes that material weakened by fracturing from Stickney yielded along planes of maximum shear stress which were controlled by the shape of Phobos. Most stickney ejecta would have been deposited over the surface, either by direct ballistic emplacement or by recapture from circum-Mars orbit, long before the non-synchronous rotation of Phobos was damped out. Hence, grooves could have been formed or regenerated subsequent to blanketing by Stickney ejecta. The unusual dynamical environment of Phobos causes variation in ejecta escape speed with surface location and direction of fragment trajectories, resulting in highly asymmetric ejecta distribution patterns.

Volcanic eruptions on Io were described by R. Strom (UA). Nine volcanic eruption plumes were observed over a period of 6 1/2 days during the Voyager I flyby. Four months later, during the Voyager II encounter, at least 7 of these plumes were still active at about the same intensities. The largest plume viewed by Voyager I, 280 km high and 1,000 km wide, was not active during the second encounter. During the first encounter Plume 2 consisted of two components: a large diffuse cloud about 210 km high emanating from the west end of a 175 km long black strip and a smaller plume less than 40 km high association with the east end. During the second encounter the smaller plume had about doubled in size. A major eruption occurred at 340° longitude and 45° N latitude sometime between the two encounters and deposited an ejecta blanket comparable in size to that associated with Plume 2. This new eruption is associated with an 80 km diameter caldera and produced major changes in surface markings first seen by Voyager 1. Several other changes in surface markings occurred between the two encounters in other areas. Most plumes are stronger in scattering sunlight forward then backward, indicating they consist of very small particles. The geometry and source regions of the plumes suggest they are associated with both long fissues and pipe vent eruptions. All active plumes and the sites of the larger recent eruptions are concentrated within 45° of the equator, but are more or less randomly distributed in longitude.

The six eruptions that have continued at a high level of activity for more than four months indicate that at least in these cases, large reservoirs of volatiles (e.g. SO_2) are available to sustain the continuous violent eruptions.

Amalthea was described by J. Veverka (Cornell) as a dark, irregular satellite about 270 km long by 160 km across. This was inferred from analysis of Voyager imaging data with resolutions as good as 8 km/line pair. The satellite is locked in synchronous rotation of 12 hours period, with the longest axis pointing toward Jupiter. Amalthea's normal reflectance is about 5 percent and spectrally very red. Several albedo markings, 20-30 km across, are twice as bright (10%) and less red. A few large apparent craters are visible in the best images, ranging from about 50 to 90 km in diameter.

S. Squyres (Cornell) and E. Shoemaker (USGS) reported on possible volume changes on Ganymede and the origin of grooved terrain. The geological relationships of grooved terrain on Ganymede suggest origin from extensional tectonism, indicating a period of global expansion. No convincing evidence of major zones of compressional deformation has been recognized. Crater densities on the grooved terrain indicate that most of the expansion took place near the end of heavy bombardment, probably in the range of 4.0 to 3.5 b.y. ago. Internal melting and differentiation of Ganymede could have led to a substantial surface area increase while refreezing of a liquid water mantle would not cause a significant surface area charge.

PLANETARY CRATERING, TECTONISM, AND VOLCANISM

This session in a real sense typifies the breadth of topics and approaches within planetary geology: interplanetary comparisons, field studies of terrestrial analogs, laboratory simulations and theoretical models.

R. J. Pike, D. J. Roddy and D. W. G. Arthur (USGS) reported results of crater morphology comparisons between planets, examined with the intent to discriminate between target strength and effects of gravitational acceleration. They noted both aspects influence the shape of craters on the terrestrial planets, and showed that crater morphology on the Galilean satellites Ganymede and Callisto were consistent with "soft" target materials. They also presented a photogrammetrically-derived martian fresh crater depth/diameter relation.

The primary purpose of fracture analysis is to determine the stresses that have effected the rocks under study. In such analyses, it is important to demonstrate that the orientations of fractures are indigenous to the rocks in which they occur. George McGill (U Mass) reported preliminary results from a study within the Grand Canyon which indicate that overlying rocks have not inherited jointing sets or other fractures from underlying materials. He noted that in the same region major faults and fault systems have been reactivated, so there is a scale-dependent quality to inheritance that must be factored into fracture analyses.

M. Womer (ASU) presented first results of a scale-model simulation experiment of lava flows done collaboratively with R. Greeley (ASU), J. D. Iverson (Iowa State), and J. Kremer (UT Austin). He described the formulization of their experiments using the Buckingham Pi Theorem to derive dimensionless parameters to address the inertial, viscous, and thermal properties of the model, and to compare these parameters with similar values for natural lava flows. Qualitatively, the results of the experiments appear reasonable. Much more work needs to be performed to check the quantitative accuracy of the model.

W. E. Elston, J. C. Aubele, L. S. Crumpler, and D. B. Eppler (UNM) examined the nature and distribution of calc-alkalic rocks over the Earth in the hope of finding a pattern for their occurrence that might lead to an understanding of their potential occurrence on other planets. Calc-alkalic rocks are not unique to any one terrestrial tectonic regime, although they are especially abundant at convergent plate margins. The absence of convergent plate margins on other planets (especially Mars) does not preclude the occurrence there of calc-alkalic rocks, since terrestrial examples are known from regions of extensional tectonics, such as the Basin and Range province, Rio Grande rift, and Colorado Plateau.

J. L. Whitford-Stark (Brown) raised a cautionary voice to studies aimed at determining magma composition from volcanic landforms. He presented many terrestrial examples of features that did not prove diagnostic of composition owing to many variables, including eruption mechanisms and post-eruption environmental modification.

Impact heating of H_2O ice targets was examined by M. J. Cintala, J. W. Head, and E. M. Parmentier (Brown). Four important findings of their work were: (1) impacts into H_2O ice targets; (2) silicate clasts in a large H_2O impact melt sheet will settle efficiently owing to their higher densities - this would aid in differentiating the crustal materials of ice-rich bodies; (3) secondary projectiles on icy bodies will probably be in various stages of fusion during ejection and flight, leading to variations in secondary cratering phenomena; and (4) large quantities of impact melt in H_2O targets may lead to the submergence of interior features, leading to difficulties in interpreting crater morphology.

R. Greeley (ASU) reported on impact experiments into viscous targets performed in collaboration with D. E. Gault (Murphys Center), D. B. Snyder (ASU), V. Sisson (Princeton), P. H. Schultz (LPI), and J. E. Guest (U London). Although not advocating that these scale models were completely analogous to features seen on Mars and the icy Galilean satellites, aspects of the experiments warranted attention. In particular, crater morphology appeared to be dependent more on target properties than on age; in 3/4 of the experiments the post-impact viscosities were significantly decreased and subsequent flow greatly modified the craters. In the experiment, an oscillating central peak produced multiple flow lobes, and this "peak" could "freeze" in any position, producing a central peak, flat floor or central pit.

MOON AND MERCURY

Recent studies of the Moon and Mercury concerned lunar basin structure, crater densities on the lunar farside and the origin of plains units on Mercury. The origin of structures associated with basins is still controversial, and very little is known about the crater distribution on the lunar farside and its implications for the evolution of highlands. Mercurian plains units (smooth and intercrater) comprise the most widespread surface terrain, and the determination of their origin is crucial to understanding both the geologic and thermal evolution of Mercury.

D. Wilhelms (USGS, Menlo Park) presented evidence that basins 570 km diameter, e.g., Hertzsprung and Humboldtianum, display interior irregularities that suggest forceful uplift origins over other mechanisms proposed for ring origin. However, oscillatory uplift also may be possible. Outer rings are also irregular, e.g., Imbrium and Crisium, suggesting differential exterior deformation and excavation. Well observed ejecta blankets are asymmetric which suggests that the impacts were oblique and most basin ejecta was ejected at shallow angles. This probably results from shallow energy release, which may greatly affect basin structure, but layering of the target material is probably an important variable.

C. A. Wood and A. W. Gifford (NASM) have studied the areal distribution of craters >25 km diameter within 20° x 20° squares on the lunar farside. They have also devised a relative age index by dividing the number of young (Copernican and Eratosthenian) and intermediate (Imbrian) age craters by the number of ancient (Nectarian and Pre-Nectarian) craters. About two-thirds of the mapped area of the lunar farside have values <1 indicating these areas have not been resurfaced recently or extensively enough to eliminate significant numbers of old craters. About 37% of the mapped area have values 0.5 indicating these surfaces are the oldest and least altered by volcanism and ejecta deposition. Values >1 are primarily associated with basins. This suggests that many crater density variations can be explained by crater destruction near impact basins and that even old basins such as South Polar-Aitken basin preserve crater density anomalies long after rim morphology is subdued. One area in the north-central part of the mapped area shows a crater density and relative age anomaly not associated with a basin, suggesting processes other than those related to basins were responsible for obliterating large numbers of old craters.

The smooth plains within and surrounding the Caloris basin on Mercury have been atttributed to either volcanism or basin ejecta deposition. J. A. Watkins (UA) studied the distribution of crater density and diameter-frequency distributions as a function of crater degrational type on the smooth plains and various Caloris impact-related terrains in order to determine the chronology of these geologic units. The areal density and statistical uncertainty were calculated for $5^{\circ} \times 5^{\circ}$ cells on these surface units. After applying rigorous statistical tests to the data, Watkins finds that the Caloris impact-related terrains all have the same relative age, but that the smooth plains units older than Caloris-related terrain are located farthest away from the basin. These areal crater density variations suggest that the smooth plains were emplaced in four major stages at the end of the period of heavy bombardment, and that because of the age differences between smooth plains and Caloris impact-related terrain, the smooth plains are largely volcanic deposits.

Two studies of plains units in the mercurian highlands were reported on. Geologic mapping of the Kuiper Quadrangle by R. A. DeHon (NLU), D. H. Scott (USGS), and J. R. Underwood (KSU) show that over 27% of the Quadrangle is covered by plains units. The older plains units (intercrater plains of Trask and Guest) cover about 16% of the Quadrangle and are interpreted to be mostly volcanic, based primarily on stratigraphic relationships. Younger smooth plains units are also interpreted to be largely volcanic because they have no clear association with impact craters of comparable age and sufficient size to indicate an ejecta origin. The plains units have been emplaced concurrently with impacts over an extended period of time early in the history of Mercury. All plains material is confined to basins or low-lying regions within rougher terrain and estimates of their thickness range from a few hundred meters to over 1 km.

M. A. Leake (UA) has mapped the entire incoming side of Mercury and dated plains material relative to degradational ages of craters embayed or superposed by the plains. She finds that the old intercrater plains span a range of ages concurrent with the period of heavy bombardment represented by the older degraded craters. Plains depositions continued into intermediate age periods. The oldest intercrater plains cover ancient features indicating they are not a primordial surface. Most intercrater plains and smooth plains are interpreted to be volcanic deposits interbedded with ballistically emplaced material and cratered by large craters and numerous secondaries. This interpretation is based primarily on the distribution of plains material, decreasing but uncorrelated areal coverage by both craters and plains, and the limited resurfacing potential of mercurian craters. Furthermore, some positive relief features may be volcanic constructs. Based on transectional relationships the hilly and lineated terrain antipodal to the

Caloris basin appears to be the same relative age as the Caloris impact dated independently by McCauley (USGS) et al. This enabled the plains units on the incoming side to be dated relative to the Caloris impact. At least on the incoming side of Mercury, plains formation was more widespread in Pre-Caloris time and decreased gradually through Caloris and Post-Caloris time.

PROGRAM ACTIVITIES

The general session consisted of presentations regarding ancillary support, administration and funding of research tasks in the Planetary Geology Program. Dr. Marcello Fulchignoni reported on research activities of the Planetology Branch of the Space/Astrophysics Laboratory, National Research Council, Rome, Italy. The Italian group is working on revised models of planetary accretion, numerical simulation of minor body close encounters with Jupiter, the geomorphology of the terrestrial planets and Galilean satellites, and the development of statistical univariate and multivariate techniques to study planetary erosive processes.

R. D'Alli (ASU) presented an interim report on the Planetary Geology Adjunct Investigators project. The plan for 1980-81 has four main objectives: (1) A Summer Institute; (2) The Speakers Bureau; (3) Videotapy Lecture Series; and (4) "Impact" Program newsletter. A successful pilot summer institute was in June, 1979, at Arizona State University. The 1980 Institute will draw its participants from the Pacific Northwest and Northern Tier of states and will be held at ASU in August, 1980. The Speakers Bureau and the newsletter will be coordinated through the Project Office at ASU. A prototype videotape was shown at the PGPI meeting to demonstrate the feasibility of the medium for rapid distribution of research results to a wider scientific and educational audience than previously possible.

J. S. King (SUNY) reported that the Planetary Geology Intern Program, a follow-on to the Viking Intern Program, hosted 18 students at a variety of NASA facilities and Principal Investigators home institutions. Based on the enthusiastic response of hosts and interns and given the current level of funding for 1980, at least 19 interns will be hosted this summer. Suggestions from previous interns and hosts have been incorporated into the plans for this program which initiates talented undergraduates in the sciences into planetary research.

R. G. Strom (UA) reviewed the status of the seven regional Planetary Image Facilities now in operation. The facilities are open to the public and non-participants in the Planetary Geology Program. Videodisc storage and retrieval systems will be installed at the facilities to expedite the search for imagery required for research purposes.

R. W. Vostreys of the National Space Science Data Center/ World Data Center for Rockets and Satellites, reviewed the current holding in the Greenbelt, Maryland, Center. He indicated that on a limited basis lunar and planetary maps in print can be distributed from NSSDC.

G. L. LaPrade of Goodyear Aerospace described the Synthetic Aperture Radar short course for VOIR Photogeologists. In 1980 three courses will be taught: 21-24 January, 10-13 March, and 9-12 June. A fourth short course has been proposed for 3-6 November. The purpose of each course is to familiarize geologists with the techniques and interpretation of side looking radar as applied to geomorphology.

A. Woronow (UA) discussed the "Advances in Planetary Geology Series", a publication designed to distribute research results not generally published in professional journals (e.g. theses, dissertaions, grant summaries, etc.). Material should be submitted in camera-ready format. Questions should be addressed directly to Woronow at (602) 626-3376.

R. S. Saunders (JPL) presented an update on the status of of VOIR. The best hope at present is for a 1982 new start and 1986 launch. VOIR has the potential to map Venus comparably to Mariner 9's overview of Mars. Strong support within the community is solicited.

J. Veverka (Cornell) made a similar appeal concerning the SEPS-propelled comet rendezvous mission. The funding for a new start on the solar electric propulsion system did not appear in the federal budget just released from OMB. The community is urged to lobby for resuscitation of the new engine system for comet missions and other deep space probes.

J. M. Boyce (NASA) closed the 11th PGPI Conference with a review of the overall program and projected budget outlooks for the immediate future.

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16. Abstract

Recent developments in planetology research as reported at the 1980 NASA Planetology Program Principal Investigators meeting are summarized. Important developments are summarized in topics ranging from solar system evolution and comparative planetology to geologic processes active on other planetary bodies.

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