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VENUS DATA ANALYSIS PROGRAM: DIRECTORY OF RESEARCH PROJECTS (1993–1994)

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Lunar and Planetary Institute 3600 Bay Area Boulevard Houston TX 77058-1113

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Preface

This Directory of Research Projects provides information about the scientific investigations funded by the NASA Venus Data Analysis Program (VDAP) during fiscal year (FY) 93. The VDAP Directory consists of summary sheets from the proposals that were selected by NASA for funding in FY 93. Each summary sheet indicates the title, principal investigator, institution of the investigation, and information related to the objectives of the research activities proposed for FY 93.

The objective of the VDAP Program is to advance our understanding of the nature and evolution of Venus. VDAP supports scientific investigation using data obtained from the Magellan, Pioneer Venus, and other Venus missions, as well as Earth-based observations that contribute to understanding the physical and evolutionary properties of Venus. The program intends to enhance the scientific return from these missions by broadening the participation in the analysis of Venus data. Categories of research funded by VDAP are atmosphere, ionosphere, geology, geophysics, and mapping.

The Directory of Research Projects is intended to provide the science community with an overview of the research projects supported by this program. Research activities identified in this Directory were selected for funding in FY 93 on the basis of scientific peer review conducted by the VDAP Review Panel.

For additional information about the VDAP Program, contact Patricia G. Rogers or Jay T. Bergstralh, Code SLC, NASA Headquarters, Washington DC 20546.

Logistics and publications and administrative support were provided by the Publications and Program Services Department staff at the Lunar and Planetary Institute.

Contents

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Raymond E. Arvidson
Department of Earth and Planetary Sciences
Washington University
St. Louis, Missouri 63130
314-935-5609

CO-INVESTIGATORS: None

PROPOSAL TITLE: Surface Modification of Venusian Plains and Mountains

ABSTRACT:

a. Objectives: To use Magellan altimetry, multi-angle HH and VV SAR, and emissivity data in key areas to: 1. Derive relative age constraints from detailed geologic mapping, 2. Provide estimates of roughness and relative permittivity for various units, 3. Use results to provide quantitative constraints on local weathering processes, including the origin of high backscatter, low emissivity surfaces in elevated terrains, and the systematic homogenization of surface properties of older plains evident from preliminary analyses of Magellan data, 4. Work with collaborators to understand Venusian mineral and rock weathering and use of surface properties to infer relative ages.

b. New proposal:

c. Work Plan: Generate full resolution SAR mosaics for four key areas (Maxwell Montes; Ovda Regio; Beta and Phoebe Regiones; Sapas Mons-Maat Mons area; and plains surrounding each study region) using cycle 1, 2, and 3 data (i.e., up to 3 mosaics per site). Register altimetry and emissivity data to mosaics. Generate high resolution topographic data for selected subareas using parallax from multi-angle SAR MIDRs and BIDRs. Conduct geologic mapping to infer stratigraphy and use radar and emissivity data to constrain surface properties associated with each unit. Use results to develop constraints on mineral and rock weathering processes and explore use of results to determine regional age variations.

d. Relevant Publications: Arvidson et al., 1991, Science, v. 252, p. 270–275; Arvidson et al., 1992, EOS, v. 73, p. 161, 168–169; Arvidson et al., 1992, J. Geophys. Res., v. 97, p. 13303–13319.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Jayne C. Aubele
Department of Geological Sciences
Brown University
Providence, RI 02912
(401)863-2889

CO-INVESTIGATORS: None

PROPOSAL TITLE: Relationship and Stratigraphic Association of the Small Volcanoes and Plains Terrain of Venus

ABSTRACT:

(a) Objectives and Justification:

To analyze the relationship between fields of small volcanoes and plains terrain on Venus by using the tool of geologic mapping. A major question in Venus geology is the creation and resurfacing of the plains terrain, the source of plains volcanism, and the relationship of the plains to the volcanic evolution of Venus. One potential source of plains volcanism are the clusters of small volcanoes that occur in association with the plains. Knowledge of their stratigraphic relationship with the plains is essential in order to test theories regarding the geologic evolution of the surface.

(b) New Proposal

(c) Approach:

A detailed geologic map will be produced this year using all relevant Magellan SAR, altimetry, and surface property data products, and pertinent data from previous Venus missions, for the quadrangle to be mapped. Volcanic units will be identified, their sources assessed, and their extent and local stratigraphic relationships delineated. Mapping will be done in accordance with standard U.S.G.S. techniques modified by prior experience in mapping primary volcanic flow morphology on satellite radar images. Description and interpretation of units and analysis of the stratigraphic relationships defined by mapping will be used to address the major question of plains formation and to test the hypothesis of global resurfacing.

(d) Publications (Venus Volcanism and Geologic Mapping):

Head, J.W., L.S. Crumpler, J.C. Aubele, J.E. Guest, and R.S. Saunders, Venus volcanism: classification of volcanic features and structures, associations, and global distribution from Magellan data, J. Geophys. Res., 97, E8, 13,153-13,197, 1992.

Guest, J.E., M. Bulmer, J.C. Aubele, K. Beratan, R. Greeeley, J.W. Head, G. Michaels, C. Weitz, and C. Wiles, Small volcanic edifices and volcanism in the plains of Venus, J. Geophys. Res., 97, 1992.

Aubele J.C. and E.N. Slyuta, Small domes on venus: characteristics and origin, Earth, Moon and Planets 50/51, 493-532, 1990.

Aubele, J.C., J.W. Head, L.S. Crumpler, J.E. Guest, and R.S. Saunders, Fields of small volcanoes on Venus (shield fields): characteristics and implications (abst), LPSC XXIII, 47-48, 1992.

Condit, C.D., L.S. Crumpler and J.C. Aubele, 1:50,000 scale lithologic, geochemical and paleomagnetic maps of the Springerville volcanic field, Arizona, U.S.G.S. Misc. Investigations Map, in review.

Aubele, J.C., The Cerros Del Rio volcanic field, in New Mexico Geol. Soc. Guidebook to The Santa Fe Country, 243-252, 1979.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Victor R. Baker
(Name, Address, Telephone Number) Department of Geosciences, University of Arizona, Tucson, AZ 85721 - (602) 621-6003

Co-INVESTIGATORS:
(Name Only)

PROPOSAL TITLE: Origin of Venusian Channels, Valleys, and Related Phenomena

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

A. **Objective:** Understand the origin and general geological implications of channels, valleys, and related phenomena on Venus. Relate these newly discovered features to global volcanic and tectonic processes that distinguish Venus from the other terrestrial planets.

B. **Progress:** Although this is a new proposal, it builds upon our previous studies of channel/valley morphological classification, morphometry, and channel-forming fluids (Baker et al., 1992). It will extend modeling studies preliminarily applied to the canali-type channels which were discovered during the Magellan Mission (Komatsu et al., 1992).

C. **Proposed Work:** Abrupt termination of Magellan Mission activities by NASA interrupted support for our program of detailed channel inventory, mapping, and genetic interpretation. During the proposed project we will complete in-progress analyses of channels, valleys, and related landforms, using the highest resolution images (F-MIDRs). Geological associations will be studied by local geomorphological mapping and comparisons to regional geological interpretation. Stereo imagery, altimetry, reflectivity, radiothermal emission, morphometry, modeling, and planetary analogue studies will be used to resolve the interesting scientific questions identified by our earlier work. We will explore the broader relationships of channels and certain crater outflows to petrogenesis, volcanism, coronae tectonism, plains formation, and planetary evolution. A Venus Geological Mapping task is included for 1:5,000,000 U.S.G.S. quadrangle mapping.

D. **Publications:**

Baker, V.R., Komatsu, G., Parker, T.J., Gulick, V.C., Kargel, J.S., and Lewis, J.S., 1992, Channels and valleys on Venus: Preliminary analysis of Magellan data: Jour. Geophys. Res., v. 97, p. 13,421-13,444.

Komatsu, G., Kargel, J.S., and Baker, V.R., 1992, Canali-type channels on Venus: Some genetic constraints: Geophys. Res. Letters, v. 19, p. 1415-1418.

GEOLOGY AND GEOCHEMISTRY OF THE VENERA/VEGA LANDING SITES

PRINCIPAL INVESTIGATORS: Alexander T. Basilevsky and James W. Head

CO-INVESTIGATORS: Olga V. Nikolaeva, Mikhail A. Ivanov, Alexey A. Pronin, Vladimir P. Kryuchkov.

COLLABORATORS: R. S. Saunders, C. M. Weitz.

ABSTRACT:
A. Objectives: This is a joint proposal between Brown University and Vernadsky Institute (Russia) scientists to investigate the geology and geochemistry of the seven Venera/Vega landing sites using both Venera/Vega, Arecibo, and Magellan data sets. We plan to identify terrestrial analogs with the same geochemistry as the materials sampled by the landers and to establish their geological settings. We will reconsider Venera TV panoramas and *in-situ* measurements of physical properties of the surface materials to resolve the tuff/lava alternative for the rocks seen on panoramas. We will produce geological maps of the Venera/Vega sites and the regional geology surrounding the sites. We propose to establish correlations between the geochemistry measured by landers for the surface material and the morphology seen in the Magellan images for the landing sites. We plan to extrapolate these correlations to other places of Venus to assess other areas that might be similar to the landing sites on the basis of their radar characteristics. We will apply the results of our study to recommend potential landing sites for future missions to Venus.

B. Progress: We have identified several possible terrestrial geochemical analogs for the Venera 8 material and have made a preliminary geological map for the Venera 8 mosaic. We have made preliminary photogeological analysis of Venera 9, 10, 13 and 14 panoramas. We are now producing (jointly with JPL) geological maps from JPL-made full resolution mosaics for all the Venera/Vega landing sites. We have noted a possible correlation between steep-sided domes at two landings sites (Venera 8 and 13) and a non-tholeiitic composition measured by the landers at these two sites.

C. Proposed Work: 1) We will continue the search for terrestrial geochemical analogs for all the measured compositions made by the landers. We will determine the geological setting for the analogs on Earth and compare these with the geological settings of the landing sites on Venus. 2) We will reconsider the TV panoramas and other *in-situ* made observations at the landing sites in the context of the photogeology of the sites as observed in the Magellan images. 3) We will undertake and complete photogeological analysis of the Magellan images for the sites and produce geologic maps of the sites. 4) We will then extend photogeological analysis to the regional geology of the Venera and Vegas landing sites, establishing regional topography and slopes, and correlations in wind patterns and crater parabolas that might influence the geolgy of the sites and the regional movement of material. We will then extend the site characteristics to other regions of Venus that have similar radar properties and look at the geologic contexts of these sites. 5) On the basis of our determination of the feature and terrain perspective of the sites, we will make recommendations for future studies and for potential landing sites for future missions to Venus. The third, fourth and fifth tasks are done in collaboration with JPL.

D. Summary Bibliography:
(1) Basilevsky A.T., O.V. Nikolaeva and C.M. Weitz, Geology of the Venera 8 landing site region from Magellan data: Morphological and geochemical considerations, *J. Geophys. Res.*, in press, 1992.
(2) Basilevsky A.T. Vital problems of Venus geology: Outlook for their resolution by Magellan and post-Magellan missions, *Earth, Moon, Planets, 50/51*, 3-23, 1990.
(3) Basilevsky A.T. *et al.* The surface of Venus as revealed by the Venera landings: Part II. *Bull.Geol.Soc Amer., 96*, 137-144, 1985.
(4) Basilevsky A.T. and C.M. Weitz. The geology of the Venera/Vega Landing Sites, Int. Colloq. on Venus, Aug.10-12, 8-10, 1992.
(5) Basilevsky A.T. and C.M. Weitz, Venera 9, 10 and 13 landing sites as seen by Magellan, *Lunar Planet. Sci. XXIII*, 67-68, 1992.
(6) Ivanov M.A. Venera 13 and 14 Landing Sites: Geology from Magellan data, *Lunar Planet. Sci. XXIII*, 579-580, 1992.
(7) Nikolaeva O.V., Terrestrial chemical analogs of the Venera 8 material: Comparison with the Venera 13 material and implications for venusian crust,*Vernadsky-Brown Microsymposium XVI*, 59-60, 1992.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: David Bercovici, University of Hawaii/SOEST
(Name, Address, Telephone Number) 2525 Correa Road #364 Honolulu, HI 96822
(808)956-9717

Co-INVESTIGATORS: Dr. Jian Lin
(Name Only)

PROPOSAL TITLE: Plastic Deformation of Venus' Lithosphere over a Dynamic Mantle: Synthesis of Satellite Data Analysis with Laboratory and Theoretical Modelling

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

(a) Large scale tectonic motions on Venus are, as on the Earth, invariably driven by thermal convection in the planetary mantle. Tectonic features, however, reflect not only the dynamic forces of mantle convection, but also variations in lithospheric structure and rheology. On Venus, mantle convection is likely manifest through isostatically uncompensated highlands, coronae that are possibly similar to Earth's hotspots, and apparent extensional regions characteristic of spreading centers and rifts. In this work, we propose to examine the fine-scale morphology of tectonics on Venus to determine the characteristics of surface plastic deformation and to compare the results to analogous features generated in laboratory and theoretical models of deformation of a plastic layer over simple viscous flow. With this study, we can then begin to understand how deformation in Venus' crust is coupled to mantle flow and how the surface morphology is diagnostic of the pattern of mantle flow and the rheology of the lithsophere.

(b) New proposal.

(c) Our proposed study consists of three parts: 1) Examine tectonic features of Venus for characteristics of plastic folding. Using the high-resolution Magellan data, we will measure basic geometric parameters of fine-scale deformational features, such as the width and amplitude of fault/fold belts and the ratio of their wavelength to along-strike radius of curvature. 2) Run a series of laboratory experiments involving simple viscous flow beneath a visco-plastic layer. The stresses in the vicous fluid induce deformation in the plastic medium. The experiments will include the viscous flow caused by the ascent (or descent) of a buoyant (dense) body with a simple geometry, e.g., a sphere. We will then measure the same geometric parameters in the plastic layer of the experiments as we will measure from Venus images. We will adjust the experimental parameters (e.g., thickness or rheology of the plastic layer) to find the best correlation in scaling properties between experiments and observations. 3) Finally, we will theoretically model the laboratory experiments to obtain basic laws on how plastic deformation on Venus might be diagnostic of the underlying mantle flow and the structure and rheology of the lithosphere.

(d) Recent Papers (Abstracts will appear in the Appendices):

1. Bercovici, D., Wave dynamics in mantle plume heads and hotspot swells, *Geophysical Research Letters*, 19, 1791–1794, 1992.
2. Bercovici, D., A simple model of plate generation from mantle flow, submitted to *Geophys. J. Int.*, 1992.
3. Bercovici, D., H.J.B. Dick, T.P. Wagner, Nonlinear viscoelasticity and the formation of transverse ridges, *Journal of Geophysical Research*, 97, 14195–14206, 1992.
4. Schubert, G., D. Bercovici and G.A. Glatzmaier, Mantle dynamics in Mars and Venus: Influence of an immobile lithosphere on three-dimensional mantle convection, *J. Geophys. Res.* 95, 14105-14129, 1990.
5. Lin, J. and E.M. Parmentier, A finite amplitude necking model of rifting in brittle lithosphere, *J. Geophys. Res.* 95, 4909-4923, 1990.
6. Lin, J. and J. Phipps Morgan, The spreading rate dependence of three-dimensional mid-ocean ridge gravity structure, *Geophys. Res. Lett.* 19, 13–16, 1992
7. Lin, J. and J.Y. Chen, Isostatic compensation mechanisms of the mid-Atlantic Ridge topography, submitted to *Geophys. Res. Lett.*, 1992

PROPOSAL SUMMARY

Principal Investigator: Duane L. Bindschadler
(Name, Address, and Phone Number)
Department of Earth and Space Sciences
405 Hilgard Avenue
University of California
Los Angeles, CA 90024-1567
(310) 825-4577

Proposal Title: COLDSPOTS AND HOTSPOTS: QUANTITATIVE INVESTIGATIONS OF VENUS TECTONICS

Abstract

a. Objectives: (1) To understand the fundamental physics of the coupling of mantle convection into lithospheric deformation. (2) To characterize Venus tectonic processes in terms of observed surface tectonic features, particularly complex ridged terrain and coronae. (3) To characterize the basic structural elements that make up complex ridged terrain on Venus and the sequence of tectonic events which they represent. (4) To discover how well Venus highlands are explained as the product of hotspots, coldspots, or other tectonic mechanisms.

b. New Proposal

c. Plans for the coming year: Develop capabilities to do numerical modeling of convection-driven crustal deformation in 2D axisymmetry. Construct quantitative models for gravity and topography due to mantle downwellings (coldspots) in Venus's mantle. Using appropriate failure criteria, model the styles and sequences of deformation over coldspots, and locations, orientations, and amounts of strain recorded by predicted deformational features. Compare predictions to deformation observed in Magellan radar images and to Magellan topography and gravity data. Examine timescales relevant to hotspot tectonic models and place bounds on amount of strain which hotspot tectonics can cause. Construct models for deformation of an inhomogeneous lithosphere containing asperities or zones of significant weakness. Use this model to test the hypothesis that complex ridged terrain forms due to strain focusing into such asperities. Construct models for corona tectonics based on appropriate failure criteria and test the hypothesis that uplift and gravitational and/or thermal relaxation are the dominant processes in corona tectonics. Characterize complex ridged terrain in terms of morphologic types based upon its structural elements and map the distribution of these terrain types. Analyze Magellan images to obtain kinematic histories of regions of complex ridged terrain and quantitative measures of strain they have undergone and compare these observations to model predictions. Measure widths and spacings of broad structural ridges and graben in complex ridged at various elevations to establish the degree of correlation between structural wavelengths and elevation. Produce geologic map of a region dominated by complex ridged terrain.

d. Relevant Recent Publications:

(1) Bindschadler, D.L., G. Schubert, and W.M. Kaula, Coldspots and hotspots: Mantle dynamics and global tectonics of Venus, *J. Geophys. Res.*, in press, 1992. (2) Bindschadler, D.L., A.V. deCharon, K.K. Beratan, S.E. Smrekar, and J.W. Head, Magellan observations of Alpha Regio: Implications for formation of complex ridged terrains on Venus, *J. Geophys. Res.*, in press, 1992. (3) Janes, D.M., D.L. Bindschadler, G. Baer, G. Schubert, V.L. Sharpton, S.W. Squyres, and E.R. Stofan, Geophysical models for the formation and evolution of coronae on Venus, *J. Geophys., Res.*, in press, 1992. (4) Solomon, S.C., S.E. Smrekar, D.L. Bindschadler, R.E. Grimm, W.M. Kaula, G.E. McGill, R.J. Phillips, R.S. Saunders, G. Schubert, S.W. Squyres, and E.R. Stofan, Overview of Venus tectonics from Magellan observations, *J. Geophys. Res.*, in press, 1992. (5) Stofan, E.R., D.L. Bindschadler, J.W. Head, and E.M. Parmentier, Corona structures on Venus: Models of origin, *J. Geophys. Res.*, *96*, 20,933-20,946, 1991.

e. Personnel: 1 Asst. Research Geophysicist (part-time)

PROPOSAL SUMMARY

Principal Investigator: Dr. Stephen W. Bougher
Department of Planetary Sciences
Lunar and Planetary Laboratory
The University of Arizona
Tucson AZ 85721
(602) 621-4900

Co-Investigator: Dr. Donald M. Hunten

Proposal Title: VTGCM Analysis of Pioneer Venus Orbiter Entry Data: Neutral Densities

ABSTRACT

The NCAR Venus thermospheric general circulation model (VTGCM) has proven to be a very valuable tool in the study and analysis of Pioneer Venus Orbiter (PVO) thermospheric neutral density, temperature, and airglow data [Bougher *et al.*, 1988; 1990; Fox and Bougher, 1991]. Four years of Pioneer Venus Guest Investigator (PVGI) funding have supported this research that has focused on analysis of global data, including ONMS (Orbiter Neutral Mass Spectrometer) neutral densities from early in the PVO mission (1978-81). This period corresponds to a maximum in the solar cycle EUV/UV output (F107 = 180-240). New neutral density data at another point in the solar cycle (F107 = 110-140) will be obtained as the PVO spacecraft enters the atmosphere in the later half of 1997. Low periapsis altitudes (below 200 km) will once again be sampled at nightside local times, and possibly onto the dayside. The nightside region is known to be quite variable on short time scales resulting from the changing thermospheric wind system and local eddy mixing and turbulence. Nightside helium densities serve as a very sensitive tracer of the wind system. The proposed dayside heat budget [Bougher and Roble, 1991] and temperature variations over the solar cycle [Keating and Bougher, 1992] must be validated using additional in-situ data. This proposal describes research to analyze in-situ PVO entry data using the Venus TGCM model as an analysis tool.

INVESTIGATIONS OF THE IONOSPHERE AND IONOTAIL OF VENUS

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Larry H. Brace, Space Physics Research Laboratory, 2455 Hayward, The University of Michigan, Ann Arbor, MI 48109-2143 (313-764-9462)

CO-INVESTIGATOR: Professor Andrew F. Nagy, Same Address

ABSTRACT

(a) Objectives and justification: Our primary goal is to improve the understanding of the Venusian nightside ionosphere and ionotail through the use of Pioneer Venus measurements of the plasma and magnetic field parameters; in part using data to be acquired during the entry period (Sept-Dec 1992) to examine solar cycle variations, and in part by performing a more detailed analysis of existing OETP raw volt-ampere characteristics to examine the two-temperature nature of the nightside ionosphere. In support of these goals, we will use a newly developed 2-dimensional theoretical model to calculate effects of nightward ion flow.

A second goal will be to cooperate with other Venus VDAP investigators by supplying and interpreting the OETP data they will require for their own investigations, particularly when special analysis is needed beyond that required for the data we have routinely supplied to the NSSDC. Our experience in the PV Guest Investigator program suggests that the VDAP program will generate many such requests. Cooperative investigations that we have already agreed to support during our final year of Project funding (FY-93) include one by J. G. Luhmann of the magnetic behavior of the nightside ionosphere, one by T. Donahue who will investigate the H^+ and D^+ escape rates, and one by R. Hartle who will calculate the upward ion flux in the nightside ionosphere, based primarily on ion composition and electron temperature measurements.

A final goal will be to support the continued participation of L. H. Brace in the work of COSPAR subcommission C in its planned revision of the Venus International Reference Atmosphere (VIRA), an activity for which he will supply electron temperature and density measurements and schemes for globally modelling them.

(b) Accomplishments

During the PVO mission, we have employed OETP measurements and those from several other instruments to explore the electron temperature (T_e) and density (N_e) behavior in the Venusian ionosphere. The PI has authored or co-authored 70 articles, reviews or book chapters based on the PVO measurements obtained over the past 14 years. By the end of FY-93 the standard N_e and T_e measurements will have been submitted to the NSSDC.

(c) Work to be done

PVO measurements, primarily by the OETP and OMAG instruments, will be used to investigate the thermal structure of the ionosphere and the ionotail, with emphasis on solar cycle variations. The proposed work will require continued access to the OETP raw data in FY-94 and 95 to explore the dual-temperature nature of the nightside ionosphere and to recover measurements of the small scale density structure. Neither of these features are easily enough derived to have been routinely obtained and archived earlier, but they will become available through our participation in the VDAP program. Theoretical modelling of the ionospheric energy balance and the nightward ion flow will be done, primarily to attempt to explain the observed solar cycle variations

(d) Publications

"The Response of the Venus Nightside Ionosphere and Ionotail to Solar EUV and Solar Wind Dynamic Pressure", L. Brace, R. Theis, and J. Mihalov, *JGR*, *95*, 4075, 1990.

"The Structure of the Venus Ionosphere", L. Brace and A. Kliore, *Space Sci. Rev.*, *55*, 81-163, 1991.

SUMMARY AND ABSTRACT

PRINCIPAL INVESTIGATOR: Dr. Robert Brakenridge
Dept. Geography
Surficial Processes Laboratory
Dartmouth College, Hanover, NH 03755
603-646-2870

COLLABORATOR: Dr. Leslie Sonder
Dept. Earth Sciences/ Dartmouth College

PROPOSAL TITLE: REGIONAL GEOLOGY AND TECTONICS OF THE V26 AND V38 QUADRANGLES, VENUS

ABSTRACT:

a. This proposal is for a combination of detailed geological mapping and regional tectonic syntheses to be carried out on two adjoining 1:5,000,000 quadrangles between N25° and S25° in eastern Aphrodite Terra. The general scientific question to be addressed is: To what degree is plate tectonic theory applicable to Venus? The specific objectives are to, in the course of mapping the quadrangles: 1) Determine whether there exist crater density variations, on a regional scale and in correct spatial relationship to structural features, that are indicative of coherent crustal age trends; 2) Determine whether there exist other variations in crustal surface properties such as backscatter cross section, emissivity, reflectivity, RMS slope, or topography that may relate to age; and 3) Use observable displacements of landforms and detailed stereoscopic mapping in an attempt to place better constraints on compressional, extensional, and possible transcurrent faulting in the chasmata portions of the study area.

b. New Proposal

c. V26 will be the first quadrangle to be mapped and should be completed near the end of the first year. In conjunction with this work, the P.I. , Dartmouth collaborator, and graduate student will be working with other mapping efforts to standardize map symbology, accuracy, projections, and age nomenclature.

d. Brakenridge, G.R., 1990, The origin of fluvial valleys and early geological evolution, Aeolis Quadrangle, Mars: Journal of Geophysical Research, v. 95, p. 17289-17308.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Bruce A. Campbell
Center for Earth and Planetary Studies
National Air and Space Museum
Washington, DC 20560
(202) 357-1424

CO-INVESTIGATORS: Donald B. Campbell, Cornell University
Robert A. Craddock, Ctr. for Earth & Planetary Studies

PROPOSAL TITLE: GEOLOGIC STUDIES OF VOLCANIC TERRAINS ON VENUS BASED ON RADAR DATA ANALYSIS, COMPARISON TO TERRESTRIAL ANALOG SURFACES, AND NUMERICAL SIMULATION

A) Objectives: We propose to carry out detailed geologic investigations of large volcanic regions on Venus using Magellan and Arecibo radar data. These data will be compared to aircraft radar observations of potential analog terrestrial surfaces and micro-topography data to develop techniques for classifying the morphology of Venus lava flows, plains, and perhaps crater ejecta deposits. Magellan altimeter data will be compared to the expected near-nadir backscatter behavior of terrestrial surfaces determined from field topography data. These radar interpretation techniques will be used to produce geologic maps of Western Eistla Regio, Theia Mons, Mylitta Fluctus, and portions of Ishtar Terra. At least one of these maps will conform to USGS guidelines for 1:5 M scale geologic map products. Numerical simulation techniques for modeling lava flow emplacement will be improved and the results will be compared to observed flow and channel dimensions on Venus.

B) This is a new proposal

C) Work Plan (Year 1): We will assist D.B. Campbell in completing the reduction of 1988 Arecibo radar images. The depolarized circular data for the southern hemisphere will be mapped, permitting dual-polarization analysis of such areas as Mylitta Fluctus. Aircraft radar observations of terrestrial lava flows will be compiled and published as an aid to Magellan data interpretation. Existing topographic data will be analyzed as they relate to both large scale (quasi-specular) and small-scale (diffuse) roughness, and additional data at both scales will be collected. Geologic mapping of study areas will begin as proposed quadrangles become available.

D) References: (1) Campbell, B.A., and Campbell, D.B., 1992, Analysis of volcanic surface morphology on Venus from comparison of Arecibo, Magellan, and terrestrial airborne radar data,*J. Geophys. Res.*, in press. (2) Campbell, B.A., 1992, Comparison of Magellan measurements of surface roughness on Venus and topographic profiles of terrestrial basaltic lava flows, *LPSC XXIII*, 201-202. (3) Campbell, B.A., Arvidson, R.E., and Shepard, M.K., 1992, Radar polarization properties of volcanic and playa surfaces: Applications to terrestrial remote sensing and Magellan data intepretation, submitted to *J. Geophys. Res.* (4) Campbell, B.A., and Campbell, D.B., 1990, Western Eisila Regio: Radar properties of volcanic deposits, *Geophys. Res. Lett.*, 17, 1353-1356. (5) Campbell, B.A., Zisk, S.H., and Mouginis-Mark, 1989, A quad-pol radar scattering model for use in remote sensing of lava flow morphology, *Rem. Sens. of Env.*, 20, 227-237.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Mary G. Chapman
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CO-INVESTIGATOR: Randolph L. Kirk

PROPOSAL TITLE: *Coronae, arachnoids, and novae: Stratigraphic relations and geologic evolution*

ABSTRACT:
(a) Objectives: The primary objective of this three-year study is to better understand Venusian coronae, arachnoids, and novae occurring both in a chain and in a contrasting cluster through application of well-established geologic principles and detailed analysis of SAR images and altimetry data from Magellan.

Specific tasks of the study are to (1) apply geologic mapping principles to determine genetic relations between coronae, arachnoids, and novae; (2) examine genetic relations of coronae and corona-like features to mantle plumes; (3) determine the existence on Venus of a rigid "hotspot" reference frame; and (4) determine geologic relations between coronae and corona-like "hotspot" features and spatially associated flood lavas.

As a by-product of research carried out under tasks 1-4, compile and submit (in 1993 and 1994) a geologic map of one Venus quadrangle (V40) containing a cluster of cononae for formal publication by the USGS at 1:5 million scale as part of NASA's Venus Geologic Mapping (VGM) Program.

(b) Accomplishments: New Proposal

(c) Work Plan for FY 93: Preparation of base materials including 3-D perspective renderings and computer-mosaicked C1-MIDR views of a chain of coronae and corona-like features east of Beta Regio, preliminary geologic mapping of VGM quadrangle V40 (east of Phoebe Regio), which contains a cluster of coronae and corona-like features; and presentation of results at LPSC.

(d) Selected References: Chapman, 1992; Chapman et al., 1989, 1991a+b; Chapman and Tanaka, 1993; in press; Kirk et al., in press; Scott and Chapman, 1991; Tanaka et al., 1992.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Prof. Paul A. Cloutier
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CO-INVESTIGATORS: (none)
(Name Only)

PROPOSAL TITLE: Study of Dynamics and Morphology of Ionospheric Structures of Venus

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

(a) This proposal seeks funding for research activities related to the dynamics and structure of the Venusian ionosphere, especially related to the formation and dynamics of the interface between the post-shock solar wind and the thermal ionosphere (ionopause) on both the day and night sides of Venus. Specifically, we propose to utilize data from the Pioneer-Venus Orbiter Ion Mass Spectrometer (OIMS), the Retarding Potential Analyzer (ORPA), the Electron Temperature Probe (OETP) and the Electric and Magnetic Field Detectors (OEFD and OMAG) to extend existing models of the upper ionosphere and ionopause at Venus in an attempt to understand observed features of the ionopause and dayside and nightside ionospheres of Venus. Among the features currently incompletely understood are the thickness and altitudes of the ionopause, the response of, thickness and altitude of the ionopause to changes in solar wind conditions, the time scales for such response, the dynamical processes leading to formation of nightside ion troughs, and the instability mechanisms responsible for generation of waves and superthermal ions and electrons. Although many details of these features of the Venusian ionosphere have been revealed by measurements obtained by the Pioneer-Venus Orbiter, the present level of understanding is limited to morphological description in most cases. The purpose of this work is to extend our level of understanding beyond morphology to dynamical processes and through models of these processes attempt to establish predictive capability. An additional goal of this proposal is to provide collaborative support for several research proposals submitted by investigators at other institutions through the interactive computer facilities developed at Rice to access the Pioneer-Venus databases.

(b) new proposal.

PROPOSAL SUMMARY

TITLE: The Thermal Structure and Dynamics of the Venus Atmosphere
PRINCIPAL INVESTIGATOR: David Crisp
INSTITUTION: Jet Propulsion Laboratory, California Institute of Technology
CO-INVESTIGATORS: Stephen Bougher, Victoria Meadows, Boris Ragent

ABSTRACT

Recent observations of near-infrared (NIR) emission from the night side of Venus have contributed substantially to our understanding of the Venus surface and atmosphere. Our efforts to analyze these observations also suggest new approaches for extracting additional information from the Pioneer Venus (PV), Venera, VEGA, Galileo, and Magellan spacecraft observations of Venus. We propose to combine these ground-based and spacecraft data to produce a more comprehensive description of the thermal structure and dynamics at three levels of the Venus atmosphere.

The PV Orbiter Ultraviolet Spectrometer (OUVS) observations reveal dramatic spatial and temporal variations in the atomic oxygen and nitric oxide airglow at thermospheric levels. Even larger variations are seen in recent ground-based NIR observations of $O_2(^1\Delta)$ airglow from the upper mesosphere. We will use the Venus Thermospheric General Circulation Model (VTGCM) to determine the implications of these variations for the thermal structure and dynamics of the mesosphere and thermosphere of Venus.

The high-contrast NIR markings seen on the Venus night side at wavelengths near 1.74 and 2.3 μm are produced as thermal emission from the hot lower atmosphere emerges through regions of the middle and lower cloud decks that have substantially different optical depths. This discovery prompted members of our team to search for and identify similar cloud-related markings in PV Orbiter Cloud Photopolarimeter (OCPP) 935-nm images of the Venus day side. The presence of these day-side markings suggests that the entire 14-year OCPP 935-nm data set can be used for studies of winds within the middle and lower clouds. We propose to track UV and NIR features in PV OCPP 365- and 935-nm polarimetry maps to produce a comprehensive description of the dynamics of the cloud-layer atmosphere. NIR feature-tracked winds within the middle cloud will be compared to VEGA Balloon δ-VLBI tracking results to determine how well these features track the true wind speeds at these levels. The OCPP 935-nm observations will also be used to determine if the balloons floated in relatively clear or cloud regions.

Finally, the recent discovery of NIR windows centered near 1.0, 1.1, and 1.18μm provides new opportunities to probe even deeper into the Venus atmosphere. NIR images at these wavelengths reveal intensity variations associated with surface topography, since much of the radiation in these windows originates at the surface, and high-elevation regions are cooler and emit less than low-elevation regions. We propose to combine these observations with Magellan altimetry, radiothermal emission, and radar reflectivity observations to determine the thermal structure of the boundary layer and the emissivity of the surface at NIR wavelengths. This information will provide improved constraints on the boundary layer dynamics and the nature of the anomalous radar-bright regions seen at high topographic elevations.

PROPOSAL SUMMARY

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Co-Investigators: S. Hensley, F. Leberl, T. Farr

Proposal Title: Quantitative Assessment of Venus Surface Roughness using Magellan Stereo Data

Abstract:

a) Objectives and Justification

The objective of this study is to derive the age of volcanic units from surface roughness information inherent in calibrated SAR imagery. The surface roughness is measured using image data that has been corrected using high precision digital elevation data from Magellan stereo image pairs. This correction removes both the slope dependent scattering and the radiometric calibration errors resulting from the coarse topo model enployed in the SAR signal processor. A final correction for dielectric contant variation using the MGN radiometer data permits small scale surface roughness information to be extracted directly from the F-MIDR products. These roughness maps can be related to the age of the surface volcanic units by modelling the processes of erosion, weathering and deposition. This type of quantitative information on age, volume and spatial distribution of the volcanic units can be used to infer the types, rates, and magnitudes of surficial processes that have operated on Venus and will help determine the dominant mechanism of heat transport.

b) New Proposal

c) Work to be Done this Year

i) Select areas of study and acquire SAR F-MIDR and radiometer data; ii) Design and develop data analysis software for: Correcting residual radiometric errors in Primary SAR Processor; Extraction of surface slopes from stereo derived digital terrain data; and Production of surface roughness maps from F-MIDRs (Note that the software to derive the digital terrain data from the stereo F-MIDRS has already been completed by the investigators); iii) Development of an inversion model to derive the surface roughness statistics from the corrected SAR images; iv)correlate roughness maps with maps showing relative age relationships to derive an age-roughness relation.

d) References

Curlander, J. and R. McDonough (1991). Synthetic aperture radar, systems and signal processing, Wiley, New York.

Leberl, F. W. (1992). Initial results from the Magellan stereo experiment, J. Geophys. Res., 97, pp. 13675.

Farr, T. (1992). Microtopographic evolution of lava flows at Cima volcanic field, Mojave Desert, California, J. Geophysical R., in press.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Merton E. Davies
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PROPOSAL TITLE: The Rotation Period, Direction of the North Pole, and Geodetic Control Network of Venus

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

a. The two purposes of this proposal are (1) to improve the current determination of the rotation period, the spin-axis direction, and the geodetic control network of Venus, based on Magellan data, and (2) to improve a similar but largely independent determination of the rotation period and spin-axis direction of Venus based on a combination of Venera 15/16 and Magellan Data.

The rotation period and spin-axis direction of Venus are parameters of great scientific interest. In particular, they are fundamental to Geodesy and Cartography. Furthermore, as determinations of these parameters get better and better, it becomes conceivable to look for Venusian precession and polar motion, which provide insight into the interior processes of the planet.

b. New proposal

c. Using Magellan data, the Venus rotation parameters can be determined better than ever before, but errors in the spacecraft ephemeris have degraded the accuracy of the solution. A new technique has been developed to improve the spacecraft ephemeris by including tie-point measurements in the ephemeris solution. This new technique has greatly contributed to the accuracy of the spin-axis-direction and control network solution, but the improved ephemerides were available for only 40 of the 682 orbits. During the upcoming year, it is expected that improved ephemerides will become available for more orbits, and the accuracy of the new ephemerides will be even better due to the use of new and improved gravity fields. These new improved ephemerides will be incorporated into the geodetic network solutions. The number of ties between the south polar and north polar will also be increased.

Another determination of the Venus rotation parameters based on a combination of Venera 15/16 images and Magellan data will also be improved. Although this promised to be an accurate determination, ephemeris errors degraded the solution, and the preliminary results were disappointing. As part of this proposal, the Venera ephemeris will be improved via a technique similar to that used for the Magellan ephemeris, and the rotation parameters recomputed. Also, the number of common Venera/Magellan points from which the rotation parameters are computed will be increased.

d. M. E. Davies, T. R. Colvin, P. G. Rogers, P. W. Chodas, W. L. Sjogren, E. L. Akim, V. A. Stepanyantz, Z. P. Vlasova, and A. I. Zakharov
The Rotation Period, Direction of the North Pole, and Geodetic Control Network of Venus
Journal of Geophysical Research, vol. 97, no. E8, August 25, 1992

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Professor Bruce Fegley, Jr., Department of Earth & Planetary Sciences, Washington University, One Brookings Drive, St. Louis, MO 63130-4899

PROPOSAL TITLE: Interpretation of Magellan Geochemical Data using Laboratory Studies of Mineral and Rock Weathering on Venus

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year or" new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

(a) We seek funding to extend our ongoing experimental and theoretical studies of mineral and rock weathering on Venus to other reactions useful for interpreting the global geochemical trends observed by the Magellan, Pioneer Venus, and Venera spacecraft. Specifically, we propose to experimentally measure the rates of thermochemical gas-solid reactions important in the weathering (or production) of high dielectric constant minerals such as Fe oxides and sulfides which are generally believed to be present in areas of the Venusian surface characterized by high radar reflectivity and high dielectric constants. In collaboration with our colleagues at Washington University, at the University of Michigan, and at the Observatoire de Paris in France, the results of our experimental and theoretical studies will be combined with dielectric constant measurements (where relevant) of our starting materials and run products, geological and geophysical analyses of the Magellan radar images, and with spectroscopic measurements of the atmospheric abundances of chemically reactive gases (in particular sulfur gases) on Venus to produce a coherent description of the geological and geochemical processes responsible for the production and/or destruction of radar bright areas on the surface of Venus. Fundamental questions which can be addressed by application of our experimental data include the following: (1) whether or not high dielectric constant phases are a plausible explanation (as proposed by Pettengill and colleagues) for the high radar reflectivity areas on Venus, (2) whether high radar reflectivity areas represent young, high dielectric material not yet equilibrated with the atmosphere or older, high dielectric material produced by equilibration with the atmosphere, (3) whether or not it is plausible to attribute radar reflective areas in the plains (e.g., in and around some craters) to the presence of high dielectric constant phases or to some other mechanism, (4) what is the global average rate of volcanism on Venus, (5) what are the relative ages of different surface regions where high dielectric constant materials are indicated by radar observations. (b) New Proposal. (c) We propose to apply proven experimental techniques adapted from the fields of materials science and physical chemistry to measure the rates of oxidation and reduction reactions which are widely believed to be important for weathering sulfide, oxide, and ferric minerals on the Venusian surface. Well characterized (e.g., by X-ray diffraction, electron microprobe analysis, inductively coupled plasma emission spectroscopy, Mossbauer spectroscopy, scanning electron microscopy, BET gas absorption) natural and synthetic minerals and appropriate terrestrial igneous rock analogs to Venusian basalts will be used in the experiments. The latter analogs will be selected on the basis of the Venera and Vega chemical analyses of the Venusian surface and the Pioneer Venus, Earth-based, and Magellan radar observations. The experiments will be conducted using the same type of modified thermogravimetric techniques which we have been employing in ongoing studies of the reactions of SO_2 with calcite, diopside, anorthite, and wollastonite under Venusian conditions. We have already tested these techniques in preliminary studies of pyrite and pyrrhotite oxidation, and found them to be suitable for our proposed work. We will establish the reaction rate law and the dependence of the rate on temperature, surface area, oxygen fugacity, gas partial pressures, mineral crystallographic axis (pure mineral experiments), and rock type (igneous rock experiments). Sufficiently large specimens of the unreacted and reacted samples will also be used in some runs for measurements of dielectric constants to determine the rate of decrease (or increase) of the dielectric constant with the extent of chemical weathering. Where appropriate experiments involving synthetic loaded dielectrics (e.g., sulfide grains of known size and shape in an inert silicate matrix) will also be undertaken. Preparation of such samples will be facilitated by the P.I.'s experience in the fabrication and processing of ceramic materials. The dielectric constant measurements will be done in close collaboration with Dr. Dobson, an expert in the measurement of dielectric properties of materials. (d) B. Fegley, Jr. 1988 *Lunar Planet. Sci.* **XIX**, 315-316; B. Fegley, Jr. and R.G. Prinn 1989 *Nature* **337**, 55-58; B. Fegley, Jr. and A.H. Treiman 1990 *Bull. Amer. Astron. Soc.* **22**, 1055; A.H. Treiman and B. Fegley, Jr. 1991 *Lunar Planet. Sci.* **XXII**, 1409-1410; B. Fegley, Jr. and A.H. Treiman 1991, in *Proc. of the Chapman Conference on Comparative Study of Venus and Mars*, AGU; Fegley et al 1992 *Proc. 22nd LPSC*, pp. 3--19; Bézard et al 1992 *Nature*, submitted.

PROPOSAL SUMMARY

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PROPOSAL TITLE: Investigation of Venus Surface Electrical and Mechanical Properties.

ABSTRACT:

(a) We propose to use Venus altimetry and radiometry data to derive physical properties of the Venus surface. Its importance to the study of Venus is twofold: (1) to assist in the interpretation of radar imagery, since much of our knowledge of Venus geology is derived from images of radar backscatter from the top few centimeters of regolith, and (2) to derive models of the surface that are consistent with those of the lower atmosphere and with *in situ* measurements of surface mineralogy. The most challenging task will be to derive comprehensive physical models of the regions of very low emissivity (and high radar reflectivity) that have been observed in many highland areas and on the floors of several impact craters. We propose to compare two models, (1) a surface composed of a loaded dielectric whose anomalous scattering properties stem from a high surface dielectric constant, and (2) a volume scatterer whose anomalous behavior is a result of wavelength-sized scatterers buried in a very low loss substrate. The most useful data sets for this investigation will be the Magellan emissivity and power reflection coefficient measurements, but we also anticipate the need to correlate them with data sets from the Pioneer Venus and Venera spacecraft, with other Magellan data, and with earth-based observations. To accomplish this task, we propose to construct a multi-component digital database of Venus surface parameters at a 5 km sampling resolution, which would be formally presented to the Planetary Data System for use by all Venus investigators.

(b) New proposal

(c) Work during FY'93 would include (1) correcting the Magellan emissivity data set using the calibration measurements that were made for this purpose, (2) re-calibrating the Magellan power reflection coefficient data set, (3) defining and coding the surface parameter database, (4) assembling those Venus data sets not yet delivered to MIT, and (5) investigating the dependence of emissivity on emission angle, polarization, and solar zenith angle.

(d) G. H. Pettengill, P. G. Ford, and B. D. Chapman, Venus: Surface electromagnetic properties, *J. Geophys. Res.*, *93*, 14,881-14,892, 1988.

G. H. Pettengill, P. G. Ford, and R. J. Wilt, Venus Surface Radiothermal Emission as Observed by Magellan, *J. Geophys. Res.*, 97, 13,091-13,102, 1992.

P. G. Ford and G. H. Pettengill, Venus Topography and Meter-Scale Slopes, *J. Geophys. Res.*, 97, 13,103-13,114, 1992.

Proposal Summary

Principal Investigator: Jane L. Fox
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Co-Investigators: None

Proposal Title: Studies of the Nightside Thermospheres-Ionospheres of Venus and Mars

We are proposing to investigate, through numerical modeling and analysis of the Pioneer Venus data base, some problems in the aeronomy of the nightside thermosphere-ionosphere of Venus. Specifically, we propose to carry out a study of the chemistry of the Venus pre-dawn bulge ionosphere, similar to our recent investigation of the of the chemistry of the ionosphere near the anti-solar point. With the aid of a multi-stream electron transport code that we have obtained from H. S. Porter, we will compare the chemistry of these regions to that of the auroral nightside ionosphere. Since Venus at low solar activity is similar to Mars at high solar activity, we will extend the these calculations to Mars by computing the nightside ionosphere that would result from precipitation and plasma transport.

Also using the Porter electron transport code, we can now carry out more precise calculations of the production processes involved in the Venus nightside UV aurora. Emission and ion density profiles from the deep-diving phase of the PV mission this fall will be important in determining the relationship of the UV aurora to the high mass-28 ion orbits, which we have proposed are a signature of particle precipitation. We will also map the spatial distribution of the high-mass-28-ion orbits to compare to that of the UV aurora. We will attempt to determine the horizontal extent of the high-mass-28-ion orbits by looking at the correlation of mass-28 ion densities for inbound and outbound portions of orbits. An investigation of the magnetic fields that are characteristic of high- and low-mass-28-ion orbits will be carried out to determine the relationship between the ion and UV aurora and the large-scale magnetic fields described by Luhmann [1992].

We will also carry out modeling studies and data analysis of the odd-nitrogen chemistry on the nightside of Venus. During the deep-diving phase of the PV mission, there may be enough low-altitude data to enable the NO densities to be derived from the ion chemistry. A specific study that we will undertake during the first year is to evaluate the effect of a proposed change in the temperature dependence of the rate coefficient for the reaction of NO and N. This may have profound effects for the cold nightside thermosphere.

Fox, J. L., and A. I. F. Stewart, The Venus ultraviolet aurora: A soft electron source, *J. Geophys. Res.*, *96*, 9821, 1991.

Fox, J. L. and H. A. Taylor, Jr., A signature of electron precipitation in the nightside ionosphere of Venus, *Geophys. Res. Lett.*, *17*, 1625, 1990.

Fox, J. L., The chemistry of the nightside ionosphere of Venus, *Planet. Space Sci. (in press)*, 1992.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Lisa R. Gaddis
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CO-INVESTIGATOR: Randolph L. Kirk

PROPOSAL TITLE: *Formation and Emplacement of Fluidized Flows on Venus: A Comparison of Lava Flows and Crater Outflow Deposits*

ABSTRACT:

a) Objectives: The objectives of this research are: 1) to understand the morphologic diversity, rheologies, and emplacement processes of the effusive volcanism that has occurred in different geologic environments on Venus; 2) to search for changes in eruptive style that might reflect evolving compositions or conditions in magma sources both locally and globally; 3) to compare morphologies, physical properties, and emplacement modes of lava flows with those of crater outflow deposits generated or triggered by impact; and 4) to understand the compositional and thermal evolution of Venus' crust both during and since the last global resurfacing event. Accomplishment of these objectives will require: 1) classification of lava flow and outflow types and documentation of trends in their occurrence with geologic setting, terrain type, elevation, tectonic association, and relative age; 2) modeling lava flow eruption and emplacement through comparison of venusian and terrestrial flow characteristics; 3) analyses of surface texture and topography data of lava flows and outflows to infer lava rheologies and eruption rates, volumes, and durations; and 4) application of computer models of flow emplacement to validate lava flow and outflow rheologies and eruption parameters inferred in this study.

b) Accomplishments: New Proposal

c) Work Plan (FY 93): Initial research efforts will focus on collection and compilation of a comprehensive database of morphologic and contextual information for selected lava flows and crater outflow deposits. Magellan imaging radar, altimetry (reflectivity, roughness, topography), and emissivity data will be used to document and classify planimetric, surface textural and backscatter characteristics of selected flows. The fractal dimensions of flow margin geometries will be calculated, and three-dimensional color views of Magellan altimetry, radar, and emissivity data for lava flows and outflows will be used to study geologic settings and topographic relationships. Backscatter cross-section data of venusian and terrestrial lava flows will be compared to assess scattering properties and to determine the validity of terrestrial-based interpretations of flow morphologies. Systematic patterns among these lava flow and outflow characteristics will be identified and used to infer flow rheologies and emplacement characteristics. Results, including a database of planimetric and backscatter characteristics (as a function of geologic setting) and inferred rheologic properties, will be published in the open literature.

d) References:

Gaddis, L.R., 1992, Lava flow characterization at Pisgah volcanic field, California, with multiparameter imaging radar, *Geol. Soc. Am. Bull.*,104, pp. 695-703.

Gaddis, L.R. and R. Greeley, 1990, Volcanism in NW Ishtar Terra, Venus, *Icarus*, 87, pp. 327-338.

Gaddis, L., P. Mouginis-Mark, R. Singer, and V. Kaupp, 1989, Geologic analyses of Shuttle Imaging Radar (SIR-B) data of Kilauea Volcano, Hawaii, *Geol. Soc. Am. Bull.*, 101, pp. 317-332.

Gaddis, L.R., P. Mouginis-Mark, and J.N. Hayashi, 1990, Lava flow surface textures: SIR-B radar image texture, field observations, and terrain measurements, *Photo. Eng. Rem. Sens.*, 56, p. 211-224.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Dr. James B. Garvin
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CO-INVESTIGATORS: Dr. R. A. F. Grieve
Dr. C. C. Schnetzler
Mr. J. J. Frawley

PROPOSAL TITLE: *Morphometric Analysis of Large-scale Impact and Volcanic Landforms on Venus*

ABSTRACT:

(a) The abundance of discrete impact and volcanic landforms larger than ~ 50 km in diameter on Venus offers a unique opportunity for relating those large-scale landform morphometric parameters which can be measured for a representative subset of such features to fundamental planetary variables. Therefore, systematic quantification of basic morphometric properties of already catalogued impact craters, volcanic edifices, and calderas on Venus using global and regional Magellan altimeter data products is justified, if only to serve as the basis for quantitative comparison with features of similar origin on the Earth, Mars, and Moon. We propose to focus on 50 km and larger landforms, and to reliably and objectively measure volumes, heights, depths, slopes, and general shape parameters for each. The goal is to investigate empirical morphometric relationships between simple dimensional parameters (depth, diameter, height) and parameters which directly relate to basic characteristics of the Venus geologic environment, including crustal mechanical properties, volcanic volume eruption rates, and erosional styles.

(b) "NEW PROPOSAL"

(c) During FY93, a relational database of morphometric parameters for all impact features with diameters in excess of 60 km will be constructed using an interactive software system we have developed for analyzing digital elevation model (DEM) datasets. Emphasis will be on craterform interior volumes, outer rim slopes, rim heights, maximum depths, and ejecta volumes. A method for using cylindrical harmonic expansions to model the topography of crater interiors will be investigated and validated. Depth-diameter and "shape"-diameter relationships will be computed and analyzed. The balance between crater interior volume and ejecta (within 2 crater radii) will be investigated, where possible. Geologic maps of potentially anomalous impact features such as Bonheur (Quad V29), Stowe (Quad V51), and Lise Meitner (Quad V61) will be prepared to compare with existing mapping and interpretations of Cleopatra. A survey of discrete volcanic edifices larger than 50 km in basal diameter will be completed to be used in future years (FY94-95) work.

(d) Garvin J. B. and G. G. Schaber (1992) Morphometry of Large Impact Craters on Venus, *Lunar & Planet. Science XXIII*, p. 399-400.
Garvin J. B. and R. S. Williams Jr. (1990) Small Domes on Venus: Probable Analogs of Icelandic Lava Shields, *GRL 17*, p. 1381-84.
Garvin J. B. (1990) The Global Budget of Impact-Derived Sediments on Venus; *Earth, Moon & Planets 50/51*, p. 175-190.

Principal Investigator: Lori S. Glaze
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Co-Investigator: David Crisp

Proposal Title: *Analysis of SO_2 Input Into the Upper Troposphere on Venus*

Abstract:

a) The strongest evidence for current explosive volcanism on Venus is the high concentration of SO_2 measured in the upper atmosphere by Pioneer Venus during its first few years of operation. Since that time, some investigators have suggested that it is not possible for an explosive eruption on Venus to inject material directly into the upper atmosphere. We propose to analyze both the possibility of injecting material directly into the Venus cloud layer by studying the boundary conditions necessary to produce plumes of sufficient height, as well as to assess the potential for transporting material from lower plumes by atmospheric circulation.

b) New proposal

c) In the first year we propose to analyze all existing ground based, orbital and probe measurements of the Venus atmospheric structure and composition. We will synthesize this information as a function of time and location of measurement. It will then be used to more accurately determine the height to which a plume may rise on Venus. We also propose to analyze Magellan images of areas suspected to be of explosive volcanic origin in an effort to estimate the limits on possible eruption sizes. This analysis will lead into a theoretical study to determine the limits on eruption conditions using two models, one for continuous rise from a point source (Plinian style activity) and one for buoyant plume rise from pyroclastic flows (co-ignimbrite plumes). The eruptive conditions determined to be necessary for injection of SO_2 into the upper atmosphere will be assessed according to their physical and geologic viability.

d) Glaze, L.S. and S.M. Baloga (1993) The sensitivity of volcanic plume heights to ambient atmospheric conditions, submitted to *J. Geophys. Res./Atmospheres.*

Proposal Summary

Principal Investigator:	Dr. Richard Goldstein
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Co-Investigators:	Dr. Scott Hensley Scott Shaffer
Proposal Title:	Subsurface Scattering and Topographic Analysis from Magellan Interferometry Data

Abstract:

a) Objectives and Justification

The objectives of this study are 1.) to produce high resolution digital elevation data of the North polar region 2.) to obtain a pole location 3.) to determine the depth and amount of subsurface scattering at S-band. Using intracycle repeat pass interferometric data it will be possible to obtain high resolution (on the order of 300m) topographic data of the North polar region on Venus not obtainable from any other data source. Moreover, as an appreciable portion of the interferometric baseline is due to planet rotation an accurate pole determination can be made provided the Venusian rotation period is known. Quantitative data on the amount and depth of subsurface scattering in the North pole region and those areas where intercycle interferometry is possible can be computed from the interferometric data. In those regions where intercycle interferometry is possible the existence of interferometric fringes bound the amount of surface modification that has taken place due to aoelian and other surface erosional forces on Venus.

b) New Proposal

c) Work to be Done this Year

The work this year can be divided into 4 tasks, data selection and acquisition, interferogram production, phase unwrapping and height reconstruction, and determination of the amount of subsurface scattering. Data collected in the North pole region with uploads designed for optimal interferometric data collection will be examined to determine which bursts if any have fringes. Also intercycle orbit pairs with the same look angle profile will be examined for interferometric fringes. Interferograms in the North pole region will be used to generate high resolution topographic data of the pole and used to determine the pole location. Using the magnitude and phase information subsurface scattering depth and magnitude will be estimated providing information on the structure of the Venusian regolith.

d) Recent Publications

"Topographic Mapping from Interferometric Synthetic Aperture Radar", (with H. Zebker), Journal of Geophysical Research, Vol. 91, No. B5, pp. 4993-9, April 10, 1986.

"Crossed Orbit Interferometry: Theory and Experimental Results from SIR-B", (with A. K. Gabriel), Int. Journal of Remote Sensing, Vol. 9, No. 5, pp. 857-872, 1988.

"Satellite Radar Interferometry: Two Dimensional Phase Unwrapping", (with H. A. Zebker and C. L. Werner), Radio Sciences, Vol. 23, No. 4, pp. 713-720, July-August, 1988.

PROPOSAL SUMMARY SHEET—ABSTRACT

PRINCIPAL INVESTIGATOR:
Ronald Greeley
Department of Geology
Arizona State University
Tempe, Arizona 85287-1404
(602) 965-7045

CO-INVESTIGATOR:
John E. Guest, Univ. Lond Observatory

COLLABORATORS:
Raymond Arvidson, Washington, Univ.
Stephen Saunders, Jet Propulsion Laboratory
Gerald Schubert, Univ. of California, Los Angeles
David Senske, Jet Propulsion Laboratory
Ellen Stofan, Jet Propulsion Laboratory

PROPOSAL TITLE: *Venus Aeolian Geology and Geologic Mapping*

ABSTRACT

OBJECTIVE:

This proposal has two tasks; the goals of the first task are to determine the characteristics of aeolian features on Venus and to relate the features to: 1) the observed and inferred patterns of atmospheric circulation, 2) the general geology where they occur, and 3) the resurfacing history of Venus. This study would utilize an existing global data base of >8000 aeolian features that include their morphologic classification and geographic location. Although the primary aeolian features to be studied are various wind streaks, other features include dune fields and possible yardangs. The origin and evolution of these features would be investigated and the potential sources of windblown sediments would be assessed. The distribution and orientation of various types of wind streaks would be correlated with geologic setting and wind patterns on local, regional, and global scales. Results would be compared with models of atmospheric circulation derived from Pioneer-Venus and other missions. Although resurfacing on Venus is attributed primarily to volcanic processes, exogenic processes such as aeolian activity may be important locally. Consequently, the role of windblown processes in resurfacing would be assessed based on Magellan observations and theoretical modelling.

The goal of the second task is to map six quadrangles (V-25, 26; V-37, 38; V-49, 50) covering the eastern Aphrodite rift zone of Venus in order to gain insight into the complex volcanic history of this area and as part of the Systematic Venus Geologic Mapping Program; additional goals are to work with the mapping project to derive a global geologic framework for Venus and to contribute toward advancing techniques in planetary geological mapping in which radar data constitute the primary source of information.

BACKGROUND AND RELEVANCE:

Any planet or satellite that has a supply of fine, loose particles on its surface and winds of sufficient strength to move them may experience aeolian activity. Even before the Magellan results, there was speculation that Venus is subjected to aeolian processes. Magellan SAR data reveal dune fields, possible yardangs (wind-eroded hills), and thousands of wind streaks. Although concentrations of wind streaks tend to be associated with young impact craters and some tesserae terrain (both are logical sources of fine debris), they are found globally at all latitudes. Their presence signals local winds ≥0.5 m/s at the time of their formation and loose sediments. Thus, aeolian features represent the interaction of the atmosphere and the surface and can be used to understand aspects of atmospheric circulation and the geologic evolution of the surface.

Geological mapping is fundamental to planetary science because it provides the framework for deriving the geological histories for planets and satellites, as well as providing a context for geophysical, geological, and other measurements and studies. Although planetary geologic mapping techniques and procedures are well established using (primarily) optical images, the use of radar as the main source of information presents new challenges and is, of itself, a research task. The area proposed for mapping (eastern Aphrodite rift zone) is dominated by volcanic and tectonic features. The mapping proposed here would contribute toward understanding the volcanic/tectonic history of this important region and shed light on the evolution of the venusian surface.

PROGRESS: New Proposal

PUBLICATIONS:

Greeley, R. and R.E. Arvidson, 1990, Aeolian Processes on Venus, *Earth, Moon, and Planets, 50/51*, 127-157.

Greeley, R. and R. Batson, eds., 1990, *Planetary Mapping*, Cambridge University Press, Cambridge, 296 p.

Greeley, R., R.E. Arvidson, C. Elachi, M.A. Geringer, J.J. Plaut, R.S. Saunders, G. Schubert, E.R. Stofan, E.J.P. Thouvenot, S.D. Wall, and C.M. Weitz, 1992, Aeolian features on Venus: Preliminary Magellan results, *J. Geophys. Res.*, *97*, 13,319-13,345.

Guest, J.E. et al., Small volcanic edifices and volcanism in the plains of Venus, *J. Geophys. Res.* (in press).

Senske, D.A., G.G. Schaber, and E.R. Stofan, 1992, Regional topographic rises on Venus: Geology of western Eistla Regio and comparison to Beta Regio and Alta Regio, *J. Geophys. Res.*, *97*, 13,395-13,420.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR:

Robert E. Grimm
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Arizona State University
Tempe, AZ 85287-1404
602/965-0796

PROPOSAL TITLE: Gravity Modelling, Flexure, and Geodynamics of Venus

ABSTRACT:

a. Objective: To better understand the forces controlling the geological evolution of Venus. The principal focus is on testing quantitative models for Venus tectonics and lithospheric structure using radar images and altimetry from Magellan and gravity data from both Pioneer Venus and Magellan. Specific objectives include regional (100-1000 km scale) models of crust and mantle dynamics and interpretation of local (10-100 km scale) topography in terms of lithospheric flexure and viscous relaxation.

b. Progress: This is a new proposal.

c. Proposed Work: (1) Perform joint inversion of Pioneer Venus and Magellan line-of-sight accelerations for free-air gravity anomalies at Aphrodite Terra. (2) Use gravity data to constrain geodynamic models of highland (Ovda, Thetis) and corona (Artemis) formation. Quantitatively model deformation using viscous flow models. (3) Test lithospheric flexure hypothesis for coronae, including effects of in-plane force and basal shear stress. (4) Perform global search in Magellan imagery and altimetry for flexural signatures near volcanoes, mountain belts, and highland fronts. Produce map of variations in elastic lithosphere thickness at the time of loading. (5) Compare depths of impact craters from Magellan altimetry and stereo radar to predicted flexural and viscous relaxation response. Calculate acceptable range of crustal thickness, thermal gradient, and rheology consistent with data.

d. Summary Bibliography:

Grimm, R.E., and S.C. Solomon, Viscous relaxation of impact craters on Venus: Constraints on crustal thickness and thermal gradient, *J. Geophys. Res., 93*, 11911-11929, 1988.

Phillips, R.J., R.E. Grimm, and M.C. Malin, Hot-spot evolution and the global tectonics of Venus, *Science, 252*, 651-658, 1991.

Grimm, R.E., and R.J. Phillips, Gravity anomalies, compensation mechanisms, and the geodynamics of western Ishtar Terra, Venus, *J. Geophys. Res., 96*, 8305-8324, 1991.

Grimm, R.E., and R.J. Phillips, Anatomy of a Venusian hot spot: Geology, gravity, and mantle dynamics of Eistla Regio, *J. Geophys. Res.*, in press, 1992.

PROPOSAL SUMMARY

TITLE: EVOLUTION OF THE ATMOSPHERE AND SURFACE OF VENUS

PRINCIPAL INVESTIGATOR: David H. Grinspoon
INSTITUTION: University of Colorado
Laboratory for Atmospheric and Space Physics
Campus Box 392
Boulder, CO 80309-0392

CO-INVESTIGATORS:

None

ABSTRACT:

a) We are trying, through several types of modeling, to understand the long term evolution of the atmosphere and surface of Venus. We will synthesize several new groundbased and spacecraft data sets and utilize chemical and evolutionary modeling in order to achieve a deeper understanding of the evolutionary implications of the current volatile abundances. We are simulating the balance between impact cratering on Venus and the various resurfacing processes responsible for creating the spatial and size-frequency distributions of craters revealed by Magellan. This will allow derivations of the magnitude and time-dependence of sources of important trace volatiles. We wish to apply this derived information to improved models of surface-atmosphere chemical evolution on Venus. Our approach is to simulate the evolution of the surface through Monte Carlo modeling of cratering and resurfacing, exploring a range of styles and rates of these processes and comparing model results to Magellan observations. Source terms of outgassed and impact-derived volatiles will be obtained from these model results and applied to a suite of improved chemical evolutionary models, described herein.

b) New proposal.

c) During the coming year we will: (i) Implement improvements in evolutionary modeling of water and the deuterium-to-hydrogen ratio, and important sulfur bearing species in the lower atmosphere and their interaction with surface minerals. These models will utilize the newly available greatly improved constraints on lower atmosphere composition and new constraints on the magnitude and time dependence of exogenous and endogenous volatile sources on Venus.(ii) Complete the development and testing of a Monte Carlo model of cratering and resurfacing on Venus. (iii) Perform numerous runs of this model varying the nature and rates of the resurfacing processes and comparing with Magellan data in order to derive constraints on the action of these processes on the observed surface of Venus. (iv) Implement several improvements in the model to incorporate more sophisticated simulations of the range of volcanic styles observed, the observed altitude distribution of volcanic styles, and a more flexible scheme for simulating time-dependent cratering and resurfacing histories. (v) Begin creating a detailed numerical model to simulate several types of lava flows on Venus. (vi) Create an improved chemical equilibrium model of the surface and lower atmosphere of Venus.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Richard E. Hartle
Goddard Space Flight Center /Code 914
Greenbelt, MD 20771 (301) 286-8234

CO-INVESTIGATOR: Joeseph M. Grebowsky

TITLE: PIONEER VENUS ORBITER ION MASS SPECTROMETER DATA ANALYSIS: IONOSPHERIC CHEMISTRY AND DYNAMICS

(a) The general objective is to advance knowledge and understanding of the processes related to ionospheric structure, composition, chemistry and dynamics at Venus and their dependence on solar activity, applying the investigators' experience in the use of the Orbiter Ion Mass Spectrometer (OIMS) measurements on the Pioneer Venus Orbiter (PVO). Through analysis of OIMS data, coupled with that of other PVO instruments, investigations will be conducted on global and solar cycle variations in ion and neutral composition and dynamics, including ionospheric acceleration, energization and escape processes. Particular emphasis will be placed on defining and quantifying planetary escape processes to contribute to understanding the evolution of Venus' atmosphere.

(b). This is a **new proposal** for the **VDAP** program that is a continuation of work done previously under Pioneer Venus project funding as part of the OIMS science team. Within the past year, 2 papers have been submitted for publication by Hartle and Grebowsky [to JGR and Adv. Space Res.] that use the OIMS ion composition measurements to deduce vertical flows of all ion species in the nightside ionosphere and that evaluate the consequences of these flows on the planetary escape of H^+ and D^+. One paper by Grebowsky et al. [submitted to JGR] on the source and distribution of dayside superthermal ions details the specifics of how the OIMS responds to superthermal ions. Other accomplishments of the past year, which are not specifically included in the currently proposed tasks, include a published paper on VLF electron density irregularities [Grebowsky et al., J.G.R., 96, 21347, 1991] and a follow-up paper submitted to JGR by Huba and Grebowsky that compares the irregularity observations to Lower Hybrid Drift wave predictions.

(c) In the first year we plan to use recent Pioneer Venus measurements made under solar minimum conditions and compare them with early mission solar maximum observations to study the solar activity dependence of various processes, including the vertical flow and escape of H^+ and D^+. These tasks are a simple evolution of our earlier studies, using the same numerical and experimental techniques, and are important in determining more precisely how the atmosphere has evolved. One study is aimed at improving the statistical evaluation of the ratio $[D^+]/[H^+]$, an important quantity in understanding the evolution of water on Venus. Another study will be initiated to determine H and D distributions in the chemical equilibrium region for all solar conditions. The global distributions of H will then be provided to investigators planning to update empirical atmosphere models and will, in the following year, be used with a global thermosphere circulation model to evaluate the planet average escape rate of H. The response of the OIMS to superthermal ions and even subsonic and supersonic ionospheric flows will be employed to study the superthermal ion distributions at night and to complement and add to the data base of the Orbiter Retarding Potential Analyser (ORPA) measurements of ionospheric flow properties. The OIMS flow measurements have the capability of exploring ion flow variations over shorter temporal and spatial scales than the ORPA. This last task will have to be extended over several years. However, on the basis of recent solar minimum observations of a very dynamic nightside ionosphere, it will be necessary to take some of these measurements of ion dynamics into consideration during the first year since such plasma states may have a significant impact on the ion composition measurements.

(d) Recent relevant publications are cited above in (b).

ABSTRACT SUMMARY SHEET

PRINCIPAL INVESTIGATOR: James W. Head, III

COLLABORATORS: E. Parfitt, L. Crumpler, K. Magee-Roberts, S. Keddie, I. Antonenko, E. Grosfils, R. Ernst, L. Wilson, H. Pinkerton, N. Hallem, P. Ford, F. Leberl.

PROPOSAL TITLE: Venus Magmatism from Magellan Data: Formation and Evolution of the Venus Plains

ABSTRACT:
a) Objectives: To study several aspects of Venus magmatism (volcanism and plutonism) from Magellan data and to apply the findings to critical questions concerning the formation and evolution of the Venus plains and crust.
b) Progress: New proposal.
c) Proposed Work: There are three focal points designed to achieve the proposal objectives:
I. Venus Plains: Characteristics, Mode of Emplacement, and Stratigraphy, including: A) Characterization of Plains Sources and Substrates, in which type examples of the sources of plains materials are studied (large flow units, sinuous channels, coronae, novae, shield fields, and large shields); the topographic and morphologic nature of plains substrates are assessed through analysis of the character and distribution of slopes and topography, flooding experiments and an analysis of their volume implications, and in an assessment of altitude dependence; B. Emplacement of Large Flows: Theory and Observations, in which we analyze flows with levees, with filled channels, with drained channels, with breakouts partway down the flow, with near-vent breakouts and breakouts from flow fronts, and flows which are captured by topographic depressions, and we compare these characteristics with recent theoretical models of flow emplacement and eruption conditions; and C. Plains Stratigraphy: The Problem of the Emplacement and Evolution of Plains, in which we develop mapping criteria, apply these regionally to several type areas, and then synthesize the studies in terms of general models for the formation of the plains.
II. Dike Swarms on Venus and Earth: Mode of Formation and Implications for Crustal Development, including a review of terrestrial mafic dike swarms and applications to Venus, a field analysis of the internal structure of selected dikes, and the documentation and analysis of the modes of emplacement of comparable radially fractured features (novae) on Venus. We will also investigate the use of great dikes as stratigraphic markers on Venus.
III. Large Shield Volcanoes on Venus: Characteristics, Evolution, and Implications for Terrestrial Edifices, including the classification and characterization of large shield volcanoes on Venus, an assessment of volcano evolution in which the sequence of events in a series of volcanoes is established and compared to a synthesis of terrestrial models which include: i) preshield stage ; ii) shield stage; iii) postshield stage; and iv) rejuvenated stage. These results will be used to develop models for the evolution of Venus volcanoes.

In addition to the three topical studies, we propose several quadrangles which could be mapped in support of these objectives.

d) Summary Bibliography:

(1) Head, J. W., Campbell, D. B., Elachi, C., Guest, J. E., McKenzie, D. P., Saunders, R. S., Schaber, G. G., and Schubert, G. (1992) Venus volcanism: Initial analysis from Magellan data, *Science, 252,* 276-288.
(2) Head, J. W., Crumpler, L., Aubele, J., Guest, J., and Saunders, R. S. (1992) Venus volcanism: Classification of volcanic features and structures, associations, and global distribution from Magellan data, *Journal of Geophysical Research , 97,* 13,153-13,197.
(3) Parfitt, E. A., and Head, J. W. (1992) A survey of radial fracture systems on Venus, *Lunar and Planetary Science Conference, XXIII,* 1029-1030.
(4) Parfitt, E. A., and Head, J. W. (1992) Radial fracture systems on Venus: Conditions of formation, *Lunar and Planetary Science Conference, XXIII,* 1027-1028.
(5) Grosfils, E. B., and Head, J. W. (1992) Venusian stress directions from radial fractures, *Lunar and Planetary Science Conference, XXIII,* 457-458.
(6) Head, J. W., Crumpler, L. S., and Aubele, J. C. (1992) Large shield volcanoes on Venus: Distribution and classification, *Lunar and Planetary Science Conference, XXIII,* 513-514.
(7) Keddie, S. T., and Head, J. W. (1992) Sapas Mons Venus: Sequence of events in a large shield volcano, *Lunar and Planetary Science Conference, XXIII,* 669-670.
(8) Ernst, R. E., and W. R. A. Baragar, Evidence from magnetic fabric for the flow pattern of magma in the Mackenzie giant radiating dyke swarm, *Nature, 356,* 511-513, 1992.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Paul C. Hess
(Name, Address, Telephone Number) Department of Geological Sci Box 1846
Brown University, Providence, RI 02912
401-863-1929

Co-INVESTIGATORS: E.M. Parmentier
(Name Only)

PROPOSAL TITLE: The Gabbro-Eclogite Transition and Crustal Recycling on Venus

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

a) Our objectives are to understand the gabbro-eclogite transformation as a mechanism of crustal recycling on Venus. We will determine by experiment the P-T boundaries of the gabbro-granulite-eclogite facies at low temperatures under dry and hydrated conditions and examine the kinetics of the phase transformation. We will model the surface deformation and volcanism associated with eclogite diapirism and compare these results with features such as coronas and arachnoids on the Venusian surface

b) New Proposal

c) Experiments to determine the P-T boundaries of the gabbo-eclogite transition between the solidus and 700-800°C will be initiated., These data are the constraints required to examine the requisite conditions of eclogite diapirism.

d) Parmentier, E.M., and Hess, P.C., (In Press) Chemical differentiation of a convecting planetary interior: Consequences for a one plate planet such as Venus. GRL

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Walter R Hoegy
Goddard Space Flight Center /Code 914
Greenbelt, MD 20771 (301) 286-3837

CO-INVESTIGATORS: L. H. Brace, R. F. Theis

TITLE: PIONEER VENUS LANGMUIR PROBE DATA ANALYSIS

ABSTRACT:
(a) The objectives of the proposed research are to analyze the PVO Langmuir probe data (along with PVO correlative data) to investigate: 1) Suprathermal electrons using a new two temperature fitting algorithm; isolated hot spots in the nightside ionosphere; and T_e energy budget. 2) Density and temperature of CO_2 at 80-160 km using EUV limb absorption of the Ipe solar flux during high bit rate 4096 passes. 3) Electrodynamics of Venus ionosphere and solution of the electron and ion momentum equations for electric currents and diffusion of the magnetic field in the subsolar region. 4) Ionospheric manifestation of gravity waves. 5) EUV flux measurement for aeronomic consequences, solar oscillations, and solar activity. 6) Small-scale plasma irregularities. 7) Ion drift velocities using spin modulation of the Langmuir probe ion current after subtracting the well known solar flux component, I_{pe}. Suprathermal electrons in the range of 1-2 eV have been found in the OETP data in many regions of the Venus ionosphere. In some regions they dominate the electron population, elsewhere they are the tail of the distribution. It is important to analyze the OETP volt-ampere curves and add suprathermal electrons to the UADS database in order to understand electron energetics in the Venus ionosphere. Analysis of the hot spots or regions of elevated electron temperatures will provide clues to better understand flow of energy into the nightside ionosphere [Hoegy et al., 1990]. Densities and scale heights of CO_2 in the altitude region below the PVO in situ measurements obtained from EUV limb absorption profiles of the photoelectron flux will add to the database defining the Venus atmosphere and will help in the revision of the atmospheric model of Hedin et al. [1983]. Use of T_e and N_e from OETP along with the magnetic field and T_i has enabled Cole and Hoegy [1992] to derive the currents, ion and electron drift velocities, and the electric field in the dayside ionosphere. Further analysis is needed to explore the consequences of the Cole and Hoegy finding of anomalous resistivity above 200 km (one such consequence would be anomalous heating). Gravity waves and plasma irregularities are important for understanding transport and energy sources in the ionosphere. The solar EUV flux measured by OETP is an important resource which will be exploited to investigate the effects of solar activity on the Venus ionosphere and ionosphere-solar wind interaction. High ion drifts are easily detectable with the Langmuir probe using ion densities in a spacecraft spin cycle, and such data would complement the ion drifts derived from the ORPA and may aid the investigation of ion drifts in the holes.
(b) New proposal.
(c) Work to be done this year: 1) Develop the interactive program to derive suprathermal electrons and hot ion densities by fitting volt-ampere curves, and analyze a sample of orbits at high and low solar activity to determine the morphology of the suprathermal electrons and the sensitivity to solar activity. 2) Analyze those orbits having a 4096 bps data rate that contain limb occultation data to determine the CO_2 density and scale height. 3) Analyze dayside orbits to determine the consistency of the data with the electron and ion momentum equations, determine the regions where the classical equations breakdown, and examine further consequences of the anomalous resistivity. 4) Analyze plasma wave data at low and high solar activity. 5) Investigate small-scale plasma irregularities found in the volt-ampere curves when analyzing the data for suprathermals. 6) Determine ion drift velocities in the trans-terminator region and compare velocities in the dawn and dusk regions, and attempt to derive velocities from the low solar activity entry period of PVO.
(d) Publications: K.D. Cole and W. R Hoegy, "Electric currents in the dayside Venus lower ionosphere", submitted J.G.R., 1992; W.R Hoegy, L.H. Brace, R.F. Theis, and H.G. Mayr, "Electron temperature and heat flow in the nightside Venus ionosphere", J.G.R. 85, 7811-7816, 1980; W.R Hoegy, L.H. Brace, W.T. Kasprzak, and C.T. Russell, " Small-scale plasma, magnetic and neutral density fluctuations in the nightside Venus ionosphere", J.G.R., 95, 4085-4102, 1090.

Proposal Summary

Principal Investigator: R. Richard Hodges Jr
The University of Texas at Dallas
Center for Space Sciences, MS FO-22
Richardson, Texas 75083-0688
(214) 690-2856

Co-Investigators: [none]

Title: Study of the Pioneer Venus Sounder Probe Neutral Mass Spectrometer Data

Abstract

Among the mass spectrometric data sets that have been obtained in the course of planetary exploration, that from the Pioneer Venus sounder probe neutral mass spectrometer (LNMS) is unique in several ways. The LNMS had very high mass resolution (> 400) that permitted separation, by nuclear defect, of species with the same atomic mass number, e.g. at 40 amu, the peaks of ^{40}Ar and C_3H_4 were distinct. At 50 different altitudes between 60 km and the surface of Venus, the LNMS sampled 236 discrete mass settings from 1 to 208 amu It was LNMS measurements that revealed the anomalous excess primordial ^{36}Ar on Venus, as well as a hundredfold enrichment of deuterium relative to D in water vapor. Following the cessation of NASA support for probe data analysis, the study of LNMS data was essentially dormant for almost a decade. Some realities have caused us to seek to reverse this situation: the data represent an experiment that will not be repeated in the foreseeable future; and more important, the complexities involved in the deconvolution of the measurements into spectral peak amplitudes precludes the meaningful extraction of information by casual browsing of the data at some future date. Recently, we published a ten year old manuscript on the distribution of water vapor in the lower atmosphere of Venus (Donahue and Hodges [1992a]), and we have found evidence for a large excess of weakly deuterated methane that suggests, among other things, both active volcanism and a substantial increase in the total abundance of D on Venus (Donahue and Hodges [1992b]). In resuming active study of the LNMS measurements, we have rediscovered that the data are rich in unreported information about the Venus atmosphere. **We propose to formalize the ongoing LNMS studies at the University of Texas at Dallas and The University of Michigan by bringing them into the Venus Data Analysis Program.**

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Albert T. Hsui
(Name, Address, Telephone Number) Dept. of Geology, University of Illinois
245 NHB, 1301 W. Green
Urbana, IL 61801 217-333-7732

Co-INVESTIGATORS:
(Name Only)

PROPOSAL TITLE: Thermal History & Mantle Dynamics of Venus

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

a) The objective of this research proposal is to develop a realistic thermal history model for Venus on the basis of a finite-element, three-dimensional spherical convection simulation. Effects of variable viscosity and phase changes are examined to evaluate if Venusian mantle evolved cooler or warmer relative to the Earth, and to examine the resultant implications to Venusian surface tectonics. Because of the new Magellan data and the increasing computing power, meaningful and realistic evolution models for Venus are now conceivable and computable.

b) New proposal.

c) This year, I plan (1) to examine effects of variable viscosity on 3-D convective patterns and to study their implications to surface tectonics of Venus, and (2) to implement phase changes in our 3-D convection model to investigate their effects to thermal histories and mantle flow patterns of Venus. These model studies are based on a finite-element, 3-D spherical convection model that we have recently developed. The convection model is now operational even for moderate variable viscosity cases. Therefore, calculations of Venusian thermal history represent straight forward computer simulations that may require some necessary code modifications. My proposed study is designed to provide realistic and quantitative information for the interpretation of Venusian surface tectonic features as observed by the Magellan and the earlier spacecraft missions.

d) Hsui, A. T., Application of fluid mechanic principles to the study of geological processes at trench-arc-back arc systems, Pure and Applied Geophys., 128, 661-681, 1988.

Hsui, A. T., X. Tang and M. N. Toksöz, On the dip angle of subducting plates, Tectonophysics, 179,163-175, 1990.

PROPOSAL SUMMARY

TITLE: *WAVE PHENOMENA IN THE VENUS IONOSPHERE*

PRINCIPAL INVESTIGATOR: J.D. Huba
Naval Research Laboratory
Washington, DC 20375

CO-INVESTIGATOR: H.L. Rowland

ABSTRACT (NEW PROPOSAL)

A comprehensive theoretical and computational research program is proposed to study wave phenomena in the ionosphere of Venus. The primary emphasis of the program concerns the origin of the electric field bursts observed by the Pioneer Venus Orbiter Electric Field Detector (*Scarf et al.*, 1980). This is a controversial subject and, despite over ten years of research, fundamental questions still remain. The wave observations can be split into two categories: (1) wave frequencies below the electron gyrofrequency, and (2) wave frequencies above the electron gyrofrequency. With regard to the first category (i.e., primarily 100 Hz signals), the major issue is to determine whether the observed signals are generated by lightning (i.e., whistler waves), by a local plasma instability (e.g., the lower-hybrid-drift instability), or by a combination of the two depending upon ambient conditions. To this end, we propose to carry out, for the first time, an extensive set of plasma simulations of electromagnetic wave propagation in the atmosphere and ionosphere of Venus for realistic ambient conditions. In addition, we intend to study the spatial mode structure of the lower-hybrid-drift instability, as well as its nonlinear evolution. For both scenarios, we will compare the theoretical and numerical results with observational data to assess the validity of the models. With regard to the second category (i.e., 5.4 kHz, 30 kHz, and usually 730 Hz signals), we propose to investigate electromagnetic electron cyclotron waves. These waves may be able to propagate across an ambient magnetic field even though the wave frequency is below the plasma frequency. A secondary emphasis of the program will focus on the large-scale density, temperature, magnetic field waves observed in the post-terminator (*Brace et al.*, 1983) and nightside (*Hoegy et al.*, 1990) ionosphere of Venus. We propose to investigate several fluid instabilities which could generate these waves using theoretical and numerical simulations based upon a modified set of MHD equations.

The following papers are relevant to the proposed research. They were completed by the Principal Investigator under the Pioneer Venus Guest Investigator Program.

Huba, J.D., "Theory of small-scale density and electric field fluctuations in the nightside Venus ionosphere," *J. Geophys. Res.*, *97*, 43 (1992).

Huba, J.D. and J.M. Grebowsky, "Small-scale density irregularities in the nightside Venus ionosphere: Comparison of theory and observations", submitted to *J. Geophys. Res.* (1992).

Huba, J.D. and H.L. Rowland, "Propagation of electromagnetic waves parallel to the magnetic field in the nightside Venus ionosphere," submitted to *J. Geophys. Res.* (1992) (under revision).

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Dr. Devrie S. Intriligator
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PROPOSAL TITLE: VENUS EVOLUTION AND THE DYNAMICS OF THE NIGHTSIDE IONOSPHERE: ANALYSES OF PVO ATMOSPHERIC ENTRY PLASMA ANALYZER (OPA) LOW ENERGY ION MEASUREMENTS

ABSTRACT:

a) The current atmospheric entry phase of the Pioneer Venus Orbiter and the switch to the low energy ion mode for the plasma analyzer (OPA) provide a unique opportunity to obtain data that will permit significant contributions regarding Venusian evolution, including a determination as to whether Venus was "wet," and the dynamics of the nightside ionosphere.

CRC proposes to use its OPA data, previous analyses, computer facilities and programs, and long-established ties with other leading institutions and researchers to take advantage of the atmospheric entry phase and the OPA low energy ion mode data to determine ion densities, speeds, temperatures, angles of flow, pressures, and (using magnetic data) plasma betas. As a result, CRC will be able to make significant contributions regarding the planetary water budget and planetary evolution due to ion escape and to discern the dynamics and configuration of the ionotail and its relation to other phenomena, such as solar wind pressure, local electric fields, horizontal and vertical flows, and gradients.

b) New proposal

c) This first year CRC will concentrate on:

1. Development of a multicomponent ion species fit program for determining OPA low energy (0 to 250 V) ion parameters. This will make use of programs CRC previously developed to analyze OPA high energy (250 to 8,000 V) ion data.
2. Analyses of new atmospheric entry OPA low energy ion nightside ionosphere data for orbits selected based on flux versus time plots of the OPA low energy ion data and on OETP electron density plots. We will employ previously developed CRC software and the new multicomponent ion species fit program for low energy ions.
3. Comparisons for these selected orbits of simultaneous PVO observations from other experiments, including OETP, OIMS, ONMS, ORPA, OEFD, to determine the configuration of the nightside ionosphere for these orbits.
4. Analyses and interpretation of the above results to determine the dynamics of the nightside ionosphere for these orbits. Preliminary estimates will be made of ion escape rates to evaluate the planetary water budget.
5. Preparation of paper(s) and their submission to scientific journals.

d) Relevant recent publications:

Intriligator, D.S., L. Brace, P. Cloutier, W. Kasprzak, W. Knudsen, and R. Strangeway, Analyses of new Pioneer Venus Orbiter (PVO) observations of the Venus ionotail at altitudes < 3000 km, COSPAR talk presented, Washington, DC, August 1992a.

Intriligator, D.S., L. Brace, P. Cloutier, W. Kasprzak, W. Knudsen, and R. Strangeway, Analyses of recent PVO observations in the Venus ionotail at altitudes ~ 1100 km: Evidence for ion acceleration, preprint, 1992b.

(See also Intriligator, Geophys Res. Lett., 16, 167, 1989 and Intriligator et al., Geophys. Res. Lett., 18, 61, 1991).

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Dr. Jon M. Jenkins
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PROPOSAL TITLE: Investigation of the Atmosphere of Venus between 32 and 160 km

ABSTRACT: (a) brief statement of the overall objectives and justification of the work; (b) brief statement of the accomplishments of the prior year, or "new proposal"; (c) brief listing of what will be done this year, as well as how and why; and (d) one or two of your recent publications relevant to the proposed work.

(a) We propose to study properties of the atmosphere and ionosphere of Venus through analysis and interpretation of data from high-quality radio occultation experiments conducted with the Magellan spacecraft. These data will yield valuable information regarding the background structure of the atmosphere and ionosphere, including average electron density profiles, pressure, density and temperature profiles in the neutral atmosphere, and abundance profiles of sulfuric acid vapor (H_2SO_4) below the main cloud layer. Based on our current research regarding optimal methods for processing radio occultation data, and the exceptional capabilities of the Magellan spacecraft, we expect to produce profiles which span an unprecedented range of altitudes, and which have smaller uncertainties than previous radio science investigations of the Venus atmosphere. In addition, the availability of data recorded during consecutive orbits makes it possible to investigate zonal variations in the inferred atmospheric properties.

The profiles derived from Magellan radio occultations will be compared with earlier radio occultation studies conducted with the Pioneer Venus Orbiter to investigate long-term variations in the thermal structure of the atmosphere, and abundance and distribution of $H_2SO_4(g)$.

(b) New proposal.

(c) Efforts in the first year will be directed toward analysis of data from three radio occultation experiments conducted with the Magellan spacecraft in late 1991. We will apply optimal digital filters and Abel inversion theory to retrieve vertical profiles of average electron density in the ionosphere, thermal structure in the neutral atmosphere, and abundance of $H_2SO_4(g)$ below the main cloud layer. We will compare and correlate the results of these three experiments to detect and characterize zonal variations in the atmosphere between 32 and 160 km.

(d) Jenkins, J. M. (1992). Variations in the 13-cm opacity below the main cloud layer in the atmosphere of Venus inferred from Pioneer Venus radio occultation studies, 1978-1987. Ph.D. Thesis. Georgia Institute of Technology, Atlanta, GA.

Jenkins, J. M. and P. G. Steffes (1991). Results for 13 cm absorptivity and H_2SO_4 abundance profiles from the season #10 (1986) Pioneer-Venus Orbiter radio occultation experiment. *Icarus* **90**, 129-138.

Steffes, P. G., Klein, M. J. and Jenkins, J. M. (1990). Observations of the microwave emission of Venus from 1.3 to 3.6 cm. *Icarus* **84**, 83-92.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Donna M. Jurdy
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Co-INVESTIGATORS: Michael Stefanick
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PROPOSAL TITLE: Analysis of Distribtuion and Morphology of Major Features for an Understanding of the Tectonics of Venus

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

(a) We propose an analysis of the distribution and morphology of major features and a curvature analysis of the opographic field. Various sets of features, such as coronae, planitiae, and chasms, appear to have a non-uniform, non-random distribution and to cluster in disjoint fields. We propose an analysis of the distribution of these and other features, using the expanded atlas, to understand their arrangement as an indication of underlying processes. We propose a curvature analysis of the topographic field that accentuates features with similar geometric properties, clarifying the identification of them. We propose a spectral analysis of the morphology of features for a quantitative comparison and categorization of them, for an estimate of their age and strength. We will attempt to take the detailed snapshot of the surface of Venus at present and extract both the overall current tectonic pattern as well as information about the time evolution of activity.

(b) new proposal

(c) analysis of distribution of features, morphology analysis, curvature of topographic field

(d) Jurdy, D.M. and M. Stefanick, Models for the hotspot distribution, Geophys. Res. Lett., vol. 17, pp. 1965-1968, 1990.

Jurdy, D.M. and M. Stefanick, The forces driving the plates: constraints from kinematics and stress observations, Phil. Trans. Roy. Soc. London, A, vol. 337, pp. 127-139, 1991.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Jeffrey S. Kargel
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Co-INVESTIGATORS: Randolph L. Kirk
(Name Only)

PROPOSAL TITLE: Low-Viscosity Volcanism on Venus

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

ABSTRACT: (a) Objectives: We propose to examine physical processes and lava compositions thought to pertain to the origin of volcanic channels and associated volcanic deposits on Venus. Our focus will be on channel-fed deposits such as lava deltas and lava-filled basins. We will consider geologic, morphologic, physico-chemical, and petrogenetic aspects of their origin. This focus complements the VDAP proposal of Baker et al., who plan to engage related problems from the different geologic, morphologic, and physical perspectives of channel erosion. Mapping will help elucidate important geologic relations (including tectonic ones) of volcanic channels and channel-fed deposits. Topographic and morphologic analyses will provide needed dimensional parameters for channels and channel-fed deposits. Rheologic measurements of plausible channel-forming lavas will provide data required to model physical processes involved in the origin of volcanic channels and channel-fed volcanic deposits on Venus.

(b) New proposal: Although this proposal is new, it follows from preliminary work by the PI in collaboration with V. Baker and colleagues. We have explored the petrogenesis of venusian silicate lavas as constrained by Venera/VEGA analyses and Magellan orbital SAR images (Kargel *et al.* 1992, attachment 1), and have examined the morphologies and geologic associations of volcanic channels and fluidized ejecta outflows, and have considered possible genetic aspects (Kargel *et al.* 1991, Baker *et al.* 1992, Komatsu *et al.* 1991, 1992; attachment 1). 'Fluvial-like' morphologic characteristics of many channels favor erosion by a very-low-viscosity lava, while the great lengths and down-stream continuity of the widths and depths of canali also favor a low-temperature lava. To date we have considered basalt, komatiite, sulfur, and carbonatite as candidate lavas.

(c) Work plan (FY 1993): We have devised four tasks to be conducted simultaneously and completed in three years. These tasks entail: (1) mapping a Venus quadrangle at 1:5,000,000 scale, mapping important subareas (mainly channel-fed lava deltas and lava-filled basins) at 1:500,000 scale, and comparing these features with possible analogs on Earth and elsewhere on Venus; (2) morphometric analysis of volcanic features in our map area utilizing radar altimetry and radarclinometry; (3) laboratory measurements of the rheologic properties of multi-component sulfur-rich and carbonate-rich liquids; and, (4) application of knowledge gained through these tasks to produce models of volcanic depositional processes. Preliminary work will be conducted in all four tasks in the first year.

(d) Recent bibliography (reprints and preprints in attachment 1): Baker, V.R., G. Komatsu, T.J. Parker, V.C. Gulick, J.S. Kargel, and J.S. Lewis, 1992, Channels and Valleys on Venus: Preliminary Analysis of Magellan Data. *J. Geophys. Res.*, 97, 13421-13444. Kargel, J.S., G. Komatsu, V.R. Baker, J.S. Lewis, and R.G. Strom, 1991, Compositional Constraints on Outflow Channel-Forming Lavas on Venus (abstract). *Lun. Planet. Sci.* **XXII**, 685-686. Kargel, J.S., G. Komatsu, V.R. Baker, and R.G. Strom, 1992, The Volcanology of Venus Landing Sites and the Geochemistry of Venus, *Icarus* (submitted). Komatsu, G., J.S. Kargel, and V.R. Baker, 1992, Canali-type Channels on Venus: Some Genetic Constraints, *Geophys. Res. Let.*, 19, 1415-1418.

PROPOSAL SUMMARY

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COLLABORATORS: S.W. Bougher, D.M. Hunten
R.E. Hartle, J.M. Grebowsky

PROPOSAL TITLE: PIONEER VENUS ORBITER NEUTRAL MASS SPECTROMETER (ONMS) DATA ANALYSIS

ABSTRACT:

a) Statement of overall objectives and justification of work
An existing semi-empirical model of the Venus thermosphere, based primarily on ONMS data taken during high solar activity, will be updated by: adding ONMS data from the 1992 reentry phase of the mission at lower solar activity, improving the description of minor species below 150 km based on VTGCM model results, incorporating hydrogen and other new and revised density sets from the orbiter and probes, and extending the formulation into the lower atmosphere in order to provide a unified description of the Venus atmosphere. Wave-like variations in the ONMS neutral density data and superthermal ions detected by the ONMS will be compared with models and other data to improve our understanding of atmospheric and ionospheric processes on Venus.

b) Brief statements of accomplishments of the prior year
New proposal

c) Brief listing of what will be done this year
Neutral density data sets will be acquired for the empirical model, and merged with the solar activity data. Model source code will be modified, preliminary fitting of the new ONMS data will be done, and conditions for the incorporation of other data sets will be explored. Data sets for the superthermal ion model comparison and neutral wave analysis will be generated.

d) Relevant publications

Hedin, A.E., H.B. Niemann, W.T. Kasprzak and A. Seiff, Global Empirical Model of the Venus Thermosphere, *J. Geophys. Res.*, **88**, 73-83, 1983.

Kasprzak, W.T., A.E. Hedin, H.G. Mayr and H.B. Niemann, Wavelike Perturbations Observed in the Neutral Thermosphere of Venus, *J.. Geophys. Res.*, **93**, 11237-11245, 1988.

Kasprzak, W.T., H.B. Niemann and P. Mahaffy, Observations of Energetic Ions on the Nightside of Venus, *J. Geophys. Res.*, **92**, 291-298, 1987.

PROPOSAL SUMMARY

Some Studies of the Macro and the Micro Structures of the Venusian Bow Shock and the Ionosphere. In response to NRA-92–OSSA-14

Krishan K. Khurana Principal investigator,
Margaret G. Kivelson Co-Principal investigator,
Institute of Geophysics and Planetary Physics,
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ABSTRACT

MHD parameters like the Alfvenic and sonic Mach numbers and the interplanetary magnetic field profoundly affect the interaction of the solar wind with non-magnetized conducting objects like Venus. The two Mach numbers are known to control the size of the bow shock whereas the direction of the magnetic field introduces asymmetries in the shape of the bow shock. The direction of the magnetic field also controls the nature and strength of the bow shock.

Four broad investigations concerning the interaction of the non-magnetized planet Venus with the solar wind are proposed. The work will use MHD theory, magnetic field data, plasma data and plasma wave data from Pioneer Venus Orbiter and Galileo to address these problems.

The first investigation concerns the development of a new class of bow shock models which adjust their shape and size according to the upstream plasma and field conditions. We will use insights from the MHD theory of shocks at point objects and empirical information from actual bow shock crossings to derive these semi-empirical semi-theoretical models. These models were first developed by us from data obtained from the Venus flyby of Galileo. We propose to use this technique on the much more extensive Pioneer Venus Orbiter data to build extremely precise and versatile models of the Venus bow shock.

The second investigation concerns studying the micro-structure of the Venusian bow shock. The new modeling technique described in this proposal can predict the location of the bow shock as a function of time and therefore the instantaneous velocity of the bow shock with respect to the spacecraft can be obtained. This way the thickness of the structure and its constituents (foot, ramp and overshoot) can be obtained uniquely from the measurements of a single spacecraft.

The third investigation concerns the search for intermediate shocks in Pioneer Venus Orbiter data. It is suggested that the Venus bow shock may have the intermediate shock type characteristics on its flanks. We will obtain the shock normals by using coplanarity analysis. We will then look for the intermediate shock characteristics in the rotated data and also verify that the Rankine-Hugoniot conditions are satisfied.

The fourth investigation concerns deducing the height of the ionopause from the comprehensive bow shock modeling results that will be obtained from this work. We will parametrize the contribution of the magnetic barrier and the ionosphere to the obstacle size. Effects of solar wind parameters and EUV flux on the height of the ionosphere will be studied.

All of the proposed investigations are "New Tasks".

PROPOSAL SUMMARY

Principal Investigator:

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Co-Investigators:

None

Proposal Title:

Mantle Plume Dynamics and the Formation and Evolution of Highland Regions on Venus

Abstract:

a) The proposed research is intended to improve our understanding of the dynamics of mantle convection on Venus and of the relationship between convection and the surface topography, tectonism, and volcanism. I will model the time-dependent dynamics of mantle plumes with temperature-dependent rheology, calculate the magma production associated with such plumes, and model viscous flow in the crust overlying plumes. Based on the results of these studies, I will calculate the geoid and topography associated with plumes and the distribution and orientation of tectonic features produced by plumes. I will compare these results with Magellan observations of the geology, topography, and gravity of the Equatorial Highlands of Venus. This should lead to an improved understanding of the processes which produced these major highland features.

b) New Proposal

c) During 1993, I will focus on modeling time-dependent mantle convection with temperature-dependent viscosity and on calculating the magma production associated with time-dependent plumes. These calculations will be performed in spherical axisymmetric geometry using finite element techniques. I will also begin a preliminary assessment of tectonic and volcanic features in Magellan imagery of the Equatorial Highlands which may be related to the proposed plume model.

d) W.S. Kiefer and B.H. Hager, A Mantle Plume Model for the Equatorial Highlands of Venus, *J. Geophys. Res., 96,* 20,947-20,966, 1991.

W.S. Kiefer and B.H. Hager, Geoid Anomalies and Dynamic Topography from Convection in Cylindrical Geometry: Applications to Mantle Plumes on Earth and Venus, *Geophys. J. Int.,* 108, 198-214, 1992.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Yunjin Kim
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CO-INVESTIGATOR: Sasan Saatchi
Ernesto Rodriguez

PROPOSAL TITLE: Retrieval of Venus Surface Parameters by Using a Combination of Magellan SAR, Radiometer, and Altimeter Data

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of recent publications relevant to the proposed work.)

(a) In order to understand the physical properties and processes occurring on Venus' surface, information on the dielectric constant and roughness of the surface play an important role. We propose to develop an algorithm for accurate estimation of surface parameters by simultaneously using the Magellan SAR(Synthetic Aperture Radar), radiometer, and altimeter data since these instruments are sensitive to complementary physical properties of the surface. This proposal uses the physically based two scale approximation for surface scattering to improve over the previously used Hagfors scattering function and the implementation of a semi-empirical model for surface emissivity.

(b) This is a new proposal.

(c) An inversion algorithm to estimate the dielectric constant and surface roughness will be developed using the two scale approximation and semi-empirical model. Then, the Magellan SAR, radiometer, and altimeter data of several selected areas of Venus will be used as inputs of the algorithm. The areas of interest will be high land, low land and crater regions since they show drastic contrast in dielectric constant and surface roughness. Several maps of these parameters will be generated.

(d) [1] Y. Kim and E. Rodriguez, "Comparison of the Unified Perturbation Method with the Two Scale Expansion," IEEE Geoscience and Remote Sensing, V30, 510-515, 1992. [2] S. Saatchi and U. Wegmüller, "Modeling and Measurement of Microwave Emission from Bare Soil Surfaces", submitted for publication, 1992. (see Appendix A)

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Randolph L. Kirk
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Co-INVESTIGATORS: Lisa R. Gaddis
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PROPOSAL TITLE: Splotches on Venus: Characteristics, Origins, and Implications.

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

(a) Objectives: The goal of this project is to understand the novel surface features known as "splotches" on Venus: (1) their physical characteristics and formation (they are widely assumed to be impact-related, but the size and composition of the bodies that created them are poorly known, and the existence of pyroclastic splotch-like features has not been ruled out), (2) their relation to other features such as craters and crater-related "parabolae" (splotches are probably a limiting case, the simplest and easiest to understand of a large number of phenomena resulting from the interaction of impactors with the dense Venusian atmosphere), and (3) the constraints that they provide on the history of endogenic and exogenic modification of the Venusian surface. To achieve this goal, we will combine the compilation and statistical analysis of a database of splotch characteristics with detailed modeling of both the surface structure of splotches (as revealed by the Magellan radar investigations) and the roles of impact-induced erosion, deposition, and comminution, as well as endogenic processes, in creating the splotches.
(b) Progress: New Proposal.
(c) Work Plan: Four parallel efforts will be carried out over the 3-year proposal period. (1) Compilation of a comprehensive database of splotch characteristics, which will be an important input to our analyses of the processes and properties controlling splotch formation. This database will also be published and serve as a valuable resource for future investigators. We will build this database by augmenting an existing (unpublished) catalog that currently contains the locations, approximate diameters, and a simple, backscatter-based classification of approximately 400 splotches. We will add both new features and new observations to the database (*e.g.*, Magellan measurements of elevation and surface electrical properties; radial profiles of backscatter cross-section; description of splotch structure, if any; diameter and morphology of the associated crater or central impact-disrupted zone, if any; geologic description of the surrounding terrain). (2) Because the splotches have yet to be studied systematically in any detail, we expect that considerable insight can be gained by starting with empirical, statistical studies of the splotch database. For example, how many types of splotches exist? Can splotches resulting from asteroidal impacts be distinguished from those resulting from cometary impact, thereby improving out understanding of the cratering record of the inner Solar System? Are there endogenetic (*e.g.*, pyroclastic) splotches? Can the geologic and environmental conditions conducive to splotch formation be identified in the data, and (by comparison with physical models of splotch formation) be used to map the properties of the Venusian surface? These are only a subset of the questions that may be answered directly by a consideration of the data. (3) In addition, we will attempt to determine the surface texture of the splotches by modeling their backscatter behavior. We will constrain these models by using (a) Magellan SAR backscatter measurements at as many as three different incidence angles for a given splotch, (b) Magellan measurements of reflectivity and RMS slope, and (c) comparison of the backscatter from morphologically similar splotches at a range of incidence angles. In combination, these data should let us estimate both the surface particle size and the depth of deposition or erosion, and thereby constrain models of splotch formation by impact and pyroclastic processes. (4) We will use simple numerical models of the propagation of an atmospheric shock wave generated by a hypervelocity body to evaluate the size of the zones in which the surface is significantly comminuted (or even melted) and eroded. These models will be calibrated against more detailed, published models of impactor distruption and atmospheric shock wave formation, and will be compared with the observations.
(c) Relevant Publications: Roddy, *et al.* (1992), Schaber, *et al.* (1992), Soderblom, *et al.* (1992), Kirk *et al.* (1992), Gaddis (1992)

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VENUS RADIO OCCULTATION DATA ANALYSIS

ABSTRACT

a) The objective of this investigation is to use the Pioneer Venus radio occultation (ORO) data, including those collected during October-December 1992, supplemented by Venera and new Magellan radio science data to: 1. Establish the behavior of the main ionization peak and the ionopause of the dayside ionosphere with solar activity and the solar wind dynamic pressure, 2. Establish the behavior of the nightside main and subsidiary peaks of the ionosphere with solar cycle and investigate dependence on dayside solar wind pressure. The first two objectives are important to the understanding of the solar wind interaction with the Venus upper atmosphere and its dependence on the solar cycle 3. Establish the behavior of the middle atmosphere of Venus with the solar cycle and local time. This is important to study the effects of the solar cycle on the persistent circulation pattern in the middle atmosphere of Venus. 4. Conduct correlative studies with PV OETP and ORPA data from the 1992 entry phase, 5. Conduct the transfer of all data to PDS.

b) New proposal

c) Ionospheric electron density and atmospheric temperature-pressure profiles will be collected into a single data base, which does not currently exist, containing previous PV and Venera data. Magellan and Pioneer Venus FY'93 data will be analyzed and added to the data bases, one for the ionosphere and one for the neutral atmosphere. These data bases will then be used to investigate the dayside ionopause height with EUV flux and s.w. pressure; the main ionospheric peak on the dayside, and the main peak region on the nightside with SZA and s.w. pressure to study the solar wind interaction with the upper atmosphere and to further define the mechanism for maintaining the nightside ionosphere. The lower atmosphere data base will be used to study the variability of middle atmosphere temperatures with the solar cycle and local time, and to construct cyclostrophic zonal wind fields at various times in the solar cycle.

d) Kliore, Arvydas J., Janet G. Luhmann, and Martina H.G. Zhang, The Effect of the Solar Cycle on the Maintenance of the Nightside Ionosphere of Venus, J. Geophys.Res. 96, 11 065-11,071,1991.

Kliore, Arvydas J., Radio Occultation Observations of the Ionospheres of Venus and Mars, in Venus and Mars: Atmospheres, Ionospheres and Solar Wind Interactions AGU Monograph 66, 265-276, 1992.

PROPOSAL SUMMARY

Principal Investigator: William C. Knudsen
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Proposal Title: Improved Ion Temperature and Concentration Analysis for an Improved Calculation of Hydrogen Loss from Venus

ABSTRACT

Understanding the loss rate of atomic hydrogen from Venus is essential for understanding the reason for the extreme lack of water on Venus. The largest source of hydrogen loss is presently believed to be charge exchange between hot hydrogen ions (H+) and neutral hydrogen atoms in the nightside dawn sector of the planet. The latest calculation of this loss is overestimated because it was calculated prior to our present understanding of the factor of ten decrease in density of the nightside Venus topside ionospheric layer during solar cycle minimum. It is also overestimated because the hydrogen ion temperature is significantly colder than the common ion temperature for hydrogen and oxygen ions previously reported. The latest calculation may also be flawed because the ion temperature for Venus has only been reported in coarse solar zenith angle intervals with dawn and dusk sectors of the planet lumped together. It is the purpose of this study to re-analyse Pioneer Venus retarding potential analyzer data to determine the median density and temperature of H+ (as distinct from that of the oxygen ions) as a function of altitude and solar hour angle in increments of one hour over the nightside of Venus both at solar maximum and, to the extent possible from Pioneer Venus re-entry data, at solar minimum. This data will be published for the purpose of permitting a more accurate assessment of the present loss rate of atomic hydrogen from Venus.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Janet G. Luhmann
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PROPOSAL TITLE: Assessment of Ion Scavenging Processes at Venus and Their Evolutionary Significance

ABSTRACT

(a) It is here proposed to carry out joint analyses of Pioneer Venus Orbiter (PVO) magnetometer and plasma data from the Langmuir probe (OETP) and the plasma analyzer (OPA) for the purpose of extending our knowledge of solar wind related atmosphere scavenging processes. The investgation includes the development, assessment, and application of models of constituent losses related to the observed solar wind interaction so that the evolutionary implications for the Venus atmosphere can be considered.

(b) This is a new proposal.

(c) During the first year we will investigate the details of "bulk" ionospheric escape mechanisms by examination of OETP I-V curves for "clouds" and "tail rays" in different magnetic field configurations. We will also examine the global distribution of OPA pickup ion detections, organized by a coordinate system determined by the interplanetary field orientation. In parallel, we will develop and test appropriate models for the observed scavenging processes for comparison with the data and later application to the evolutionary problem.

(e) Luhmann, J. G. and S. J. Bauer, Solar Wind effects on atmosphere evolution at Venus and Mars, in Venus and Mars: Atmospheres, Ionospheres and Solar Wind Interactions, p.417 in Geophysical Monograph 66, American Geophysical Union, 1992.

Luhmann, J. G. and J. U. Kozyra, Dayside pickup oxygen ion precipitation at Venus and Mars: Spatial distributions, energy deposition, and consequences, J. Geophys. Res., 96, 5457, 1991.

PROPOSAL SUMMARY

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CO-INVESTIGATORS:

PROPOSAL TITLE: Rates of Geologic Processes on Venus

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objective and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.

a) The general objectives of this investigation are to 1) evaluate the several time-dependent processes discovered in Magellan data, and amplified by model calculations, to determine how well they can be synthesized into a set of tools for determining age and rate information about specific surfaces on Venus; 2) use these tools, along with more traditional techniques such as cross-cutting relationships, to determine the local and regional tectonic and resurfacing history in several key locations in order to determine whether an integrated, global history can be developed; 3) and to synthesize, if possible, these results into this integrated, global history, and then to use this history, in collaboration with other investigators, in evaluating geophysical models of venusian tectonics. The justification for the proposed work is that a temporal framework is needed in order to help discriminate between disparate concepts of venusian planetary evolution. Many of the models have inherent timescales over which they operate; judging their consistency with other rates of change on the planet offers one form of corroboration.

b) new proposal

c) During the first year, a small map-scale (~1:25M) global terrain map will be prepared digitally, using C-MIDRs as a base. The areas of each terrain type will be determined. Also during the first year, about one-half of the ~850 craters ≥5 km diameter will be inspected for the number and type of cross-cutting structures, attributes not included in the existing catalog. Their relationship to terrain-type will be confirmed or modified as needed. The relationship of each structure superimposed by a crater or cross-cutting a crater will be extended to the surrounding terrain(s). Cross-cutting between structures will be used to extend the relative chronology to the margin of each terrain type. These tasks will continue during the second and third year of the investigation.

d) Phillips, R. J., Grimm, R. E., and Malin, M. C. (1991) Hot-spot evolution and the global tectonics of Venus, Science 252, 651-658.

Malin, M. C. (1992) Mass movements on Venus: Preliminary results from Magellan cycle 1 observations, J. Geophys. Res. (in press).

Arvidson, R. E., Greeley, R., Malin, M. C., Saunders, R. S., Izenberg, N., Plaut, J. J., Stofan, E.R., and Shepard, M. K. (1992), Surface modification of Venus as inferred from Magellan observations of plains, J. Geophys. Res. 97 (E8), 13303-13317.

PROPOSAL SUMMARY

PROPOSAL TITLE: MHD Simulations of Mass Loaded Boundary Layers Along theVenus Ionopause

PRINCIPLE INVESTIGATOR/INSTITUTION: John E. McGary / Clarkson Eng.

ABSTRACT

To better understand the ionopause - magnetosheath region, I developed a numerical MHD code to simulate the mass loading phenomena in the solar wind flow around the dayside of Venus. The MHD model extends the gasdynamic formalism to include magnetic forces on the flow in a self consistent method that reasonably describes the magnetosheath region. My MHD simulations showed that boundary layers formed along the ionopause for mass loading rates and solar wind conditions consistent with low ionopause altitudes. The boundary layer flow properties are in agreement with the overall flow behavior observed from Pioneer Venus that measured decreasing solar wind speeds toward the ionopause and detected a few percent of flowing O^+. Furthermore, the MHD results agree with the measured flow speeds in this region which are less than other numerical model predictions. These MHD model results are the first to show that boundary layers form along the ionopause due to mass loading which supports Pioneer Venus data. To date, only low altitude simulations have been performed and knowledge of their formation is not clearly understood. It is not known at this time if boundary layer formation is possible at higher altitudes using reasonable mass loading rates. Therefore, I propose to carry out MHD boundary layer simulations at higher ionopause altitudes for specific orbits using the corresponding OIMS data and the upstream solar wind parameters. This will also provide information about the required mass loading rate as a function of altitude. To understand what upstream solar wind conditions are required to produce these boundary layers, parametric studies involving the mass flux, ram pressure, Mach number, and thermal pressure will be performed for specific altitudes. These simulations will produce correlations with the ionopause altitude, since the boundary layer is connected with it, and help resolve some of the physical processes responsible for establishing the ionopause shape and location. As a future extension to the model, I will begin implementing a simple turbulent viscosity model to investigate dissipation effects on the flow. These model simulations also help establish validation between other numerical codes. I am requesting support for 4 man months of labor, publication cost, and travel. Dr. Paul A. Cloutier will provide data and help with the analysis at no cost to the project.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: George E. McGill
(Name, Address, Telephone Number) Department of Geology and Geography
University of Massachusetts
Amherst, MA 01003
(413) 545-0140

Co-INVESTIGATORS: None
(Name Only)

PROPOSAL TITLE: Structural Evolution of Venusian Plains

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

a. Objectives: To determine the tectonic evolution of the venusian plains by combining geological mapping with global and local mapping and analysis of structural features such as wrinkle ridges and grabens. Knowledge of crustal stress orientations as functions of time and place will be an important constraint on global tectonic models.

b. Accomplishments: New proposal.

c. Proposed effort: Global mapping of wrinkle ridge and deformation belt trends using Magellan SAR images in both digital and hard-copy formats to determine global domains of these structures. Local mapping and analysis of structures in key areas, with associated geological mapping, to characterize kinematic and mechanical relationships in detail.

d. Sample Publications: Solomon, S.C. and 10 co-authors, including G.E. McGill, Venus tectonics: an overview of Magellan observations, J. Geophys. Res., 97, 13,199-13,255, 1992.

McGill, G.E., Wrinkle ridges on venusian plains: indicators of shallow crustal stress orientations at local and regional scales, Abs., International Collog. on Venus, Lunar Planet. Inst. Contr. No. 789, 67-68, 1992.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: William B. McKinnon
Dept. Earth and Planetary Sci.
Washington University
Saint Louis, MO 63130
314-889-5604

CO-INVESTIGATOR: None

TITLE: **Formation and Evolution of Impact Craters on Venus**

ABSTRACT: (Type single-spaced within box below. Paragraphs numbered (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

a) Objectives and Justification: The main purpose of this work is to better understand how large ringed craters on Venus form, based on analyses of Magellan radar images, altimetry and gravity, and theoretical calculations. Constraints can then be placed on Venusian subsurface rheologic structure and thermal evolution, as well as important conclusions drawn for terrestrial craters of the same scale (e.g., Chicxulub). Arecibo, Venera, and Magellan images and altimetry imply that multiringed basins of the Cordilleran/megaterrace type can form on Venus at (final) diameters as small as ~150 km across, and that peak ring craters can form at diameters as small as ~40 km. These transitions are at much smaller sizes than documented for the other terrestrial planets except the Earth, and even for the Earth multiringed basins are only suspected (e.g., Sudbury, Vredefort). The ringed crater data set for Venus, ~75 relatively undegraded structures, offers an unparalleled opportunity to advance the understanding of impact mechanics at large scales and attendant effects on planetary evolution.

b) New proposal

c) To be done this year: (1) analyses of ringed craters using Magellan images and available stereo, altimetry, and gravity will continue, providing the fundamental data to model and interpret; (2) A finite element study of viscoelastic crater relaxation on Venus will check and synthesize previous analytical and numerical work; (3) the same code will be used to study prompt impact basin collapse and megaterrace formation on Venus, subject to the limitation that inertial forces will not be modeled. A range of simple rheological structures with depth will be studied, as well as more detailed structures based on temperature-dependent and temperature- and stress-dependent rheologies; (4) analytical and numerical models for impact melting will be further developed and then applied as a possible explanation for peak ring formation; (5) from all the above, constraints will be developed on the Venusian heat flow at specific locales during the last ~500 m.y., and possibly on impactor type and velocity.

d) Relevant Publications: Alexopoulos, J.S., and W.B. McKinnon (1992). Multiringed impact craters on Venus: An overview from Arecibo and Venera images and initial Magellan data. *Icarus* **100**, in press; Brackett, R.A,. and W.B. McKinnon (1992). Cratering mechanics on Venus: Pressure enhancement by the atmospheric "ocean." *Geophys. Res. Lett.* **19**, in press; Alexopoulos, J.S., and W.B. McKinnon (1992). Ringed impact craters on Venus: An analysis from Magellan images. In *Papers Presented to the International Colloquium on Venus*, 2–4.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: H. Jay Melosh
(Name, Address, Telephone Number) Lunar and Planetary Laboratory
The University of Arizona, Tucson AZ 85721
(602) 621-2806

Co-INVESTIGATORS:
(Name Only)

PROPOSAL TITLE: Aspects of Impact Cratering on Venus

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

(a) This proposal involves three loosely related tasks intended to elucidate the nature of impact craters on Venus. These tasks complement ongoing research by the PI, but extend present projects to the peculiar conditions of Venus. These tasks are (1) a more detailed study of meteorite entry into the Venusian atmosphere, including fragmentation processes in the face of significant compression of the projectile (when the entry time and time for a sound wave to traverse the projectile are comparable). (2) further study of the radar-dark parabolas surrounding the youngest impact craters, using a previously-developed theory of parabola formation to fit all of the known parabolas. (3) evaluation of the extent to which viscous flow can modify large impact craters under plausible Venusian crustal conditions, and prediction of tectonic patterns and interactions expected to result from relaxed craters. This last work will use a fully viscoelastic finite element code capable of treating plasticity, faulting, and non-newtonian flow in both 2 and 3 dimensions. The results of this work will improve our understanding of impact craters on Venus, and aid in the interpretation of the geologic history and rheologic structure of the planet.

(b) New Proposal

(c) In this year we expect to complete a comprehensive study of projectile fragmentation upon entry into Venus' atmosphere by coupling our previously developed continuum fragmentation model to an atmospheric flow model using the unique eulerian/lagrangian capabilities of the hydrocode SALE. Chris Shaller and I will compete fits to the dark parabolas surrounding all of the 29 well-imaged young impact craters with parabolas and determine how ejected particle size and size-velocity relation depends upon crater size, obliquity, etc. Valerie Hillgren and I will complete a study of viscoelastic crater relaxation using my recently upgraded finite element code TEKTON. We will employ a variety of plausible crustal rheologies, and hope by this means to use the apparent lack of relaxation of large impact craters to put lower limits on the viscosity of the Venusian crust and upper mantle.

(d) H. J. Melosh, Atmospheric breakup of terrestrial impactors, in *Multiring Basins*, Proc. Lunar Planet. Sci 12 A, pp. 29-35 (1981); R. J. Vervack and H. J. Melosh, Wind interaction with falling ejecta: Origin of the parabolic features on Venus, GRL 19, pp. 525-528 (1992); V. J. Hillgren and H. J. Melosh, Crater relaxation on Ganymede: Implications for ice rheology, GRL 16, pp. 1339-1342 (1989), K. E. Cyr and H. J. Melosh, Tectonic patterns and regional stresses near Venusian coronae, Submitted to Icarus, 1992.

PROPOSAL SUMMARY

Principal Investigator: Kent L. Miller
Center for Atmospheric and Space Sciences
Utah State University
Logan UT 84322-4405
(801) 750-3592

Co-Investigator: William C. Knudsen

Proposal Title: Analysis of Ion-Mode Measurements by the Pioneer Venus Retarding Potential Analyzer

Abstract

Analysis of the data from the retarding potential analyzer on the Pioneer Venus Orbiter (ORPA) has made many important contributions to the understanding of the plasma environment in and above the Venus ionosphere. We propose to continue the analysis of these valuable data, with emphasis on two aspects of ion data.

First, we request support for a study of small scale variability using data from a high-time-resolution mode that was designed to measure small scale variations in ion density. This mode was used on about one orbit in ten, and represents a significant fraction of the ORPA data set. However, data from this mode have not been analyzed. This study will consider three specific topics for which this measurement mode is ideally suited: plasma waves in the vicinity of the ionopause; ion flow in plasma clouds and streamers; and waves and counter-streaming ions within the ionosphere. This study will increase our understanding of small scale plasma dynamics in the regions near the ionopause.

Second, we propose a study of ion velocities, densities, and temperatures using a recently improved and highly accurate reduction algorithm. Characteristics of ionospheric ions in the Venus ionosphere have been studied in detail since the beginning of the Pioneer Venus mission. These studies have added greatly to our knowledge of this unmagnetized ionosphere, but they have also raised several questions when results were unexpected and where instrumental effects could not be ruled out. In order to reduce uncertainties in the quantities measured by the ORPA, Dr. W. C. Knudsen has recently completed an exhaustive study of the analysis software and its description of the details of the interaction between the ORPA and the plasma environment.

The portion of this proposal involving the first objective, the study of small-scale ion variability, was submitted earlier this year to the NASA Planetary Atmospheres Programs. Results of this proposal are not yet available. In the event that both proposals are successful, it is anticipated that the budgets of the two projects would be merged to reflect the amounts requested in this proposal.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Henry J. Moore MS-975, U.S. Geological Survey
(Name, Address, 345 Middlefield Road, Menlo Park, CA 94025
Telephone Number)
(415) 329-5175

CO-INVESTIGATORS: None
(Name Only)

PROPOSAL TITLE: GEOLOGY OF VENUS

ABSTRACT: Type single-spaced below line. Lettered paragraphs (a) through (d) should included: a. brief statement of the overall objectives and justification for the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

A. OBJECTIVES AND JUSTIFICATION.

(1) Contribute to the understanding of the geology of Venus by mapping quadrangles V49 and V50.
(2) Develop criteria for the definition and interpretation of rock-stratigraphic units, their planet-wide correlation, and their physical characteristics.
(3) Establish relations between tectonic events and rock-stratigraphic units.
(4) Examine the physical-chemical processes involved in producing lava flows, volcanic edifices, impact craters, and bright outflows of impact craters.
(5) Estimate the relief and shapes of small volcanic landforms, impact craters, and other small landforms.

The Magellan images and other data contain a wealth of information on an exciting planet which is not fully understood at this time. Systematic analyses and mapping are a way to begin to understand the geology of Venus.

B. ACCOMPLISHMENTS. New proposal.

The proposer is a Magellan Mission Guest Investigator and a member of the Magellan Orbiter Sequence and Stereo Analysis Working Groups. He submitted geologic maps of the Alpha Regio region for inclusion in the Magellan Global Geologic Map (area in 4 C1-MIDRPs).

C. WORK PLAN.

Analyze landforms in and prepare a geologic map of two VGM quadrangles (V49 and V50).

D. PUBLICATIONS.

Moore, H. J. et al., 1992, JGR, v. 97, E8, p. 13,479; Schaber, G.G., R.G. Strom, H.J. Moore, et al., 1992, JGR, v. 97, E8, p. 13,257.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Kurt R. Moore
Los Alamos National Laboratory
SST-8/D438
Los Alamos, NM 87545
505-665-1462

Co-INVESTIGATORS: NONE

PROPOSAL TITLE: Plasma and Magnetic Field Variations in the Venus Magnetotail Over Solar Cycle 21

ABSTRACT:
(a.) Galaxies, planets, moons, comets, and even spacecraft form wakes or magnetotails in flowing plasmas. There are large gaps in our understanding of these tail structures despite the ubiquity of magnetotails and wakes in space plasmas. The long running Pioneer Venus mission has made the draped Venus magnetotail the best sampled magnetotail besides the Earth's. This is a proposal to determine the plasma and magnetic field variations in the Venus magnetotail over solar cycle 21. The statistically averaged plasma and magnetic field properties in the distant magnetotail during sunspot maximum of solar cycle 21 have already been investigated [*Moore et al.*, 1990]. The proposed study will extend this earlier work by (1) examining the distant tail properties during solar cycle 21 sunspot minimum and determining the physical interactions that differ as a function of solar cycle and (2) examining the near-planet magnetotail during the full solar cycle 21.

(b.) new proposal

(c.) During the first year, the required Pioneer Venus plasma, magnetic field, and ephemeris data will be obtained from NSSDC and preliminary data analysis will be performed using existing software and hardware. Acquisition and analysis of the data are the major preliminary steps in the proposed study.

(d.) Moore, K.R., D.J. McComas, C.T. Russell, and J.D. Mihalov, A statistical study of ions and magnetic fields in the Venus magnetotail, *J. Geophys. Res.*, **95**, 12,005, 1990

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Dr. Peter J. Mouginis-Mark
Planetary Geosciences
University of Hawaii
Honolulu, Hawaii 96822
(808) 956-3147
(808) 956-6322 (FAX)

PROPOSAL TITLE: EVOLUTION OF VOLCANOES AND THEIR SUMMIT CALDERAS ON VENUS

ABSTRACT:

A) Objectives: We propose three related studies to investigate constructional volcanism in the high pressure/high temperature surface environment of Venus: 1) The majority of this investigation will be devoted to the study of the geologic evolution of calderas and volcanoes on Venus using the Magellan radar images and altimetry. 2) By a comparison between the Magellan data for Venus volcanoes, and aircraft radar data for Hawaiian volcanoes, we hope to be able to quantitatively interpret the Magellan SAR data in a manner that lets us constrain the eruption rate and style of emplacement of lava flow fields on Venus. 3) Through comparisons with terrestrial examples in Hawaii, Galapagos, the Aleutians, and the Indian Ocean, we hope to develop an understanding of how the distribution of lava flows and fissures on the flanks of volcanoes on Venus can be used to infer the internal structure of these volcanoes.
B) Work Plan: We intend to work on the following projects over the three years of this proposal: *1) Caldera Structure and Volcano Evolution on Venus.* There are a number of topics we will address through geologic mapping of the Venus calderas: Is there a trend in the size progression of caldera collapse events on Venus? Was the collapse rapid or protracted? Where are the youngest vents located? What is the distribution of radar-dark flows on each volcano? Do we see any unusual volcanic landforms? Is there a consistent morphology to Venus volcanoes that have summits with low radar emissivity? *2) Magellan Radar Studies and Terrestrial Radar Analogs.* This work will focus on the quantitative analysis of the Magellan radar backscatter and altimetry, and a comparison between aircraft radar data for Hawaii and comparable features on Venus. *3) Comparisons with Terrestrial Volcanoes*: We will address the structure of Venus calderas through the study of calderas found in Hawaii, the Galapagos, the Aleutian Islands and the Indian Ocean. Field work will be done on Mauna Loa volcano, Hawaii, while other terrestrial volcanoes will be studied using already obtained satellite images of these other volcanic centers.
C) Progress: This is a new proposal.
D) References: 1) Mouginis-Mark, P.J. & Robinson, M.J. (1992). Evolution of the Olympus Mons caldera, Mars. *Bull.Volcanol.* 54, 347 - 360. 2) Mouginis-Mark, P.J. (1981). Late-stage summit activity of Martian shield volcanoes. *Proc. Lunar Planet. Sci. Conf.*, 12B, 1431 - 1447. 3) Gaddis, L.R., Mouginis-Mark, P.J., and Hayashi, J.N. (1990). Lava flow surface textures: SIR-B radar image texture, field observations, and terrain measurements. *Photogram. Eng. Rem. Sen.* 56, 211 - 224. 4) Rowland, S.K. and Walker G.P.L. (1990). Pahoehoe and a'a in Hawaii: Volumetric flow rate controls the lava structure. *Bull. Volcanol.* 52, 615 - 628.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: (Name, Address, Telephone Number)
Duane O. Muhleman
California Institute of Technology, 170-25
Pasadena, California 91125

Co-INVESTIGATORS: (Name Only)

PROPOSAL TITLE:
The Physical State of the Venus Surface as Revealed from Magellan Radio Emissivity and Reflectivity Data

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

ABSTRACT: (a) Many regions exist on the surface of Venus which exhibit anomalous radar and radiothermal emission properties which apparently are structures altered by the geochemical effects and/or unique erosion associated with the atmospheric vertical profile. We will analyze the Magellan data in an effort to determine the chemical and physical state of the materials in these (usually) high altitude features.

(b) This is a new proposal but the PI has worked on these problems as a member of the Magellan investigation team, primarily developing scattering theories to explain the anomalously high reflectivities coupled with anomalously low emissivities.

(c) Work will continue on the radiative transfer models used to explain the radio data in terms of the geophysical properties of the Venus surface, particularly for the high altitude anomalies. Magellan images will be searched for other regions of unusual emission such as "stealth-like" structures which would be evidence of relatively deep, rock free deposits, either wind blown of volcanic origin.

(d) Muhleman, D.O., B.J.Butler, A.W. Grossman and M.A. Slade, Radar images of Mars, Science, 253, 1351-1367, 1991

Tryka, K.A. and D.O. Muhleman, Reflection and emission properties on Venus: Alpha Regio, Jour. Geophys. Res. , 97, 13,379-13,394 , 1992

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Michael J. Mumma
(Name, Address, Telephone Number) Code 690 NASA/GSFC / Greenbelt, MD 20771
(301) 286-6994

Co-INVESTIGATORS: Vladimir A. Krasnopolsky
(Name Only) Space Sciences Laboratory/Berkeley, CA 94720

PROPOSAL TITLE: Chemical Kinetic Modelling of the Lower Atmosphere of Venus

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

a) Measurements of the chemical composition of Venus' troposphere by the Galileo, Pioneer Venus, Vega and Venera missions and by ground-based spectroscopy should be analyzed in terms of chemical kinetics. (By chemical kinetics modeling we mean photochemical modeling in atmospheric regions where photolysis is relatively unimportant). All previous models of the troposphere assumed thermochemical equilibrium and were unable to reproduce some of the measured data or to predict densities of some unmeasured species. We propose to develop the first chemical kinetics model of the massive, hot and dense lower atmosphere of Venus. The chemistry should be driven by 1) photolysis of S_3 at 400-463 nm (so-called blue absorption), 2) downward transport of nonequilibrium species (H_2SO_4, CO, S_x, Cl_2) from the middle atmosphere, and 3) high temperature and pressure which make many endothermic reactions possible and important. The situation with reaction rate coefficients is discussed, and the conclusion is drawn that the current knowledge of these coefficients allows this modeling, perhaps using a few rate coefficients as parameters. Preliminary photochemical estimates show validity of this approach.

b) This is a new proposal for a period of less than 2 years.

c) The work includes an analysis and choice of chemical reactions and their rate coefficients, a modeling of radiative transfer in the 400-500 nm range to derive photolysis rates of S_3, the determination of boundary conditions, the development of a computer code, computer runs for few dozen models with variable parameters, an analysis of the computed versions, and writing the paper.

d) This proposal is a further development of the photochemical modeling of Venus' atmosphere made previously above and now below 50 km (see V. A. Krasnopolsky and V. A. Parshev: Photochemistry of the Venus Atmosphere, chapter in *Venus* (editors: D. M. Hunten, L. Colin, T. M. Donahue, and V. I. Moroz), U. of Arizona Press, Tucson, p. 431, 1983, and V. A. Krasnopolsky: *Photochemistry of the Atmospheres of Mars and Venus*, Springer, NY, 1986).

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Chan Y. Na
(Name, Address, Telephone Number) SwRI, Div. 15, 6220 Culebra, San Antonio, TX 78238
(512) 522-2848

Co-INVESTIGATORS: Larry Esposito
(Name Only) Ed Barker

PROPOSAL TITLE: Venus Data Analysis: Time Variability of Horizontal Variation of Venus SO_2

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

a). The scientific objectives for the work proposed here are 1) to examine the time variability of the horizontal distribution of SO_2 in the middle atmosphere of Venus and 2) to provide observational constraints for photochemical models and atmospheric dynamical models of the Venus middle atmosphere. The results of the proposed research would help in distinguishing between the two different theories explaining the decadal decline of SO_2 above the clouds of Venus.

b). New Proposal

c). 1) Drs. Na and Esposito will reduce and model the full set of PV multicolor images from 1978 to 1992 to produce a database which includes the latitudinal and longitudinal distribution of SO_2 and its temporal variation.
2) Drs. McClintock and Na will reduce and model the Galileo data to produce the map of SO_2 distribution at the time of Galileo flyby.
3) Drs. Barker and Na will reduce and model the ground-based observations of Venus.

d). Na, C. Y., L. W. Esposito and T. E. Skinner (1990), *JGR*, 95,7485

PROPOSAL SUMMARY

Principal Investigator: Dr. R. Steven Nerem
NASA/Goddard Space Flight Center
Space Geodesy Branch, Code 926
Greenbelt MD 20771
(301) 286-3220

Co-Investigator: Dr. Bruce G. Bills

Proposal Title: An Improved High Resolution Gravity Model for Venus Using Magellan and Pioneer Venus Orbiter Tracking Data

ABSTRACT

The objective of this investigation is to determine a high resolution model of the Venusian gravitational field using Doppler tracking data from the Magellan and Pioneer Venus Orbiter (PVO) missions. Previous models of the Venusian gravity field have been either low degree spherical harmonic expansions (with a resolution of approximately 1000 km) or maps of gravity anomalies (with a resolution of approximately 300 km) computed from the line-of-sight (LOS) accelerations. Recently, a gravity model was developed from only PVO tracking data which is complete to degree 50 in spherical harmonics [*Nerem et al.*, 1992b]. The initial gravity field model resulting from this investigation will be complete in spherical harmonics to degree 70, corresponding to a shortest half-wavelength resolution of 270 km. While the Magellan and PVO data sets will not support such a high resolution model over the entire planet, the resolution available at each location can be obtained by careful application of a priori constraints for each coefficient. The high degree gravity model will allow an improved interpretation of the geophysics of Venus as well as improved orbit determination accuracies for computing the topography from the Magellan radar altimeter data. As part of a PVO Guest Investigation, we have developed an initial Venus gravity model complete to degree 50 (Goddard Venus Model - 1, GVM-1) using tracking collected early in the PVO mission (1979-1982) and the results show a remarkable improvement over previously published models [*Nerem et al.*, 1992b]. If this investigation is funded, the inclusion of Magellan X-band tracking data from Cycle 4 should result in a high resolution model of the Venusian gravity with unprecedented resolution and accuracy. The Magellan data should particularly improve the gravity field in the polar regions since its orbit has a much lower eccentricity than PVO, thus it will be closer to the planet in the polar regions even though the periapse altitude of both orbits is about the same. In addition, the Magellan X-band tracking data has much less noise than the PVO S-band data, yielding further improvement over PVO-only gravity models. With the end of the PVO mission in late 1992 and the Magellan mission in 1993, a final simultaneous analysis of the Magellan and PVO Doppler tracking data for determining the gravity field of Venus is warranted and timely.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Richard J. O'Connell
(Name, Address, Telephone Number) Harvard University / Dept. of Earth & Planetary Sciences
(617) 495-2532

Co-INVESTIGATORS: Cheryl A. Stewart
(Name Only)

PROPOSAL TITLE: Symmetry Analysis of Magellan SAR, Altimetry and Gravity Data

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

ABSTRACT

Proposed here is an investigation of the symmetries inherent in the global pattern of convection in the mantle of Venus. The admittance of Venus has been studied with the purpose of inverting for the radial viscosity and density structure of these planets Both Earth and Venus exhibit evidence that the pattern of convection in their respective mantles are dominated by low-degree spherical harmonic modes; however, Earth's convective pattern is dominated by a degree-two pattern, whereas Venus' is dominated by degree three. Because these convective patterns impose a high degree of symmetry on the convective flow, we propose to analyze the flow field for the symmetries inherent in the data, and the degree of departure from those symmetries. Thermal convection in spherical shells characterized by different symmetry groups have significantly different time-evolution and routes to chaos [Friedrich and Haken, 1986; Armbruster and Chossat, 1991]. It is significant, therefore, that the time evolution of thermal convection in the Earth is very different from that in Venus: evidence from the cratering record indicates that the time-evolution of thermal convection in Venus—whether it is expressed either volcanically or tectonically— was far more active 500 MYA, resulting in a resurfacing of the planet. The purpose of this study is to find the connection between the time-evolution and the pattern of convection in the mantle of Venus; however, the global pattern of accumulated convergence and divergence on the surface of Venus as compared with the pattern of upwelling and downwelling necessary to make this connection needs to be reconstructed, and the symmetries inherent in these data need to be quantified in order to do this.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Timothy J. Parker
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Co-INVESTIGATORS: none
(Name Only)

PROPOSAL TITLE: Origin of Venusian Channels

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

a.) Objectives: Investigate the origin of Venusian channels with the following three major objectives: (1) characterize the geologic associations, timing, and development of a set of representative channels through detailed full-resolution mapping using Cycle 1/Cycle 2 and Cycle 1/Cycle 3 SAR stereo pairs; (2) Reconstruct the longitudinal gradients of the channels using the altimetry data in conjunction with stereo parallax measurements to be used for objective (3) and for measuring post-channel regional tectonic deformation; and (3) estimate the discharge volumes and rates through lava flood channels that exhibit well-defined source-conduit-sink relationships through application of longitudinal slopes and cross-sectional areas to simple models of channel discharge.

b.) New Proposal.

c.) Proposed work: Task 1: Map the geology of six representative Venusian channels on full-resolution Magellan SAR images. Measure the longitudinal gradients and local geometry using stereo parallax measurements, altimeter-derived topography and individual altimeter echo profiles. Apply these dimensions to model fluid discharge and duration of lava flood channels and measure post-channel regional tectonism. Task 2: Compile geologic maps of Venus 1:5,000,000 quadrangles V58, V59, V49, and V50 (in order of priority), which cover a vast, channel-bearing plains region in eastern Aino Planitia. This task enables characterization of sinuous plains channel relationships to geologic structures and regional tectonism. The high density and great extent of channels in this region provides a clear connection between plains surfaces separated by structures that might otherwise appear to be separate units.

d.) Summary Bibliography:

Application of Left and Right Looking SAR Stereo to Depth Measurements of the Ammavaru Outflow Channel, Lada Terra, Venus. Parker, T. J., *International Colloquium on Venus*, Lunar and Planet. Inst., 3p., 1992.

Channels and Valleys on Venus: Preliminary Analysis of Magellan Data. Baker, V. R., Komatsu, G., Parker, T. J., Gulick, V. C., Kargel, J. S., and Lewis, J. S., *Journ. Geophys. Res.* 97, p. 13421-13444, 1992.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR:
Roger J. Phillips
Washington University
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314/935-5609

CO-INVESTIGATORS: None

PROPOSAL TITLE: Magmatic and Tectonic Evolution of Venus

ABSTRACT:

a. *Objectives*: To gain an improved understanding of the evolution and present thermal and mechanical state of Venus by (i) estimating the present relative age distribution of surface units on the planet, (ii) determining the roll of exogenic forces in the evolution of tesserae, and (iii) formulating and testing a model for passive magmatism on Venus.

b. *New Proposal*

c. *Proposed Work*: (i) Study areas of anomalous crater density for embayment and tectonization of craters, extended ejecta deposits, and relationships of volcanism to cratering. Use observational results to establish relative age and test resurfacing models. (ii) Study boundaries of tessera regions with full resolution SAR images and high resolution, stereo-derived topography to determine endogenic or exogenic origin of tessera deformation; use results to constrain models of tessera evolution. Use finite element modeling to study deformation of tesserae from exogenic forces. (iii) Study selected volcanotectonic regions (and relate to crater density) in an attempt to establish active or passive relationships between volcanism and tectonism. Model passive magmatism conditions; model thermal and mechanical evolution of a compositional diaper. Relate results to mode and origin of lithospheric stress.

d. *Summary Bibliography*:

Phillips, R. J. *et al.*, Impact craters on Venus: Initial analysis from Magellan, *Science, 252*, 288–297, 1991.

Phillips, R. J., R. E. Grimm, and M. C. Malin, Hot-spot evolution and the global tectonics of Venus, *Science, 252*, 651-658, 1991.

Smrekar, S. E., and R. J. Phillips, Venusian highlands: Geoid to topography ratios and their implications, *Earth Planet. Sci. Lett., 107*, 582–597, 1991.

Solomon, S. C., with R. J. Phillips *et al.*, Venus tectonics: An overview of Magellan Observations, *J. Geophys. Res., 97*, 13,199-13,255, 1992.

Phillips, R. J., *et al.*, Impact craters and Venus resurfacing history, in press, *J. Geophys. Res.*, 1992.

Grimm, R. E., and R. J. Phillips, Anatomy of a venusian hot spot: Geology, gravity, and mantle dynamics of Eistla Regio, in press, *J. Geophys. Res.*, 1992.

Herrick, R. R., and R. J. Phillips, Geological correlations with the interior density structure of Venus, in press, *J. Geophys. Res.*, 1992.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Jeffrey J. Plaut
(Name, Address, Telephone Number) M/S 230-225 4800 Oak Grove, Pasadena, CA 91109
(818) 393-0875

Co-INVESTIGATORS: None
(Name Only) None

PROPOSAL TITLE: Properties of Volcanic and Impact - Related Surfaces from Radar Observation of Venus.

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

a. Magellan observations of Venus have revealed a broad spectrum of landforms, including complex volcanic terrains and enigmatic impact crater deposits. Assessment of the origin and geological significance of these features requires analysis of the properties of the surface from the standpoint of radar remote sensing. Among the issues to be addressed are: the texture, density and composition of the full range of lava flow types observed, the relationship of these parameters to mechanisms of emplacement and post-emplacement modification, the nature of impact-related "halo" and "parabola" surface materials, and the mechanisms of impactor-atmosphere-surface interactions that lead to the emplacement of the extended impact-related surfaces.

b. New proposal.

c. Magellan SAR, altimetry and radiometry data will be used to constrain the geometric and constituitive properties of volcanic and impact-related surfaces of Venus. A catalogue of lava flow types will be developed, based on both morphological and radar scattering criteria. Models of radar scattering and emission will be applied to the observations to extract surface parameters relevant to the emplacement and modification of surface materials. Radar and field observations of terrestrial surfaces analogous to the Venus surfaces will be used to identify relationships among primary textures, composition, surface modification, and radar signatures. Where available, Earth-based radar observations of Venus will be used to supplement the observations of radar scattering behavior from Magellan. For the tasks related to impact-related features, the focus of first-year efforts will be on the origin of parabolic features that display a strong azimuthal asymmetry in scattering behavior. Constraints on surface geometries will be obtained from detailed modelling of the observed scattering anomalies.

d. Plaut, J.J. and R.E. Arvidson, 1992, Comparison of Goldstone and Magellan radar data in the equatorial plains of Venus, J. Geophys. Res. 97, in press.

Plaut, J.J., R.S. Saunders, E.R. Stofan, R.L. Kirk, G.G. Schaber, L.A. Soderblom, P.G. Ford, G.H. Pettengill, D.B. Campbell, N.J.S. Stacy, R.E. Arvidson, and R. Greeley, 1992, Anomalous scattering behavior of selected impact "parabola" features: Magellan cycle-to-cycle comparisons (abstract), Papers presented to the Intl. Colloq. on Venus, LPI Contr. No. 789, 92-93.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: James B. Pollack
(Name, Address, Telephone Number) NASA/Ames Research Center
415/604-5530

Co-INVESTIGATORS: David H. Grinspoon
(Name Only)

PROPOSAL TITLE: Properties of the Clouds and Gases in Venus' Atmosphere

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

a. Determine key properties of the Venus clouds and their spatial variability to better understand their radiative and dynamical impact. Derive an accurate vertical profile of the water vapor mixing ratio from the cloud base to the surface to constrain chemical processes in its present atmosphere and the history of water.

b. New Proposal

c. 1) Construct a baseline model of the clouds by synthesizing relevant data from the Pioneer Venus probes and orbiters and other data sets. 2) Analyze the image cubes obtained by the NIMS experiment on the Galileo spacecraft to derive limb darkening curves for the longer wavelength channels and two wavelength correlation plots for several mixes of the shorter and longer wavelength channels. 3) Simulate some of these data with a radiative transfer model to determine the key components of cloud opacity at thermal wavelengths that control the thermal output from the planet and to evaluate the altitudes at which variable cloud opacity is occurring. 4) Modify the radiative transfer program to simulate intensities measured from a probe on the dayside for later application to near infrared spectra obtained from Venera probes to determine the water vapor mixing ratio profile.

d. J.B. Pollack, J.B. Dalton, D. Grinspoon et al. (1992). Near-infrared light from Venus' nightside: A spectroscopic basis. Icarus, in press; R.W. Carlson et al. (1991) Galileo infrared imaging spectroscopy measurements at Venus. Science 253, 1541-1548.

Proposal Summary

Principal Investigator: C. T. Russell
Institute of Geophysics and Planetary Physics
University of California
Los Angeles, California 90024-1567
Tel (310) 825-3188

Co-Investigators:

Proposal Title: An Investigation of the Induced Magnetosphere of Venus and Its Interaction with the Solar Wind

Abstract

a) The objectives of the proposed investigation are to complete the study of the low altitude Pioneer Venus data obtained during the entry phase, to pursue new studies of the interaction of the induced magnetosphere of Venus with its solar wind plasma environment (Coronal Mass Ejections, upstream waves, the bow shock, the magnetosheath and reconnection in the tail), to compare Pioneer Venus observations with recently available numerical simulations, and to assist other researchers in their studies of the Pioneer Venus magnetometer data. These studies will provide a basis of understanding of the interaction of the solar wind with an unmagnetized planets that will prove critical for the interpretation of the Mars Observer data, just as it was in the case of the recent Phobos mission to Mars. These analyses will also provide an understanding of the upstream waves and low Mach number bow shocks superior in many ways to our understanding of the terrestrial upstream waves and low Mach number shocks because of the relative weakness of the waves (so that they can be treated with linear theories) and because of the large number of shock crossings available.

b) This is a new effort but previous work has resulted in the presentation of over 400 papers at meetings and over 200 papers in journals and books.

c) This year we will study the results of the entry phase, the coronal mass ejection study, the upstream wave study and the reconnection study all of which have initial results and need to maintain their momentum. We will also support other collaborators.

d) C. T. Russell, The Pioneer Venus mission, in Geophys. Monograph 66, p.225, AGU, Washington, DC, 1991.

C. T. Russell (editor) Venus Aeronomy, 489pp., Kluwer Academic Publishers, Dordrecht, 1991.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Charles G. Sammis
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Los Angeles, CA 90089-0740 (213) 740-5836

Co-INVESTIGATORS:
(Name Only)

PROPOSAL TITLE: Quantitative Characterization of the Small-Scale Fracture Patterns on the Plains of Venus

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

Magellan radar images of the plains of Venus have revealed a rich variety of fracture patterns the origin and tectonic implications of which we are only beginning to understand. Large scale structures developed on scales of hundreds of kilometers contain information about the thickness of the lithosphere and convection in the deeper interior. The areas between these large scale structures contain a variety of fracture patterns developed on the kilometer scale which indicate distributed deformation. Some of these patterns are polygonal and have been interpreted as cooling cracks because of their morphological similarity to known cooling patterns. However, other patterns consist of extremely long, regularly spaced fractures which we have interpreted a being produced by regional tension. We have developed a shear-lag model for their origin which predicts that the spacing should be independent of the thickness of the basalt layer in which they are developed. Rather, the spacing depends mostly on the tensile strength of the basalt, which suggest that variations in fracture spacing may indicate differences in basalt rheology either indicating intrinsic differences in the basalt at different locations or differences in the tectonic loading rate. The shear-lag model for these patterns also requires a mechanically homogeneous layer; this implies that they form early in the tectonic history of a given basalt flow. We now propose to use composite radar images (both in photo and CD format available at JPL) to map the locations of these linear patterns and to characterize each set in terms of its orientation, mean spacing, and fluctuations about this mean. In addition to testing predictions of the shear-lag model, we anticipate that the relation of these small-scale patterns to the larger structures and their possible correlation with local geology may help constrain the tectonic history of the plains of Venus.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: David T. Sandwell
(Name, Address, Telephone Number) Scripps Institution of Oceanography
(619) 534-7109

Co-INVESTIGATORS:
(Name Only)

PROPOSAL TITLE: Analysis of Trench/Outer Rise Topography on Venus

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

(a) High resolution altimetry collected by the Magellan spacecraft has revealed trench and outer rise topographic signatures around major coronae and chasmata which are similar in planform, amplitude and wavelength to trench and outer rise signatures observed at terrestrial subduction zones. Out hypothesis is that the lithosphere around these large coronae is flexed downward by the weight of the overriding coronal rim and/or by the negative buoyancy of subducted lithosphere. We propose that this flexural topography provides sufficient signal to investigate the thickness and rheology of the Venusian lithosphere as well as the dynamics of the uppermost mantle. The similarities between trenches on Venus and Earth indicate that lithospheric subduction may occur on Venus. If subduction does occur, it provides a mechanism for cooling the interior of Venus as well as for recycling the lighter crustal rocks back into the interior. In addition, since subduction zones drive the plate tectonic motions on the Earth, evidence for lithospheric subduction on Venus raises the possibility of limited plate tectonic-like activity on Venus.

(b) New proposal.

(c) To address the issues of lithospheric rheology and possible lithospheric subduction on Venus, we propose the following two-year project:

–Identify major flexures on Venus and estimate elastic thickness, plate curvature and bending moment on a global basis using Magellan altimeter profiles.

–Use these flexural parameters to investigate the rheology of the lithosphere and its spatial variations including viscous and visco-elastic models of a dynamic lithosphere.

–Estimate similar flexural parameters at Earth trenches and relate them to age, dip angle and penetration of subducted slabs.

–Use topography and line of sight gravity anomalies to determine if the overriding coronal rim can supply the bending moment needed to support the trench and outer rise topography.

These results will help to:

–Establish a model for global heat transport on Venus (i.e., conductive, convective, extrusive).

–Provide information on lithospheric strain rates and thus a tectonic time scale.

–Quantify the role of possible subduction in heat transport and crustal recycling.

(d) Sandwell, D. T., and G. Schubert, Flexural ridges, trenches and outer rises around Venus coronae, submitted to J. Geophys. Res., 1992. (see Appendix A)

Sandwell, D. T. and G. Schubert, Evidence for retrograde lithospheric subduction on Venus, v. 257, pp. 766-770, August, 1992.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: R.S. Saunders
(Name, Address, Telephone Number) M/S 230-225, Jet Propulsion Laboratory, 4800 Oak Grove Pasadena, CA 91109 (818) 393-0877

Co-INVESTIGATORS: Ellen Stofan, Annette deCharon, Catherine Weitz, Alexander Basilevsky, Boris Ivanov, Konstantin Marchenkov Alexander Zakharov

PROPOSAL TITLE: Regional Stratigraphic Relationships on Venus

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

(a) The overall objective of this proposal is to determine the three-dimensional structure and fundamental geologic relations between major surface types on Venus - Complex Ridged Terrain (CRT) and lowland plains. Several tasks are proposed that are related to the objectives. (1) Geological mapping and geophysical modeling will address interior structure and regional correlation of CRT and plains units. (2) Crater studies will address crustal structure and weathering processes. (3) Long runout landslides will be studied because of their bearing on surface modification processes and properties of surface materials. (4) Venera landing site studies will allow us to relate surface observations and geochemical measurements to Magellan data and examine the significance of the lander data for regional geology. These tasks all relate to fundamental knowledge of stratigraphic relationships and nature of surface material, interior structure and geologic evolution of Venus.

(b) New proposal

(c) Preliminary geologic maps of two 1:5 million scale quadrangles will be produced and the styles and sequence of tectonic events within the CRT assessed. We will begin geophysical modeling of Western Aphrodite using the new Magellan topography data with PVO gravity data. We will analyze large craters on Venus to to provide data to constrain the properties of the Venusian crust and mantle. We will identify craters that have low emissivities to study crater modification processes. We will study impact craters on CRT to determine how and why craters differ in morphology from plains craters. Specific examples of landslide debris will be examined to obtain reliable volumes, and establish the observational techniques to initiate a study of long runout avalanches. We will examine in detail the Magellan data sets for each of the Venera/Vega landing sites to understand why these sites differ in geochemistry.

(d) Saunders, R.S., R. Arvidson, J.W. Head, G.G. Schaber, S.C. Solomon, and E. R. Stofan. 1991, Magellan: A first overview of Venus geology, Science.252, 249-252.

Solomon, S.C., S.E. Smrekar, D.L. Bindschadler, R.E. Grimm, W.M. Kaula, G.E. McGill, R.J. Phillips, R.S. Saunders, G. Schubert, S.W. Squyres, and E. R. Stofan, Venus Tectonics: An overview of Magellan observations, J. Geophys, Res. 97,13,199-13, 256, 1992

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Gerald G. Schaber
U.S. Geological Survey
2255 N. Gemini Drive
Flagstaff, AZ 86001
(602) 556-7485

CO-INVESTIGATOR: Kenneth L. Tanaka

PROPOSAL TITLE: *Geologic Studies of Niobe Planitia, Tesserae, and Impact Crater Outflows on Venus*

ABSTRACT:

(a) Objectives: The primary objective of this three-year study is to better understand Venusian geologic processes through application of well-established geologic principles and detailed analyses of SAR images, altimetry, and physical-properties data from Magellan and other sources.

Specific tasks of the study are to (1) apply geologic mapping principles to establish relative chronologies of tectonism and primarily "domefield" volcanism in Niobe Planitia, with the goal of developing a regional stratigraphy and structural history; (2) identify the processes that have created, modified, and destroyed tesserae (complex ridged terrain) on Venus, establish the geologic evolution for these features, and compare it with that of terrestrial continents; and (3) document the morphologic indicators of changes in material properties and depositional mechanisms in radar-bright outflows from impact craters.

As a direct result of research carried out under task 1, we propose to compile and submit (in 1994 and 1995) geologic maps of two Venus quadrangles (V-11 and V-12) for formal publication by the USGS at 1:5 million scale as part of NASA's Venus Geologic Mapping (VGM) Program.

(b) Accomplishments: New Proposal

(c) Work Plan (FY 93): (1) Document, through detailed photogeologic analysis of superposition and cross-cutting relations, the relative chronologies of episodes of volcanism and tectonism in western Niobe Planitia (latitude 20° to 50° N., longitude 90° to 120° E.). (2) Map the structural framework of Ovda and Thetis Regiones, using crosscutting and superposition relations to determine relative ages of different areas within each of these tessera plateaus. We will document discrete boundaries between areas having different degrees of deformation, suggestive of accreted terrains. (3) Further develop the "lavalike flow" and "turbulent flow" models for emplacement of large impact-crater outflows. We will document changes in the morphology of flow channels, variations in backscatter along the outflow, and modifications of flow directions as evidence of changes in materials properties and depositional mechanisms.

(d) Selected References (1982-present): Schaber, 1982a,b,c; Schaber *et al.*, 1987; Schaber and Kozak, 1989; Schaber, 1990; Schaber and Kozak, 1990; Schaber, 1991; Chadwick *et al.*, 1992a,b; Pohn and Schaber, 1992; Schaber *et al.*, 1992; Senske *et al.*, 1992; Tanaka and Schaber, 1992.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Gerald Schubert
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CO-INVESTIGATORS: William Kaula
(Name Only)

PROPOSAL TITLE: Venus: Dynamics of its Interior, Surface, and Lower Atmosphere

ABSTRACT:

a. Overall Objectives and Justification: The main objectives of this proposal are to learn about the dynamical processes in the interior and lower atmosphere of Venus that have been responsible for producing the surface features of the planet. The approach is to analyze the surface features, e.g., the topography, nature of deformation, and spatial distribution of features, and through modelling, constrain the dynamical processes that could produce the features. The focus is on the dynamics of the mantle and lithosphere and surface features such as coronae, chasmata, and domical and plateau-shaped highlands. In addition we will study wind streaks and their relation to the circulation of the lower atmosphere.

b. Statement of Accomplishments: As members of the Magellan RADIG and GRAVIG, we have contributed to the initial analysis and interpretation of Magellan data and have co-authored Magellan papers in special issues of *Science* and *J. Geophys. Res.* We analyzed the planform and topography of trenches around Artemis and Latona coronae on Venus, pointing out the essential similarity of these features to terrestrial circum-Pacific subduction zones, and suggesting the occurrence of retrograde subduction on Venus. We analyzed the azimuths of wind streaks on the surface of Venus and found a predominantly equatorward streak orientation, a result that is consistent with a lower atmosphere Hadley circulation. This is the first constraint to be placed on the circulation of the lower atmosphere of Venus.

c. Proposed Work:

1). Global survey of possible subduction zones (trenches) on Venus and flexural analyses of trench-outer rise topographies. Implications for global heat transport and mantle dynamics.

2.) Flexural studies of small Venus coronae with axisymmetric flexure theory. Implications for global variations in lithosphere thickness.

3) Development of gravity models for large Venus coronae (Artemis).

4. Statistical and geological analyses of wind streak data. Implications for lower atmosphere circulation.

5. Numerical models of cylindrical upflows and downflows in the mantle of Venus with realistic mantle rheology and interaction with the crust and lithosphere. Derivation of surface topography and gravity. Comparison with Atla, Beta, Ovda, and Thetis Regiones and western Ishtar Terra.

d. Recent Publications Relevant to the proposed Work: 3 papers in *Science*, 7 papers in *J. Geophys. Res.*, 1 paper in *Nature*, 1 paper in *Geophys. Res. Letters*.

PROPOSAL SUMMARY/ABSTRACT

PRINCIPAL INVESTIGATOR: Peter H. Schultz
Brown University
Department of Geological Sciences
Box 1846
Providence, RI 02912
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CO-INVESTIGATORS:

PROPOSAL TITLE: Geologic Signatures of Atmospheric Effects on Impact Cratering on Venus

ABSTRACT:
a.) Objectives: 1.) To contrast the response of the surface (cratering) and atmosphere (blast effects) to bolides with respect to scale, intensity, and time. 2.) To characterize the energy, momentum, and nature of impactors following crater formation. 3.) To assess energy scaling relations for impact craters on Venus from source energies inferred from contrasting surface expressions of atmospheric effects and crater size.

b.) New Proposal

c.) Proposed Research: Four major tasks are proposed: 1.) Assess the geologic processes responsible for surface expressions of airblasts on Venus from terrestrial explosion data, laboratory simulations, and surface effects inferred from analysis of Magellan data. 2.) Characterize the nature of impacting bodies as a function of scale including impactor direction, angle, and downrange atmospheric response. 3.) Assess the extent and time scales of the general atmospheric response to impact formation including non-ballistic emplacement styles and afterwinds.

d.) Summary Bibliography:

Schultz, P.H. and Gault, D.E. (1990) Prolonged global catastrophes from oblique impacts. *Geol. Soc. Amer. Spec. Pap., 247*, 239-261.

Schultz, P.H. (1991) Atmospheric Effects on Oblique Impacts. In *Lunar and Planet. Sci. XXII*, Lunar and Planetary Institute, Houston, TX, pp. 1191-1192.

Schultz, P.H. (1991) Resolving Early-time Impact Processes on Venus from Magellan. *EOS, 72*, 173.

Schultz, P.H. (1991) Style and Sequence of Ejecta Emplacement on Venus from Magellan. *EOS, 73*, 288.

Schultz, P.H. (1992) Atmospheric effects on cratering efficiency. *J. Geophys. Res., 97*, E1, 975-1006.

Schultz, P.H. (1992) Atmospheric effects on ejecta emplacement. *J. Geophys. Res., 97*, E7, 11,623-11,662.

Schultz, P. H. (1992) Atmospheric effects on ejecta emplacement and crater formation on Venus. *J. Geophys. Res.* (in press).

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Virgil L. Sharpton
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Co-INVESTIGATORS: Paul D. Spudis, Paul Schenk, Robert Herrick

PROPOSAL TITLE: ***Topography from Magellan Radar Image Pairs: Compilation and Analysis of a New Crater Morphometry Data Base***

ABSTRACT: *(a. Objectives and Justification; b. Accomplishments, or 'new proposal'; c. this year's goals and strategy; d. relevant references)*

(a) Reliable topography for fresh craters on Venus is essential to understanding the controls over the planetary cratering process (gravity, atmosphere, target strength, etc.) and to provide a reference against which the effects of any venusian degradation processes (viscous relaxation, volcanic or aeolian infilling) can be evaluated. Degraded craters record the extent and mechanisms of surface modification operating on Venus. We propose to compile and analyze a data base of Digital Elevation Models (DEM) for impact craters and their ejecta deposits using Magellan radar image stereo pairs. This data base will encompass craters spanning the range of sizes, degradation states, and target types observed on Venus. Using this topographic data base, we will determine size and volume of various crater features (e.g., crater cavity, peaks/peak rings, ejecta thicknesses), assess azmuthal variations in crater depth, and rim height (possibly associated with impact trajectory or preexisting target conditions), and determine variations in floor topography, possibly associated with radial and concentric structures in large venusian basins, and with small, compound craters produced by atmospheric breakup of the projectile. *(b)* 'New Proposal' *(c)* Compile discrete topographic measurements for craters covered in Magellan Cycle 1 - Cycle 2 data using method outlined in text. As the data are compiled, we will pursue the scientific issues addressed above. (d) Sharpton, V.L. (1992), Paradigm Lost: The Role of Gravity in Crater Modification, *Large Meteorite Impacts and Planetary Evolution*, 65-66; Sharpton, V.L., (1992) Fresh Crater Depths and Evidence for Crater Degradation on Venus, *Geol. Soc. America Annual Meeting*, Cincinnati, *in press;* Sharpton, V.L. (1992)Venus Crater Depths, Central Structures and Rim Heights, *Fall Am. Geophys. Union Meeting*, in press. Schenk, P.M. (1991) *J. Geophys. Res., 96,* 15635-15664.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Dr. C. K. Shum
Center for Space Research 60605
The University of Texas at Austin
Austin, TX 78712
(512) 471-5573

PROPOSAL TITLE: Determination of the Venusian Gravitational Field and Topography Using Pioneer Venus Orbiter and Magellan Radar Altimeter Data

(a) The scientific objectives of the proposed investigation include (1) the determination of a medium resolution Venusian gravity field (complete to degree and order 50 in spherical harmonics); (2) the mapping of the precise Venusian topography resulting from improved orbits using geophysical crossover measurements; and (3) the application of the enhanced Venusian gravity field to provide constraints to allow interpretation of the geological interior of Venus. In contrast to line-of-sight doppler tracking data, the altimeter data will have a distinct advantage for being able to directly sense the gravitational perturbation from a planet-centered coordinate system, and for its global geographical coverage. The proposed approach is to use altimeter crossover measurements from both Pioneer Venus Orbiter (PVO) and Magellan in the form of single satellite (PVO or Magellan) crossovers and dual satellite crossovers between PVO and Magellan.

(b) The proposal represents a new proposed investigation to suugest the first use of altimeter crossover measurements for the improvement of the Venusian gravity field and its topography. The Principal Investigator and the Co-Investigators have considerable experience in the use of satellite altimeter measurements to the determination of the Earth's gravitational field and other geophysical parameters. Recent accomplishment relevant to the proposed investigation include the development of the University of Texas Geopotential Model, TEG-2B, which is complete to degree and order 50 [Tapley et al., 1991]; and the use of single- and dual-satellite altimeter crossover measurements for the recovery of gravity field and other geophyscial parameters [Shum et al., 1990]. The characteristics of the PVO and the Magellan orbits will allow the generation of altimeter crossovers which will help improve the orbits (and thus improved determination of the topography) and the Venusian gravitational field.

(c) During the first year of the proposed investigation, historical gravity field solutions for Venus will be evaluated to be used as a priori information for the proposed improvement of Venusian gravity field using the altimeter crossover measurements and the line-of-sight Deep Space Network (DSN) tracking data. The methodology used to generate PVO and Magellan crossovers using the altimeter height reduced by the MIT Group will be developed based on the techniques reported by Shum et al. [1990]. Activities during the subsequent years will include the use of the crossovers to determine the gravity field and the topography of Venus.

(d) The recent publications relevant to the proposed investigation include the following:

Shum, C. K., B. H. Zhang, B. D. Tapley, and B. E. Schutz, Altimeter crossover methods for precision orbit determination and the mapping of geophysical parameters, *AAS Journal of the Astronautical Sciences, 38*(3), 335–368, July–September 1990.

Tapley, B. D., C. K. Shum, D. N. Yuan, J. C. Ries, R. J. Eanes, M. M. Watkins, and B. E. Schutz, The TEG-2B geopotential model, *Proc. IUGG Symposium*, Vienna, Austria, 1991.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR
(Names, Address,
Telephone Number)

Suzanne E. Smrekar
M.I.T., 54-512
Cambridge, MA 01239 (617) 253-6299

CO-INVESTIGATORS:
(Name Only)

TITLE: Tectonics of Mantle Plumes on Venus

ABSTRACT: (Type single-spaced within box below. Paragraphs numbered (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal"; c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

(a) The primary objective is to understand the influence of mantle and lithospheric structure on surface tectonics as a means of unraveling planetary evolution and tectonic history.

(b) New proposal.

(c) The goal is to investigate the interaction of mantle plumes with a possible depleted layer in the upper mantle of Venus. We employ a finite element description of an upwelling plume to model thermal and buoyancy forces and to predict flow, stresses and the production of melt. This modeling approach, combined with constraints from the analysis of new radar, topography, and gravity data from the Magellan mission, have the potential to address many long-standing questions about the tectonics and interior of Venus.

(d) Smrekar, S., and R.J. Phillips, Venusian highlands: Geoid to topography ratios and their interpretation, *Earth Planet. Sci. Lett.*, *107*, 582-597, 1991.

Smrekar, S.E., and Solomon, S.C., Gravitational spreading of high terrain in Ishtar Terra, Venus, *J. Geophys. Res.*, in press, 1991.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Sean C. Solomon

(Names, Address, Telephone Number) Carnegie Institution of Washington, DTM
5241 Broad Branch Road, N.W.
Washington, D.C. 20015 202/686-4444

CO-INVESTIGATORS:

(Name Only)

PROPOSAL TITLE: The Tectonics of Volcanic and Rifted Areas on Venus

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal"; c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

(a) Our broad goal is to understand the tectonics of areas of major volcanic centers and rift zones on Venus and the relationship of near-surface deformation and magmatism to the interior temperature and mantle flow fields.

(b) New proposal.

(c) In the coming year our proposed work includes the analysis of Magellan imaging and topographic data from large volcanoes to recover the thickness of the elastic lithosphere from the flexural response to the volcano load; an assessment of elastic lithosphere thickness estimates from our work and that of others in terms of the thermal and mechanical structure of the lithosphere and the processes responsible for lateral variations in that structure; an analysis of imaging and topographic data from large rift zones to constrain the degree of lithospheric stretching, the consequent melt generation, and the lithospheric response to crustal unloading; and the inversion of gravity and topographic data over regions of major volcanic centers and rifting to constrain the relative contributions to crustal thickness of lithospheric stretching and magmatism and to relate the deformation to mantle flow fields.

(d) Solomon, S.C., and J.W. Head, Fundamental issues in the geology and geophysics of Venus, *Science*, *252*, 252-260, 1991.

Solomon, S. C., et al., Venus tectonics: Initial analysis from Magellan, *Science*, *252*, 297-312, 1991.

Solomon, S.C., et al., Venus tectonics: An overview of Magellan observations, *J. Geophys. Res.*, *97*, 13199-13255, 1992.

Smrekar, S.E., and S.C. Solomon, Gravitational spreading of high terrain in Ishtar Terra, Venus, *J. Geophys. Res.*, in press, 1992.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Dr. Steven W. Squyres
(Name, Address, Telephone Number) CRSR, Cornell University, Ithaca, NY 14853
(607) 255-3508

Co-INVESTIGATORS: Dr. Daniel M. Janes
(Name Only)

PROPOSAL TITLE: Plains Tectonism on Venus

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

A: The goal of this proposal is to understand two major classes of tectonic features on the venusian plains, deformation belts and coronae. We seek to determine the constraints that the topography and tectonics of these features place on formation mechanisms, planetary structure, and geologic histories. Both of these features are widespread over the planet, allowing for the determination of systematic variability in the parameters that control their final form. The plains units themselves represent the majority of the surface of Venus, and as complete a knowledge as possible of them is crucial to any understanding of the planet.

B: New Proposal

C: We will conduct detailed studies of the morphology and morphometry of deformation belts, coronae, and related features to build a complete descriptive model of these features. We will then employ analytical and finite-element techniques to model their formation so that we can investigate the nature and dimensions of the driving forces responsible for them as well as the compositional and thermal structure of the plains during their formation. We will determine the extent to which variability in these features can be directly tied to variability in the geologic and tectonic setting in which they form. Finally, we will use our results to construct a synoptic view of the geologic history of the venusian plains.

D: Squyres, S.W., D.G. Jankowski, M. Simons, S.C. Solomon, B.H. Hager and G.E. McGill, Plains Tectonism on Venus: The Deformation Belts of Lavinia Planitia, *J. Geophys. Res.* 97, 13579–13599 (1992).

Janes, D.M., S.W. Squyres, D.L. Bindschadler, G. Baer, G. Schubert, V.I. Sharpton and E.R. Stofan, Geophysical Models for the Formation andEvolution of Coronae on Venus, *J. Geophys. Res.*, in press.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR & INSTITUTION: Dr. Stephen S. Stahara
RMA Aerospace, Inc.
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(415) 961-0560

CO-INVESTIGATOR: Prof. John R. Spreiter

PROPOSAL TITLE: Quantitative Determination of Mass Loading Effects in the Solar Wind/Venusian Ionosphere Interaction: Application of a Global 3-D MHD Model

ABSTRACT

(a) Brief Statement of Overall Objectives

The development and application of a multi-level computational 3-D MHD magnetosheath model to simulate the global, 3-D solar wind interaction with the Venusian ionosphere and quantitatively determine: (1) the influence that various ion creation processes including photoionization, charge exchange, and electron impact ionization have on the Venusian magnetosheath and bow shock, and (2) the structure of the pressure balanced boundary and nearby spatial regions between the magnetosheath and ionospheric plasmas including the magnetic barrier and mantle characteristics.

(b) New Proposal

(c) Brief List of First Year's Work

In the first phase, the global models for photoionization, charge exchange, and electron impact ionization as reported by Zhang et al. (Ref. 21) would be incorporated in both the initial mass loaded magnetosheath model and the new full 3-D MHD magnetosheath model. Next, an extensive systematic series of numerical case studies would be carried out with both models to quantitatively establish the individual and collective mass loading effects of these three mass loading sources on the structure of the Venusian magnetosheath and bow shock location, and comparisons carried out with PVO magnetometer (OMAG) and plasma analyzer (OPA) data to determine whether the total of these effects modeled at the continuum MHD level are sufficient to produce the observed structure of the Venusian magnetosheath and bow shock.

(d) Recent Relevant Publications

Computer Modeling of Solar Wind Interaction with Venus and Mars, Spreiter, J. R. and S. S. Stahara, in Venus and Mars: Atmospheres, Ionospheres, and Solar Wind Interactions, Ed. J. G. Luhmann, M. Tatrallyay, and R. Pepin, AGU Monograph 66, 1992.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: R. S. Steinolfson, Southwest Research Institute, 6220 Culebra Road, San Antonio, Texas 78238-5166 (512) 522-2822

PROPOSAL TITLE: MHD Modeling of the Interaction of the Solar Wind with Venus

ABSTRACT:

(a) Overall objective: The overall objective of the proposed research is to improve our understanding of the physical processes occuring in the interaction of the solar wind with Venus. This will be accomplished through the use of numerical solutions of the magnetohydrodynamic equations and through comparisons of the computed results with available observations. A large part of the proposed effort concerns processes resulting from the presence of the magnetic field, mass loading, and coupling to the ionosphere. Venus is of particular interest since the planet does not have an intrinsic magnetic field, and the interaction of the solar wind with the Venus ionosphere involves fundamentally different processes than occur at the Earth. In addition, the large quantity of observations now available for the solar wind/Venus interaction provides an excellent test bed for evaluation of physical processes included in the model. A planned close collaboration with a data analyst will serve to make the model more relevant to the data. The proposed study may also be useful in the interpretation of data that will become available from the recently launched Mars Observer.

(b) Recent Accomplishments: This is a new proposal for the VDAP program. Research that has formed the foundation for the work proposed here was carried out with support from the PVO Guest Investigator Program and is summarized in the proposal.

(c) Proposed Work for Coming Year: The general approach that will be followed in this research program is to use the numerical tools discussed in the proposal to simulate phenomena derived from analysis of the available observations. This approach along with a close interaction with observations should not only improve our understanding of the solar wind/Venus interaction but will assist in determining whether the physics included in the model may be responsible for the observed events, if some additional physics must be included, or if the model is simply not adequate. One of the major efforts during the first year will be to investigate the three-dimensional effects due to various relative orientations between the interplanetary magnetic field and the solar wind flow directions for a reasonable range of parametric values. Some specific topics of interest are the formation and role of the magnetic barrier, the length and orientation of the magnetotail, the time for the magnetic field to drape or slip around the planet, and the possible production of nightside ionospheric holes. Additional work includes studies of the observed far upstream bow shocks and the effects of mass loading the solar wind due to ionization of neutrals.

(d) Recent Publications Relevant to Proposed Work:

Steinolfson, R.S., Global MHD simulations of the interaction of the solar wind with the Venus atmosphere, *EOS*, **73**, 189, 1992.

Steinolfson, R.S., and S. Cable, Venus bow shocks at unusually large distances from the planet, *GRL*, in preparation, 1992.

Steinolfson, R.S., Three-dimensional structure of coronal mass ejections, *JGR*, **97**, 10,811, 1992.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: David J. Stevenson
(Name, Address, Telephone Number) Division of Geological & Planetary Sciences 170-25
California Institute of Technology
Pasadena, CA 91125 818/356-6108

Co-INVESTIGATORS: Vjacheslav Solomatov
(Name Only)

PROPOSAL TITLE: Venus Evolution and Structure Using Magellan Data

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

a. The proposed work is a wide-ranging theoretical modeling effort seeking to relate Magellan data to the fundamental questions of Venus structure and evolution.

b. New proposal.

c. The work has multiple tasks: (i) An extended evaluation of the role of Rayleigh-Taylor instabilies in the development of regional volcanism on Venus, with a likely focus on coronae. This is an alternative to the plume hypothesis whose applicability has implications for the structure of the uppermost mantle of Venus. (ii) Evaluation of the geoid for a range of models of mantle upwelling including partial melting and its dynamical consequences. These models will address the puzzle of Venus' large geoid/topography ratio. (iii) Numerical ("box") models assessing the fate of residue derived from partial melting, with particular attention to the question of whether Venus (unlike Earth) might develop an extended depleted layer. (iv) Development of evolutionary (initial condition) models of Venus, connecting to the aforementioned issues but focusing on aspects of early Venus that may have led to a different current mantle structure (e.g. nature and extent of a magma ocean, ability to recycle crust). This will lead to models of crustal thickness as a function of time which can be compared with current observations. (v) A relatively minor activity on the nature of Venus' core and the issue of Venus' near resonant rotation state.

d. Tackley, P. and Stevenson, D.J. In press (attached as an appendix); 3 papers on magma oceans by Solomatov, V. and Stevenson, D.J. submitted to J.G. R., 1992.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Ellen R. Stofan
(Name, Address, Telephone Number) M/S 230-225, JPL 4800 Oak Grove Dr., Pasadena CA 91109
(818) 393-0868

Co-INVESTIGATORS: David A. Crown, Jeffrey J. Plaut, Steve A. Anderson
(Name Only)

PROPOSAL TITLE: Steep-sided domes on Venus: Morphology, Origin and Evolution

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

a. We propose to analyze the morphology and radar scattering characteristics of steep-sided domes on Venus using Magellan data. Surface structures, associated volcanic features, and morphometric data will be used to assess a silicic model of origin for the domes. Radar scattering properties of Venusian domes will be measured to aid in the determination of emplacement mechanisms and degradational styles. Terrestrial silicic domes will be examined in order to interpret the surface characteristics and scattering properties of Venusian domes. Theoretical models of the thermal and rheologic evolution of steep-sided domes will be formulated and adapted to Venusian conditions to investigate the dynamics of volcanic flow emplacement on Venus, the formation of crusts on Venusian flows, and the generation of stresses on dome surfaces. We also propose to map several quadrangles for the Venus Geologic Mapping Program that are characterized by diverse volcanic landforms including steep-sided domes, coronae, and calderas. This mapping project will provide further data to evaluate the origin and significance of steep-sided domes on Venus. The results will be synthesized to assess the silicic model of origin, and determine the degradational history of steep-sided domes on Venus. The data may support a silicic origin for steep-sided domes, allowing refinement of models for the evolution of magma bodies, as well as providing significant information on the formation and evolution of the plains of Venus. Alternatively, our examination of Magellan data, terrestrial analogues of steep-sided domes, and physical analyses of Venusian volcanic processes may indicate that the Venusian domes are basaltic in origin, providing data on the variations and significance of eruptive styles on Venus.

b. New proposal.

c. In Task 1, the surface characteristics (structures, textures, marginal features, shape) will be catalogued; type examples will be examined in detail. A model of origin based on these characteristics will be developed. The radar properties of domes will be compiled in Task 2, and the topography derived from altimetry and stereo data. In Task 3, available data for terrestrial silicic domes, including AIRSAR images will be examined and initial morphologic comparisons to Venus domes will be made. A cooling model and a model for the formation of crusts on Venus lavas will be formulated for Task 4. For the Geologic Mapping task, preliminary maps will be produced.

d. Stofan, E.R., Bindschadler, D.L., Head, J.W., and Parmentier, E.M., 1991, Coronae on Venus: Models of origin. *Jour. Geophys. Res 96*, 20933-20946; Stofan, E.R., V.L. Sharpton, G. Schubert, G. Baer, D.L. Bindschadler, D.M. Janes and S.W. Squyres, Global distribution and characteristics of coronae and related features on Venus: Implications for origin and relation to mantle processes, *J. Geophys. Res.*, *97*, 13,347-13,378; Crown, D.A., and R. Greeley, 1992, The volcanic geology of Hadriaca Patera and the eastern Hellas region of Mars, *J. Geophys. Res*, in press; Plaut, J.J., and Arvidson, R.E., 1992, Comparison of Goldstone and Magellan Radar data of the equatorial plains of Venus, *J. Geophys. Res.*, *97*, in press.

Proposal Summary

PLASMA WAVES IN THE MAGNETOSHEATH OF VENUS

Robert J. Strangeway, Principal Investigator
Institute of Geophysics and Planetary Physics
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Los Angeles, CA 90024
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Abstract

We propose a three year effort to analyze plasma wave data acquired by the Pioneer Venus Orbiter in the magnetosheath of Venus. Our principal goal is understanding the nature of those regions of detached plasma known as plasma clouds. In carrying out this research we hope to show whether or not plasma clouds are associated with draping of the Interplanetary Magnetic Field, or are due to structures in the IMF being convected in the magnetosheath flow. The plasma waves can help in this by determining whether or not the currents in plasma clouds are parallel or perpendicular currents. Parallel currents are more likely to be associated with convecting structures, since there is no $\mathbf{j}\times\mathbf{B}$ force. In carrying out this work we will routinely "clean" the high resolution plasma wave data, which are usually contaminated by interference due to photoelectrons when the spacecraft is in sunlight. Since this "cleaned" data will incorporate data up to and including the bow shock, we will also analyze plasma waves observed downstream of the bow shock, as these may be important in thermalizing the shocked plasma. The cleaned data will be archived so that other members of the scientific community can have access to the data. Through analysis of the plasma waves we may be able to determine if much of the variability within the magnetosheath is spatial or temporal. In particular determining if plasma clouds are due to convecting structures may have implications for other supposedly spatial structures, such as the plasma mantle.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Robert G. Strom
(Name, Address, Telephone Number) University of Arizona, Lunar & Planetary Laboratory
Tucson, AZ 85721 (602) 621-2720

Co-INVESTIGATORS:
(Name Only)

PROPOSAL TITLE: Impact Crater Investigations of Venus

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

a. The main objectives of the proposed research are 1) completion of impact crater measurements required to understand the resurfacing history and impact processes on Venus, 2) set limits on the amount and time of resurfacing to constrain thermal and geological histories, 3) determine the lifetime of parabolic features to constrain the amount of atmospheric erosion, 4) determine the proportion of comet to asteroid impacts on Venus to better characterize the impact history in the inner Solar System, 5) set limits on the amount of impact melt and the parameters that determine its volume on Venus to better understand the origin of large ejecta flows on some craters but not others, and 6) to locate relatively shallow magma sources and their relation to geologic features to better understand subsurface structure and magma distribution.

b. This research is partly a continuation of the research on the Venus impact cratering record carried out in collaboration with G. Schaber at the U.S.G.S. in Flagstaff. This work led to the global resurfacing model. The model proposes that a global resurfacing event occurred about 500 million years ago, and was followed by greatly reduced volcanism and tectonism. Present-day activity is estimated to be less than current intraplate volcanism on Earth. The proposed research also builds on and greatly expands the statistical analyses of crater characteristics we began during this collaboration.

c. This year measurements required to address objectives 2 and 3 will be completed, and objective 2 should be accomplished. The theoretical modeling for objective 5 will be complete, and measurements required to address objective 6 will be started. Objective 3 will be completed this year, and measurements required for objective 4 will be complete.

d. Reference: Schaber, G.G., Strom, R.G. *et al.*, Geology and Distribution of Impact Craters on Venus: What Are They Telling Us?, *J. Geophys. Res.*, **97**, No. E8, pp 13,257-13,301, 1992.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Dr. John Suppe
Dept. of Geological and Geophysical Sciences
Guyot Hall, Princeton University
Princeton, NJ 08544
(609) 258-4100

PROPOSAL TITLE: Analysis of Deformation on Venus

ABSTRACT:

a. Overall objectives and justification of the work:

We propose to extend our initial semi-quantitative mapping and structural analysis of fold belts, wrinkle ridges, and rifts on Venus using more quantitative measures of deformation involving: (1) high-resolution topographic measurements of the deformed surface based on new capability in stereo radargrammetry and radarclinometry and (2) geographically-referenced mapping of structures regionally and globally using powerful GIS software. Our objectives are: 1) to determine the geometry and formation mechanisms of individual folds, fold belts, wrinkle ridges, and graben systems, 2) to quantify the strain or displacement accommodated by these structures, and 3) to map deformation features and analyze their displacements, intensities, and orientations at regional and global scales. These efforts will increase our understanding of deformation processes and rheologies of Venus at several scales, contribute to the development of global deformation models, and produce a geographically referenced database of structures that will be shared with other researchers.

b. New proposal

c. Listing of proposed work for the coming year:

(1) Development of high-resolution digital topography of selected map-scale structures for the purpose of detailed structural analysis, using stereo workstation.
(2) Quantitative analysis of high-resolution orthorectified topography of folds, fold belts, wrinkle ridges and rifts in order to: a) establish what faulting or folding mechanisms produce these structures and b) make quantitative strain and displacement measurements.
(3) Development of geographically-referenced regional and global maps of structures by: a) completing implementation of GIS capability for Venus structural data and b) begin georeferenced mapping of wrinkle ridges, folds, foldbelts, and low intensity rifting on a regional to global scale.
(4) Use results of above work to estimate strain and displacement over regional and global areas in order to constrain global tectonic models.

d. Relevant publications:

Bilotti, Frank, Chris Connors, and John Suppe. Global deformation on the surface of Venus.[abs.] International Colloquium on Venus. Pasadena: LPI, (1992): 10.

Connors, Chris and John Suppe, Characteristics of Fold-and-Thrust Belts on Venus [abs.]: In Workshop on Mountain Belts on Venus and Earth, Lunar and Planetary Institute, Houston, 1992, *in press*.

Suppe, J., and C. Connors. "Critical-Taper Wedge Mechanics on Venus: Initial Results from Magellan." J. Geophys. Res. 97 (1992): 13,545-13,561

Proposal Summary

PRINCIPAL INVESTIGATOR: Richard H. Tipping
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University of Alabama
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CO-INVESTIGATOR: Qiancheng Ma

PROPOSAL TITLE: THEORETICAL CALCULATION OF THE CONTINUOUS FAR-WING ABSORPTION OF CO_2-CO_2 PAIRS

ABSTRACT:

a. The objective of the currently proposed research is to extend the theoretical formalism developed previously by us and applied to the calculation of the continuous far-wing absorption arising from H_2O-H_2O, H_2O-N_2, and H_2O-CO_2 pairs in order to calculate the corresponding absorption arising from CO_2-CO_2 pairs. This extension is nontrivial for two reasons: (i) the leading term of the long-range anisotropic interaction in the pure CO_2 case is different from those in our previous work (quadrupole-quadrupole versus dipole-dipole in the case of pure water, or dipole-quadrupole in the cases of foreign-broadening); and (ii) the CO_2 molecule has much smaller rotational parameters than H_2O and, accordingly, a much richer spectrum. The first difference entails a complete reformulation of the angular momentum coupling scheme used in the theory, while the latter difference implies the diagonalization of much larger matrices in order to include most of the low-lying states in the formalism. This problem is further exacerbated by the high atmospheric temperatures on Venus where many excited states have significant population. However, because of the overwhelming abundance of CO_2, such absorption is expected to play an important role. This role is not restricted to radiative transfer calculations, but also has very significant effects on the mixing ratios and gradients of the minor constituents deduced from the analysis of ground-based emission spectra from Venus' nightside, the interpretation of the space-time variations responsible for the observed near-infrared brightness temperature contrasts and hemispheric asymmetry, the determination of the deuterium abundance, etc. Now that accurate hot-band intensities for CO_2 can be calculated theoretically, the far-wing absorption due to CO_2 pairs, and to a lesser extent, the corresponding collision-induced absorption, are the two most important unresolved spectroscopic problems necessary for an accurate modeling the atmospheric spectra of Venus.

b. New proposal.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Donald L. Turcotte
(Name, Address, Telephone Number) Snee Hall, Cornell University
Ithaca, NY 14853 (607) 255-7282

Co-INVESTIGATORS:
(Name Only)

PROPOSAL TITLE: An Integrated Thermal and Tectonic Model for Venus

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

We propose as a working hypothesis that the heat loss from the interior of Venus is strongly time dependent. In particular we propose that a global lithosphere on Venus stabilized about 500 MYPP and has thickened conductively since with a present thickness of about 300 km. This hypothesis is supported by the number and distribution of craters on the surface of Venus. A thick lithosphere allows us to explain the regions of high topography and associated positive gravity anomalies using Airy or thermal isostasy and to explain the large thicknesses of elastic lithosphere inferred from lithospheric flexure models of coronae. We propose to develop models for the thermal evolution and for tectonic processes on Venus based on this working hypothesis.

PROPOSAL SUMMARY

Principal Investigator: G. Leonard Tyler
Center for Radar Astronomy
Space, Telecommunications, and Radioscience Laboratory
Stanford University
Stanford, CA 94305-4055
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Co-Investigators: Richard A. Simpson

Proposal Title: Inference of Surface Properties from Composite Radar Scattering Functions

Abstract:

(a) Overall Objectives: Specific cross section $\sigma_o(\beta,\phi)$ completely describes radar backscattering by a planetary surface for incidence and azimuthal angles β and ϕ, respectively. For the first time, using Magellan data, estimates of specific cross section $\hat{\sigma}_o$ have been derived systematically and at both near-nadir and oblique angles. These functions, at spacings of a few tens of kilometers over much of Venus, are more comprehensive descriptors of surface properties than simple parameters such as rms surface slope and Fresnel reflectivity. The work proposed here will seek patterns within the set of cross section estimates and relate those to surface characteristics derived by other means, such as mapped surface units inferred from visual examination of Magellan SAR image mosaics. The overall objective is to arrive at the most complete description of Venus geology, including surface history and processes, that can be derived from the radar data.

(b) Previous Accomplishments: New proposal

(c) Work Statement for First Year: Of particular interest are anomalous Doppler offsets found during processing of Magellan altimetry echoes. These have unanticipated regional patterns that suggest anisotropic scattering, possibly under topographic or tectonic control. The large-scale topographic contribution can be calculated and removed using newly available Magellan ARCDR and GTDR data. The residual will be examined for implications about medium- and small-scale surface structure. More general relationships among scatter from large-, medium-, and small-scale structure will also be investigated, emphasizing changes in observed scattering behavior in transition zones (lava flow boundaries) and from discrete targets such as large craters.

(d) Relevant Publications: G.L. Tyler, P.G. Ford, D.B. Campbell, C. Elachi, G.H. Pettengill, and R.A. Simpson, Magellan: electrical and physical properties of Venus' surface, *Science*, *252*, 265-270, 1991; G.L. Tyler, R.A. Simpson, M.J. Maurer and E. Holmann, Scattering properties of the Venusian surface: preliminary results from Magellan, *J. Geophys. Res.*, *97*, 13115-13139, 1992.

Proposal Summary

PRINCIPAL INVESTIGATOR: Prof. G. Leonard Tyler
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Center for Radar Astronomy
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(415) 723-3535

OTHER KEY PERSONNEL: Dr. David P. Hinson
Dr. Jon M. Jenkins

PROPOSAL TITLE: Investigation of Atmospheric Waves on Venus

ABSTRACT: (a) brief statement of the overall objectives and justification of the work; (b) brief statement of the accomplishemnts of the prior year, or "new proposal"; (c) brief listing of what will be done this year, as well as how and why; and (d) one or two of your recent publications relevant to the proposed work.

(a) We propose to investigate atmospheric waves on Venus through analysis and interpretation of high-quality radio occultation data obtained with the Magellan spacecraft. Based on our success in previous studies of this type -- which led to the discovery of atmospheric waves on Titan, Uranus, and Neptune -- we believe that radio occultation data constitute a potentially powerful but underutilized source of information concerning atmospheric waves on Venus. Our immediate goal is to identify the signature of waves in the radio occultation data. Direct results should include accurate vertical profiles of wave-induced temperature perturbations; measures of basic properties such as wave amplitude, vertical wavelength, and their variation with height; and inferred constraints on horizontal structure. We will use this basic characterization of wave properties within the framework of standard theory for atmospheric waves to assess the contribution by the waves to the thermal structure, momentum budget, and eddy mixing of the upper atmosphere. Our ultimate goal is to gain a better understanding of the role played by atmospheric waves in maintaining the observed superrotation of the Venus atmosphere.

(b) New proposal.

(c) Efforts in the first year will be directed toward analysis and interpretation of data from three radio occultation experiments conducted with the Magellan spacecraft in late 1991. We will extract results of interest from the basic measurements through use of the standard, Abel transform algorithm for reduction of radio occultation data, supplemented by digital filters specialized to the study of atmospheric waves. Anticipated results include vertical profiles of the temperature perturbations caused by vertically-propagating atmospheric waves, as well as a detailed characterization of the background structure through which the waves propagate.

(d) Hinson, D. P., and J. A. Magalhães 1991. Equatorial waves in the stratosphere of Uranus. *Icarus* **94**, 64-91. Abstract included here as Appendix A.

Hinson, D. P., and J. A. Magalhães 1992. Inertia-gravity waves in the atmosphere of Neptune. In preparation for submission to *Icarus*. Draft of manuscript included here as Appendix B.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Ann M. Vickery
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The University of Arizona, Tucson, AZ 85721
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Co-INVESTIGATORS:
(Name Only)

PROPOSAL TITLE: Impact Melt Production on Venus

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

Abstract
a. Magellan images show that ~40% of Venusian craters have associated flows, which appear to have been emplaced while the material had low viscosity and which cover large areas. If this material is impact-produced melt, then there is clearly some mechanism, unique so far as is known to Venus, that produces extraordinary volumes of melt -- but only for some craters. Although there is a weak positive correlation of flow occurence with crater size, the two largest Venusian craters do not have such flows. There is no obvious correlation with any other factor, such as terrane type or location. The purpose of the proposed work is to investigate in detail the mechanism of melt production in craters in order to determine if, and under what circumstances, such flows can be produced.
b. new proposal
c. The process of impact melt formation remains poorly understood. The primary tool to be used in this study is the 2-D hydrocode CSQ, with which one can model impacts. The work of the first year would involve impact simulations using aluminum targets and projectiles. Aluminum is chosen because it has fairly simple material properties which are similar in many ways to those of silicates, without the complications of such things as high pressure phase transitions, so that it is much easier to isolate factors that control melting and vaporization in impacts. CSQ is up and running on our SPARC2 workstation, and we have performed a few preliminary calculations with impact velocities ranging from 5 to 15 km/s. The next step will be to carry out similar calculations for more geologically appropriate materials.
d. Publications
A. M. Vickery and H. J. Melosh (1991) Production of impact melt in craters on Venus, earth, and the moon, *Lunar Planet. Sci.* XXII, 1443-1444.
A. M. Vickery and H. J. Melosh (1991) An Analytic Model for Melt and Vapor Production in Impact Craters, *EOS* 72, 289.
A. M. Vickery, D. A. Kring, and H. J. Melosh (1992) Ejecta associated with large terrestrial impacts: Implications for the Chicxulub impact and K/T boundary stratigraphy, *Lunar and Planet. Sci.* XXIII, 1473-1474.

C-2.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Richard W. Vorder Bruegge
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CO-INVESTIGATORS: None

PROPOSAL TITLE: **Structural and Topographic Evolution of Maxwell Montes and Fortuna Tessera: Processes and Sequence of Events in Orogenic Belts on Venus**

Abstract

a. Mountain belts comparable to orogenic belts on Earth are observed in the Ishtar Terra Highland region of Venus. However, the specific mechanisms, sequence, and style of the deformation in the evolution of these mountain belts and their adjacent regions of tessera have yet to be thoroughly documented. Fortunately, the high-resolution synthetic aperture radar images and accompanying topographic data of the Ishtar Terra Highlands collected by the Magellan spacecraft now make it possible to examine and document the sequence and style of deformation in these areas at the sub-kilometer level. The work proposed here would address this problem through a phased approach over 3 years, beginning with the detailed structural and topographic mapping of the Maxwell Montes orogenic belt in Year 1, followed by an extension of this mapping work into the adjacent Fortuna Tessera complex ridged terrain in Year 2. During this time, the structural mapping of these regions would be explicitly linked to the detailed topography of these areas in order to produce three-dimensional views on the evolution of this region. A significant by-product of the first 2 years of effort would be a regional geologic map covering the area from 0° to 60°E and 50° to 75°N, corresponding to "Venus Quadrangle V-2." This map would be used place the detailed investigation of the Maxwell and Fortuna areas in a regional context. In Year 3, the focus of the study would turn to the Freyja Montes/ Itzpapalotl Tessera region, which would be mapped at a level comparable to that performed for Maxwell Montes and Fortuna Tessera, with the goal of comparing the evolution of these mountain belts and their adjacent complex ridged terrain in order to gain a better understanding of tectonic variations across Ishtar Terra and Venus.

b. New proposal.

c. Detailed structural and topographic mapping of the Maxwell Montes portion of Ishtar Terra will be performed in the first year of the proposed work. Features to be mapped include: anticlines, synclines, faults, scarps, and other features associated with folding, thrusting, and buckling of the crust; graben, fractures, and other features associated with extension or shear deformation; and any volcanic edifices or flows whose presence should be related to the thermal evolution of the belt. Once these features have been mapped, their stratigraphic relationships will be determined in order to define the sequence of tectonic deformation within the belt. Once mapping is complete, and the topographic and stratigraphic relationships are defined, kinematic models of the tectonic evolution of Maxwell Montes will be constructed in plan and cross-sectional views. These kinematic models will be the critical link for performing a regional geological synthesis and tying the observed deformation to models of crustal and mantle dynamics. Comparable work would be performed in years 2 and 3 for the Fortuna Tessera, Freyja Montes, and Itzpapalotl Tessera regions of Ishtar and correlated to the Year 1 work.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: John A. Wood
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Co-INVESTIGATORS:
(Name Only)

PROPOSAL TITLE: A Study of the Electrical Properties and Mineralogy of the Surface of Venus

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

a. Objectives. To carry out detailed studies of the relationship between altitude, the geological context displayed in SAR images, and radiothermal emissivity (e) as recorded in the Magellan dataset.

b. New proposal.

c. What will be done. Studies by Magellan and PVO of the emissivity (e) of Venus have revealed two types of surface material. Most of the planet is covered by material having e~0.85, a value expected for normal planetary material; but particular regions, mostly at high altitudes, display much lower values of e, which appears to require that they have special mineralogical and electrical properties. The difference can be understood in terms of the phase diagram applicable to surface rock in contact with the Venus atmosphere. Normal surface material is converted to the low-e mineralogy when it has been elevated to *high altitudes* (lower temperatures), or has been exposed to a *sulfur-rich environment* (volcanic emanations), for a *long enough time*. The transition may not occur if the primary surface material is *deficient in Fe* (magmatically evolved). Thus the distribution of low-e regions on Venus contains information about the chronology of volcanism and tectonism, and about rock compositions. The Magellan emissivity images of Venus (GeDR files) are rich in unexplored detail.

We wish to carry out detailed studies of the Venus emissivity record, in concert with photogeological studies of the correlated SAR images. Starting from the position that the first-order effect of altitude on e is understood (above), we will work to understand the *observed deviations* from this pattern: (1) High-altitude surface material on Venus sometimes does not display low e. This can mean the material was erupted at or elevated to high altitudes relatively recently, or that the rock is Fe-poor. (2) Low-altitude surface material sometimes has low e. Possible explanations for this phenomenon include seepage of S-rich volcanic emanations through the soil profile, and the recent movement of material from high to low altitudes. (3) In the majority of cases, where the first-order relationship between altitude and e holds, the altitude at which the changeover of e occurs is variable. This effect is not understood; it seems to imply less uniformity of the thermal structure of the Venus atmosphere than is currently understood to be the case.

d. Recent publications. Klose, K. B., J. A. Wood, and A. Hashimoto (1992) Mineral equilibria and the high radar reflectivity of Venus mountaintops. *J. Geophys. Res.*, in press. Robinson, C. A. and J. A. Wood (1992) Recent volcanic activity on Venus: Evidence from radiothermal emissivity measurements. *Icarus*, submitted.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: Yuk L. Yung
170-25
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California Institute of Technology
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Co-INVESTIGATOR: None

PROPOSAL TITLE: Water on Venus: Evolution and origin as constrained by present data

ABSTRACT:

(a) We consider three fundamental aspects of the problem of water on Venus: escape from the exosphere, dehydration in the middle atmosphere (by H_2SO_4 cloud), and source from the interior and impacts. Using the extensive currently available database acquired by Pioneer Venus, Magellan, Venera and ground-based observations, we propose to construct models of the atmosphere of Venus that will incorporate these observational constraints: (1) An improved model for the escape of light atoms H, D, ^{3}He and ^{4}He from the exosphere, (2) an updated photochemical model of the sulfuric acid clouds and their interaction with water vapor, (3) present degassing rate of H_2O as constrained by He flux and (4) the evolution history of water in the atmosphere of Venus.

(b) New proposal

(c) We will compute the escape efficiencies of the light atoms H, D, ^{3}He and ^{4}He due to charge exchange and via collisions with hot O atoms. This will determine the correct upper boundary conditions for these evolving gases, and the mean residence time of these gases. This will provide the proper stage for evaluating the various scenarios of atmospheric evolution.

(d) Y.L. Yung and W.B. DeMore, 1982. Photochemistry of the Stratosphere of Venus: Implications for Atmospheric Evolution. *Icarus*, **51**, 199-247.

Y.L. Yung and R. Dissly, 1992. Deuterium in the Solar System in *Isotope Effects in Gas-Phase Chemistry* (ed. J.A. Kaye), Amer. Chem. Soc., pp 369.(enclosed).

M.A. Gurwell and Y.L. Yung, 1992, Fractionation of Hydrogen and Deuterium on Venus Due to Collisional Ejection, *Planet. Space Sci.*, in press (enclosed).

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: James R. Zimbelman
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Co-INVESTIGATORS:
(Name Only)

PROPOSAL TITLE: Geologic and Tectonic Implications for Paleoslopes on Venus

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

a) Objectives: This proposal requests support to 1) produce geologic maps of areas on Venus where long (>100 km) lava flows are abundant, 2) use a three-dimensional numerical simulation of lava flow emplacement to derive constraints on the surface slopes that should have existed when the flows were emplaced, and 3) constrain possible tectonic deformation of the venusian surface through the difference between the reconstructed paleoslopes and the current topography observed by Magellan.
b) Prior Year: New proposal.
c) Proposed Work: 1) Produce three geologic maps (one per year) of areas on Venus which display abundant lava flows. Candidate quadrangles for mapping include V16, V52, V15, V61, V38, V44, and V36 (in decreasing order of preference); availability of base materials will determine the quadrangles to be mapped. 2) Simulate the emplacement of individual flows or flow units in the map area using a 3-D numerical code. Present topography will be modified until flow boundaries agree with mapped flows, resulting in paleoslopes which should have existed during emplacement. 3) Compare paleoslopes with present topography to quantify the magnitude and orientation of tectonic deformation that has occurred since flow emplacement, providing constraints on hypothesized global tectonic regimes for Venus.
d) Bibliography: a) Zimbelman, J.R., R.A. Craddock, and R. Greeley, Geologic map of the MTM -15147 quadrangle, Mangala Valles region of Mars, 1:500,000 scale (in Editorial review with USGS). b) Fink, J.H., and J.R. Zimbelman (1990) Longitudinal variations in rheological properties of lavas: Puu Oo basalt flows, Kilauea, Hawaii, in IAVCEI Proc. Volc. 2: Lava flows and domes (J.H. Fink, ed.), pp. 157-173. Springer-Verlag, New York.

PROPOSAL SUMMARY

PRINCIPAL INVESTIGATOR: M.T. Zuber
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CO-INVESTIGATORS: None

PROPOSAL TITLE: Venus Tectonics and Lithosphere Structure

ABSTRACT: (Type single-spaced below line. Lettered paragraphs (a) through (d) should include: a. brief statement of the overall objectives and justification of the work; b. brief statement of the accomplishments of the prior year, or "new proposal;" c. brief listing of what will be done this year, as well as how and why; and d. one or two of your recent publications relevant to the proposed work.)

(a) The broad objective of this work is to develop models of deformation of the Venus lithosphere that elucidate geodynamical processes and internal structure by providing a basis for interpretation of Pioneer Venus and Magellan data.

(b) New proposal.

(c) During this investigation we will: (1) analyze horizontal shortening of a lithosphere with laterally varying thickness for realistic rheological and compositional structures, and apply the models to understand the formation of fold and thrust belts and mountain belt-fringed plateau regions on Venus; (2) calculate effective elastic thicknesses of the Venus lithosphere using the coherence of gravity and topography and compare results to values derived from assumed flexural topographic profiles; and (3) investigate the mechanics of ridge belt formation through models of shortening of a lithosphere with a realistic vertical viscosity stratification and shallow viscous-plastic detachments, and models of convection of a Newtonian mantle overlain by non-Newtonian viscous lithosphere.

(d) Zuber, M.T., Ridge belts: Evidence for regional- and local-scale deformation on the surface of Venus, *Geophys. Res. Lett., 17,* 1369-1372, 1990.
Zuber, M.T. and E.M. Parmentier, The contribution of dynamic topography due to lithosphere compression to the structure of mountain belts and ridge belts on Venus (abstract), *Lunar Planet. Sci. Conf. XXIII,* 1595-1596, 1992.
Zuber, M.T., T.D. Bechtel, and D.W. Forsyth, Effective elastic thicknesses of the lithosphere and mechanisms of isostatic compensation in Australia, *J. Geophys. Res., 94,* 9353-9367, 1989.