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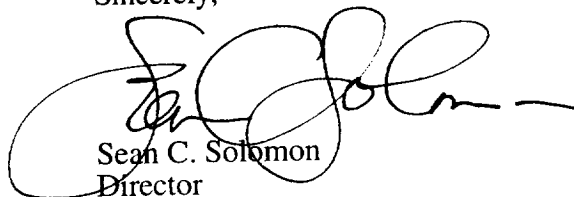
Ms. Antoinette Bigby  
Administrative Grants Officer  
Office of Naval Research, Atlanta Regional Office  
Suite 4R15  
100 Alabama Street, S.W.  
Atlanta, GA 30303-3104

Dear Ms. Bigby:

Please find enclosed a copy of the Final Technical Report for NASA Grant NAG 5-4077, entitled "Tectonic evolution of the terrestrial planets." The period of the grant extended from 1 April 1997 through 30 September 2001.

If you have any questions regarding this report, please contact me by phone (202/478-8850) or electronic mail (scs@dtm.ciw.edu).

Sincerely,



Sean C. Solomon  
Director

cc: Terry L. Stahl, DTM Fiscal Officer  
Jeffrey J. Lightfield, CIW Deputy Financial Manager  
David G. Senski, NASA Technical Officer  
Sandra R. Russo, NASA Grant Negotiator  
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**FINAL TECHNICAL REPORT**  
**to the**  
**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**  
**PLANETARY GEOLOGY AND GEOPHYSICS PROGRAM**

**NASA GRANT NAG 5-4077**  
**"Tectonic Evolution of the Terrestrial Planets"**

**for the period 1 April 1997 — 30 September 2001**

Principal Investigator: Sean C. Solomon  
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## Introduction

Grant NAG 5-4077, from the NASA Planetary Geology and Geophysics Program, supported a wide range of work on the geophysical evolution of the terrestrial planets during the period 1 April 1997 — 30 September 2001. We here provide highlights of the research carried out under this grant over the final year of the award, and we include a full listing of publications and scientific meeting presentations supported by this project.

Throughout the grant period, our group consisted of the Principal Investigator and several Postdoctoral Associates, all at the Department of Terrestrial Magnetism (DTM) of the Carnegie Institution of Washington. Postdoctoral scientists who were in the group for a portion of the grant period include Jonathan Aurnou (now on the faculty at U.C.L.A.), Andrew Dombard (now on the research staff at Washington University), Andrew Freed (now on the faculty at Purdue University), Steven Hauck (still at DTM), Catherine Johnson (now on the faculty at the University of California at San Diego), and Patrick McGovern (now on the research staff at the Lunar and Planetary Institute).

## Recent Progress

Highlights of the completed work from last year include the following:

- Our group completed a global analysis of gravity/topography admittance on Mars. The analysis makes use of topography and gravity collected by the Mars Global Surveyor spacecraft, the spatio/spectral localization methodology of Mark Simons and others, and the correction for finite-amplitude topography and interface relief of Mark Wieczorek and Roger Phillips. These procedures obviate the need to invoke anomalously dense surface material or buried excess masses in areas of highest admittance (e.g., Tharsis), as others have concluded. In general, the thicknesses of the Martian elastic lithosphere derived from a comparison of observed and forward modeled admittances decrease with the age of the loading feature, consistent with a general decline in mantle heat flux over Martian history.
- Our group also completed a more detailed analysis of the topography, gravity, and tectonics of Alba Patera in an effort to understand the evolution of one of the largest volcanic constructs on Mars. By combining finite-element models of loading with gravity/topography admittance analysis, we showed that sub-lithospheric and intrusive loads in addition to extrusive loads and regional extension played important roles in the evolution of the shape and deformation of the edifice.
- We participated in an analysis of the conditions under which the characteristics of a core in Mercury can be recovered by measurement of the obliquity, the second degree and order gravity field, and the amplitude of the physical libration forced by periodic solar torques. New work included demonstrations that core-mantle coupling by pressure forces on an irregular boundary, gravitational torques between an axially symmetric mantle and an axially asymmetric solid inner core, or magnetic coupling between a fluid metallic outer core and a conducting layer at the base of the mantle do not frustrate the conditions for recovering the state and radius of the outer core.
- Through finite-element models of loading of the lunar lithosphere by mascon maria, we showed that the absence of strike-slip faults around lunar mare basins predicted by many earlier models can be explained by including the effects of surface curvature, more complete fault-style criteria, multi-stage histories of mare flooding, and heterogeneous crustal strength. Specific models for Mare Serenitatis confirm earlier results that the underlying lithosphere was about 25 km thick at the time of local rille formation and had thickened to about 75 km by the time of late stage mare ridge formation, and that superposed global contraction is needed to account for the radial extent of mare ridges and the inferred cessation of rille formation prior to the time of emplacement of youngest mare basalts.

Each of the three postdoctoral scientists in our group during the past year carried out independent research that led to publications or to papers submitted for publication. Among these projects were the following:

- Postdoctoral scientist Andrew Dombard tested an earlier hypothesis that floor-fractured craters on the Moon may be the product of viscoelastic relaxation of topographically-induced stresses. Combining an elastoviscoplastic finite-element model and the ductile flow law of anhydrous diabase determined from recent laboratory measurements, it can be shown that relaxation is insufficient to produce the observed shoaling of floor depths in floor-fractured craters for a wide range of assumptions regarding local heat flux. Alternative hypotheses for the origin of floor fracturing (e.g., igneous intrusions) are therefore favored.

- Postdoctoral scientist Jonathan Aurnou carried out a numerical study of zonal wind generation by thermal convection in rotating spherical shells. He showed that for quasi-geostrophic, high-Rayleigh-number convection, particularly in thin shells with stress-free boundaries, strong zonal winds are predicted to be prograde (eastward) near the equator and westward at higher latitudes. Episodes of strong winds are predicted to alternate with episodes of strong convection. His models support the interpretation that the prograde equatorial jets on Jupiter and Saturn originate from deep convection.

- Postdoctoral scientist Steven Hauck completed a study of parameterized thermal history models for Mars that incorporated melt generation and fractionation of heat-producing elements during melting. Models providing the best matches to the timing of formation and present volume of crust on Mars have chondritic abundances of heat-producing elements, significant fractionation of these elements into the crust, and a mantle water content sufficiently high to lower the creep strength from that at dry conditions.

## **Publications**

During the period 1 April 1997 — 30 September 2001, grant NAG 5-4077 supported the publication of 27 articles, including 24 papers in refereed journals, one book chapter, one encyclopedia article, and one piece in a popular science magazine. In addition, the grant supported 65 published abstracts of presentations made at national and international scientific meetings.

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