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Final Report

GALILEAN SATELLITE GEOMORPHOLOGY

NASA GRANT NAGW - 139

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Task 1: Photometric and Photoclinometric Studies of Galilean Satellites

Research on this task consisted of the development and initial application of photometric and photoclinometric models using interactive computer image processing and graphics. Software was developed at the California Institute of Technology under the supervision of G. E. Danielson and transferred to Arizona State University for final applications uses.

New programs were developed to compute viewing and illumination angles for every picture element in a Voyager image using C-matrices and final Voyager ephemerides. These values were then used to transform each pixel to an illumination-oriented coordinate system. An interative integration routine permits slope displacements to be computed from brightness variations, and correlated in the cross-sun direction, resulting in two dimensional topographic data. Figure 1 shows a 'wire-mesh' view of an impact crater on Ganymede, shown with a 10-fold vertical exaggeration. The crater, about 20 km in diameter, has a central mound and raised interior floor suggestive of viscous relaxation and rebound of the crater's topography. Vertical resolution is approximately 100 m. Use of these data in geophysical modeling will be discussed in the next section.

In addition to photoclinometry, the computer models that have been developed permit an examination on non-topographically-derived variations in surface brightness. In order to conduct photoclinometric studies, albedo variations must be minimized or areally modelled, as must be the photometric function. Several anomalous photometric behavior patterns have been detected on Ganymede using these procedures. For example, prominent bright-rayed craters are proportionally bluer and appear to have a more sharply peaked phase function than less prominent (probably older) bright-rayed craters.

Additionally, some impact craters display reflectivity characteristics on sunward facing slopes that differ from those on cross-sun and terminator-facing slopes, particularly in the afternoon hemisphere. These variations may indicate transient, insolation-dependent phase changes (e.g. creation of ice fogs, etc.).

Albedo and color studies of cratered terrain, grooved terrain, smooth terrain, domes, moats, and bright and dark-rayed craters on Ganymede have been used as model inputs to geophysical studies. Similar measurements on Europa are currently being used in geologic mapping and preparation of geologic review papers.

Task 2: Geophysical Evolution of Ganymede and Callisto

Observations of the surface morphology of certain features on Ganymede and Callisto may be useful in constraining models of those satellites' geophysical evolution. Relaxation of relief owing to flow of icy materials, or variations in initial morphology owing to formation under different thermal conditions, are the principal observational characteristics. We have combined photometric and photoclinometric models of surface albedo and relief with geophysical models of parameterized convection and heat transfer within the satellites in order to test various factors and their influence on resultant geomorphic features.

Geophysical modelling was performed by R. J. Phillips at the Lunar and Planetary Institute and Southern Methodist University. Relief and albedo measurements were made at Caltech and ASU. Crater morphological characteristics, size-frequency, areal density, and terrain correlations were determined at ASU and compared with tabular and graphical data acquired from J. Plescia (JPL), R. Strom (U. of Arizona), and E.M. Shoemaker (USGS). Cratering flux models were acquired from R. Strom and A. Woronow (U. Houston), and from E. M. Shoemaker and R. Wolfe (USGS). Model parameters examined included: surface temperature (function of albedo and ice composition), fraction of chondritic radioactive heat sources in core, various parameters of ice rheology (including the exponent in a exponential-law viscosity), boundary layer thickness, regolith thickness, regolith thermal conductivity, and relief wave-number/crater depth, size).

The results of these models are graphical and tabular representation of the parametric inter-relations between factors. Additionally, by combining temporal variations in each parameter and adding relative cratering flux as determined on surfaces of different crater densities (presumably different ages) as a constraint, absolute cratering histories have been generated and compared with the present total size/frequency distribution. These results suggest that Ganymede may have formed with greater radiogenic heat, lower ice viscosity, and/or lower impacting flux rates than presently believed. This work is currently being prepared as a review article under follow-on funding.