

VARIATION OF STRESS WITH DEPTH IN GANYMEDE'S LITHOSPHERE:
IMPLICATIONS FOR TECTONIC EVOLUTION. M.T. Zuber and E.M. Parmentier,
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Bright terrain formed as a consequence of global tectonic activity on Ganymede (1). Variations in crater densities suggest that bright terrain formed over extended periods (1,2), but the cause of its formation remains unresolved. Expansion due to differentiation is one possible explanation (3), however it is important to determine whether bright terrain formation can be accounted for by radiogenic heating alone. Therefore it is necessary to determine the stress history at the satellite's surface and the variation of stress with depth for thermal histories which correspond to both a differentiated and undifferentiated interior.

Here we consider lithospheric stresses assuming that Ganymede has remained undifferentiated. The thermal history was determined for cold accretion, with heating due to chondritic abundances of U, Th, and K. The internal temperature (T_i) as a function of time was calculated using parameterized convection relationships (4) for a homogeneous, internally heated sphere. The variation of viscosity with temperature was described by $\mu = \mu_m \exp(A(T_m/T_i - 1))$ where μ_m and T_m are the viscosity and temperature at the melting point, and A is a constant related to the activation energy of creep.

The variation of near-surface horizontal stress (σ) with time and depth within a viscoelastic lithosphere due to volume change of the viscous interior and thermal stresses within the lithosphere was determined from

$$\frac{d\sigma}{dt} + \frac{\sigma}{\tau} = \frac{\alpha E}{3(1-\nu)} \left\{ \frac{dT_i}{dt} - \frac{z}{k} \frac{dq}{dt} \right\}$$

where $\tau = 6\mu(1-\nu)/E$ is the viscoelastic relaxation time, q is the heat flow, k is the thermal conductivity, z is depth, α is the volumetric coefficient of thermal expansion, E is Young's modulus and ν is Poisson's ratio.

The time-varying internal temperature is shown in Fig. 1 for a range of ice melting viscosities with $A=22$. The melting viscosity of high pressure ice was taken to be 10^{14} P (5). The presence of silicate mixed with the ice increases μ_m . From studies of particulates in viscous fluids (6), the expected viscosity increase for a silicate volume fraction of 0.5 is approximately a factor of 3. An increase in μ_m raises the temperature of the interior and causes the peak temperature to occur at a later time.

The variation of surface stress with time is shown in Fig. 2. The value of the surface stress is strongly dependent on the surface viscosity, taken here as 10^{26} P (7) for a surface temperature of 120K and μ_m of 10^{14} P. The stresses at early times for each value of μ_m exceed the tensile failure strength for ice of a few bars (8). These stresses are valid only until failure occurs on the surface. After failure occurs, the progressive fragmentation of the lithosphere will lead to the development of membrane stresses in unbroken lithospheric shells (9,10,11).

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The variation of stress with depth during Ganymede's early history is shown Fig. 3. Stresses are initially tensional and penetrate to considerable depths, but become confined to progressively shallower depths as the internal temperature increases. If the lithosphere is defined as the region which stores elastic stresses, and the width of bright terrain bands reflects the lithosphere thickness at the time of formation, then a knowledge of the stress distribution with depth may help correlate the width of bright bands with their age.

We are currently examining the case in which Ganymede's interior differentiated at the melting temperature of ice into a silicate core and icy mantle. In the core, the higher viscosity would be expected to result in higher temperatures. This would produce greater thermal expansion and surface stresses than in the undifferentiated case. However the time required for internal heating to higher temperatures would be longer, so that viscous relaxation of stresses would be of greater importance. Therefore, it is not clear whether stresses would be greater or less than for an undifferentiated interior, but the peak stress would occur later in time.

References. (1)Smith, B., *Science*, 204, 927 (1979). (2)Shoemaker, E., et al., *The Satellites of Jupiter*, Univ. Ariz. Press (1982). (3)Squyres, S., *Geophys. Res. Lett.*, 7, 593 (1980). (4)Turcotte, D. et al., *PLPSC X*, 2375 (1979). (5)Poirier, J. et al., *Nature*, 292, 225 (1981). (6)Happel, J. and Brenner, H., *Low Reynolds number hydrodynamics*, Prentice-Hall, NJ (1973). (7)Passey, Q. and Shoemaker, E., submitted to *JGR* (1982). (8)Gold, L., *J. Glaciol.*, 19, 197 (1977). (9)Turcotte, D., *Geophys. J. R. Astr. Soc.*, 36, 33 (1974). (10)Parmentier, E. and Zuber, M., *LPSC XIII*, 617 (1982). (11)McRinnon, W., *PLPSC XII*, 1585 (1981).

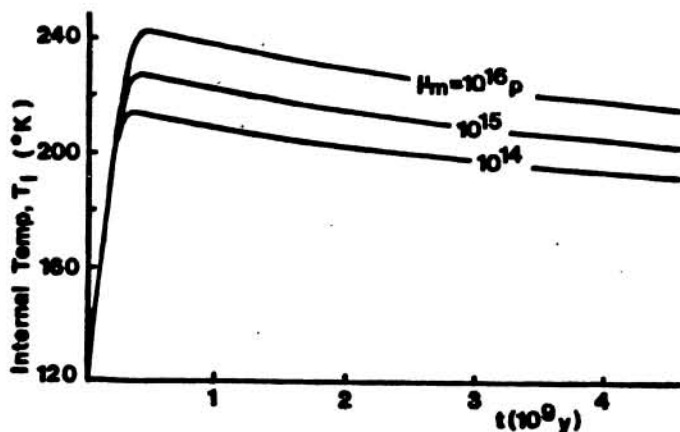


Fig. 1. Variation of internal temperature with time for an undifferentiated Ganymede for a range of ice melting viscosity.

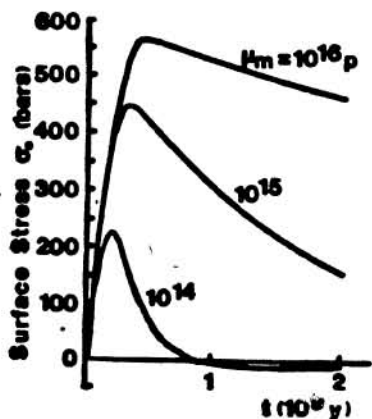


Fig. 2. Change in surface stress with time for a range of ice melting viscosity.

Fig. 3. Stress with depth for several times in Ganymede's early evolution for an ice melting viscosity of 10^{14} p.

