Geophysical Research Abstracts
Vol. 14, EGU2012-3847-2, 2012
EGU General Assembly 2012
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Modeling of Stress Triggered Faulting at Agenor Linea, Europa

A. L. Nahm (1), M. E. Cameron (1), B. R. Smith-Konter (1), and R. T. Pappalardo (2)

(1) University of Texas at El Paso, Department of Geological Sciences, El Paso, TX 79968 USA, (2) Jet Propulsion Laboratory, California, Institute of Technology, M/S 321-560, Pasadena, CA 91109 USA

To better understand the role of tidal stress sources and implications for faulting on Europa, we investigate the relationship between shear and normal stresses at Agenor Linea (AL), a ~1500 km long, E-W trending, 20–30 km wide zone of geologically young deformation located in the southern hemisphere of Europa which forks into two branches at its eastern end. The orientation of AL is consistent with tensile stresses resulting from long-term decoupled ice shell rotation (non-synchronous rotation [NSR]) as well as dextral shear stresses due to diurnal flexure of the ice shell. Its brightness and lack of cross-cutting features make AL a candidate for recent or current activity. Several observations indicate that right-lateral strike-slip faulting has occurred, such as left-stepping *en echelon* fractures in the northern portion of AL and the presence of an imbricate fan or horsetail complex at AL's western end.

To calculate tidal stresses on Europa, we utilize SatStress, a numerical code that calculates tidal stresses at any point on the surface of a satellite for both diurnal and NSR stresses. We adopt SatStress model parameters appropriate to a spherically symmetric ice shell of thickness 20 km, underlain by a global subsurface ocean: shear modulus G = 3.5 GPa, Poisson ratio ν = 0.33, gravity g= 1.32 m/s^2, ice density ρ = 920 kg/m^3, satellite radius R= 1.56 x 10^3 km, satellite mass M= 4.8 x 10^{22} kg, semimajor axis a= 6.71 x 10^5 km, and eccentricity e= 0.0094. In this study we assume a coefficient of friction μ = 0.6 and consider a range of vertical fault depths $z$to 6 km.

To assess shear failure at AL, we adopt a model based on the Coulomb failure criterion. This model balances stresses that promote and resist the motion of a fault, simultaneously accounting for both normal and shear tidal and NSR stresses, the coefficient of friction of ice, and additional stress at depth due to the overburden pressure. In this model, tidal shear stresses drive strike-slip motions, while normal stresses control a fault's frictional resistance to failure. According to this model,shear failure will occur when the shear stress exceeds the frictional resistance of the fault. We find that diurnal plus NSR stresses allow for shear failure along Agenor Linea; this result is very sensitive to fault depth, with the western end of the fault failing at shallow depths ($<$ 3 km) and the eastern end failing at 3 – 4 km depths.

Complementary to the stress accumulation model, we also calculate coseismic displacements along fault segments that meet the conditions for shear failure. Displacement calculations assume a conservative estimate of stress drop in the slip events, 10% of the total stress, although we also investigate the implication of complete stress drop in alternative models. Stress drops on the order of 10^{-1} MPa are calculated, consistent with terrestrial ice quake values of 10^{-4} – 10^{-1} MPa; resulting displacements reach a maximum of ~2 m. These displacements are used as input for the forward mechanical disclocation model COULOMB, where a fault surface is idealized as a rectangular plane for which the sense of slip, magnitude of displacement, fault dip angle, depth of faulting, and fault length are specified, and the Coulomb stress change in the volume surrounding the fault is calculated. Positive Coulomb stress changes (promoting failure) ranging between 0 and 1.0 MPa (mean 2.4×10^{-4} MPa) are calculated for vertical faults ~4 km long with depths of 3 – 4 km. These positive stress changes are primarily confined to small regions (~50 km in length) adjacent to the west and east tips of major strands with prescribed displacement, indicating fault growth is possible in these locations. Positive stress change is also observed at the intersection of the branches with the main fault, indicating that slip is likely to initiate there. Future work consists of evaluating other failure scenarios and range of stress drops and associated displacements combined with image and topographic analyses to test our model results.