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Field and Laboratory Observations Displaying Regularly Repeating Ruptures Beneath Glaciers

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We report on a pattern of repeating earthquakes associated with the flow of David Glacier through the Transantarctic Mountains. These events illuminate processes associated with slip of ice and more generally, stick-slip behavior of earthquake faults. We used data from the Transantarctic Mountain Seismic Experiment (TAMSEIS) network as well as GSN (Global Seismic Network) stations to examine the seismicity of the region in the period 2000-2010. The seismic events recurred regularly (approximately 20 minutes) for a 275-day span in 2001 and 2002. Before and after this 275-day period, the recurrence was more irregular. Source-location measurements determined that the events originated from the base of David Glacier. Analysis of P-wave first-motions indicate that the events are low-angle thrust faults with a fault-strike normal to the flow of David Glacier and a fault slip along flow. The events are of mean magnitude Mw=1.8 and are likely caused by an asperity beneath David Glacier that regularly releases stress accumulated by the flow of the glacier. We suggest that the change in seismic behavior is due to changes in debris concentration of the basal ice over time. The variation of debris load in contact with the asperity produces deformational alterations of the ice asperity system, resulting in the observed behavior.

In order to study how changes in entrained debris affects deformation of ice; we froze a number of ice samples with varying amounts of debris between 1-60% by weight. These samples of ice were sheared in a single direct shear apparatus against a piece of Westerly granite at velocities ranging from 3 to 300 microns per second under a normal load of 1.25 MPa. Frictional values were recorded for each sample of ice. Slide-hold-slide experiments were conducted, which report that an increase in hold time increased the strength of the ice, indicating healing was taking place. Velocity stepping tests were conducted showing a transition from a velocity strengthening to a velocity weakening material near a velocity of 10 microns per second. The transition had secondary effects imposed from the amount of debris contained within. We suggest that this measurement is compatible with our observations of the slipping behavior of David Glacier. Next, the stiffness of the shearing apparatus was reduced using springs to allow stick-slip behavior to occur at the low normal stresses (500 kPa) and shear stresses (150 kPa) that were used in the experiment. We successfully produced stick-slip behavior in the lab. Similarities between laboratory results and field observations are beginning to emerge which will help to scale from the one to the other.