unusual event within the past 10,000 years[3–5]. The recent rapid movement of the eccentric dipole towards the eastern hemisphere is associated with a gathering of magnetic field concentrations at high latitude in this hemisphere[3], and the appearance of a weak field anomaly in the south Atlantic region that has grown and moved towards the west. According to the numerical dynamo simulations of Olson and Deguen, similar rapid changes in the eccentric dipole position often occur when there is a drop in dipole intensity, particularly before significant directional changes such as full reversals of polarity or temporary excursions.

Olson and Deguen[5] use a rather simple numerical dynamo model to show how asymmetric growth of Earth's inner core may contribute to the observed eccentricity of the geomagnetic dipole. Extrapolation of the details of numerical dynamo calculations to the conditions of Earth's core remains controversial, but the prospect of fresh insights into the mechanism by which Earth's magnetic field operates is tantalizing. ❐

Christopher C. Finlay is at the National Space Institute, Technical University of Denmark, Kongens Lyngby, DK-2800, Denmark.
e-mail: cfinlay@space.dtu.dk

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PLANETARY SCIENCE

Slippery sliding on icy Iapetus

Enigmatically, some landslides flow farther than normal frictional resistance allows. Cassini images of Saturn's icy moon Iapetus reveal a multitude of long-runout landslides that may have been enabled by flash heating along the sliding surface.

Antoine Lucas

Friction is an unavoidable force of nature, on Earth and beyond. Some landslides, however, travel longer horizontal distances over shallow slopes than would be expected under the normal friction conditions of sliding rock. Several mechanisms have been proposed to temporarily reduce the friction for these long-runout landslides, such as lubrication by water or air, thermal pressurization, acoustic fluidization or flash heating[1–5]. An anomalous reduction in friction is not limited to Earth environments; mass wasting processes are common on other planetary bodies, and long-runout landslides have been observed on terrestrial planets and the icy satellites[6–8]. Combined, these different planetary environments make up a laboratory for testing hypotheses of landslide emplacement. Long-runout avalanches on cold and airless icy satellites challenge existing explanations for reduced friction. Writing in *Nature Geoscience*, Singer and colleagues[9] present analyses of long-runout landslides on Saturn's moon Iapetus and propose that frictional heating of icy avalanche rubble makes the interface between avalanche and ground slippery.

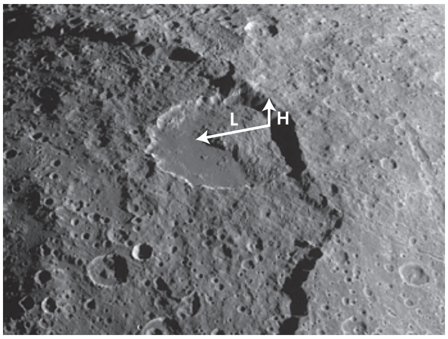

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Figure 1 | Images from the Cassini ISS probe reveal numerous landslides across the surface of Iapetus. Originating from unstable slopes such as steep crater walls, these landslides often flow greater distances (L) than expected for their fall heights (H) under the normal frictional properties of ice. Singer *et al.*[9] propose that such long-runout landslides can be explained by a slippery sliding surface caused by frictional heating during the landslide.

Landslides are often characterized by the ratio of drop height to runout length. This ratio has been frequently used to approximate the friction coefficient for terrestrial and martian landslides[6,10]. For landslides on Earth and Mars, the height–length ratio decreases with increasing landslide volume[6], starting from a value of 0.6 for a purely frictional sliding mass with a small volume of less than 100,000 m^3, and dropping to values lower than 0.07 for large volumes of more than 16 km^3.

Understanding these events is important for landslide disaster mitigation and management on Earth. However, the underlying mechanisms that control these landslides are the subject of an active debate, in part because of the limited available data. Planetary exploration has revealed that long-runout landslides are ubiquitous throughout the Solar System, and these far-flung landslides have much to teach us about their underlying causes.

Singer and colleagues[9] catalogued mass wasting deposits on icy Iapetus. They use data from the Cassini mission and photogrammetric techniques to map Iapetian landslides. In doing so, they assembled the largest data set of landslides beyond Earth and Mars. They found that, like Earth and Mars, Iapetus is rife with mass movements, including long-runout landslides. The conditions on Iapetus are particularly favourable for landslide triggering, both because topographic relief is great relative to the moon's small size and because the moon's surface is ancient. Therefore, there are many precarious slopes that are vulnerable to collapse. As a laboratory of mass wasting investigations, Iapetus is a rare gem in having a large number of long-runout landslides that formed in similar environmental conditions, and readily available spacecraft data to study them.

According to Singer and colleagues' measurements, typical height–length ratios of landslides on Iapetus lie between 0.1 and 0.3. On the lower end, this is analogous to terrestrial submarine landslides and mudflows; the upper end is comparable to small subaerial rock avalanches on Earth or large landslides on Mars. Unlike those on Earth and Mars, the Iapetian landslide ratio does not show a dependence on the size of the landslide. However, laboratory measurements[11] indicate friction coefficients of low-temperature water ice (around 0.7) that would prohibit such long-runout landslides on the icy moon's surface. A frictional weakening mechanism must therefore be at work on Iapetus.

Singer *et al.*[9] propose that the most likely cause of the long-runout landslides on Iapetus is frictional heating of the icy rubble by shear along sliding surfaces until they become slippery. Although similar mechanisms employing basal melting — whether involving the melting of ice or rock — have also been proposed for long-runout landslides on Earth and Mars[2,3,12], further studies are needed to test this explanation. It has been shown that friction is not always well approximated by the ratio of landslide height to length because of geometric biases and topographic effects[13,14]. Further constraints on topography and landslide volume are therefore needed for better estimates of the frictional weakening behaviour during landslide emplacement.

Numerical modelling has shown that friction for long-runout landslides on Mars is very low[15] and, according to Singer *et al.*[9], similar values are expected on Iapetus. Moreover, further work with the data set could differentiate between landslides and rock falls, which are likely to have different formation mechanisms (for example, rock avalanche as opposed to cliff collapse). Despite these caveats, flash heating is a reasonable hypothesis to explain long-runout avalanches on Iapetus. The upcoming European Space Agency's JUICE (Jupiter Icy Moon Explorer) mission, set to launch in 2022, might provide data to test this hypothesis on the other icy satellites, for long-runout landslides as well as faults cutting the icy crusts, which might show similar frictional weakening.

Singer *et al.*[9] show that, with its many landslides and relatively simple surface conditions (as compared with warmer, wetter planets), Iapetus is a useful playground for landslide science. At first glance, Earth and a small icy satellite such as Iapetus may seem nothing alike, but many of the same geomorphic processes are observed. Understanding the long landslides on Iapetus may help us to understand the causes of similar destructive events on our own planet. ❐

Antoine Lucas is at the Division of Geological and Planetary Sciences, California Institute of Technology, 1200 East California Boulevard, Pasadena, California 91125, USA.
e-mail: alucas@caltech.edu

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