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Magnetic reversals and the geodynamo: a whole-Earth perspective (Petrus Peregrinus Medal Lecture)

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Polarity reversals and excursions are the most extreme forms of geomagnetic variability and are defining properties of the geodynamo. Advances in resolving the paleomagnetic field structure during polarity reversals has been matched by advances in modeling the reversal process in the core using first principles numerical dynamos. This talk surveys recent progress on understanding how magnetic reversals occur in the core and their significance for the dynamics of the mantle-core system. Numerical dynamos show that the dipole field intensity decrease usually seen in paleointensity records prior to reversals corresponds to the accumulation of reversed magnetic flux inside the core, with reversed flux spots emerging on the core-mantle boundary. Reversed flux often develops in one hemisphere then spreads throughout the core, producing a weak multipolar transition field out of which the new polarity emerges. Polarity excursions represent metastable polarity reversals, according to dynamo models. Although individual geomagnetic reversals are essentially random events, their sequencing shows more regularity, with periods of frequent reversals alternating with superchrons over an approximately 200 Myr. cycle. Numerical dynamos explain this sequencing in terms of core-mantle interaction. Because the average frequency of reversals increases with the length of the day and with the vigor of convection in the core, the normal secular cooling of the core and tidal deceleration of Earth's rotation produce little change in reversal frequency over time, whereas fluctuations in lower mantle convection related to deep subduction and super-plume formation and collapse events produce large changes in reversal frequency, with superchrons corresponding to quiet times in the core.