Apparent and True Polar Wander and the Geometry of the Geomagnetic Field in the Last 200 Million Years

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We have constructed new synthetic Apparent Polar Wander Paths (APWPs) for the African, Antarctic, Australian, European, Greenland, Indian, and North and South American plates over the last 200 Ma. We have used a selection of 19 paleomagnetic data from DSDP sites, 2 poles computed from skewness of marine magnetic anomaly profiles in the Indian Ocean and 221 cratonic paleomagnetic poles. A total number of 242 independent data has been retained, with a good distribution of site longitudes (ranging from 120 W to 155 E). Updated kinematic models allowed us to relate the paleomagnetic data of all plates over the entire period of interest and to construct a master synthetic APWP, using the data of all plates transferred onto a single one and averaging them within 10 and 20 Ma sliding windows. Moderately far-sided poles are consistent with a persistent quadrupole moment (on the order of 3% of the dipole over the last 200 Ma), but its amplitude can be neglected for most applications and in that sense the geocentric axial dipole (GAD) hypothesis is confirmed on the time scales of interest to our study. The successions of tracks, standstills, loops, and directional changes for all APWPs are discussed. The overall shape of the Eurasian and North American APWPs between 150 and 50 Ma confirms the existence of a loop, though somewhat smaller and more complex than previously recognized. The timing of the so-called Cretaceous standstill appears to be slightly later than previously thought: 60-120 Ma rather than 70-130 Ma, and a cusp occurs near 140 Ma. Paleomagnetic and (Indo-Atlantic) hotspot APW are then compared, and a new determination of "true polar wander" (TPW) is derived, with both 10 and 20 Ma time window averaging. Under the (debatable but reasonable) hypothesis of fixed Atlantic and Indian hotspots, we confirm earlier findings that true polar wander appears to be episodic in nature, with periods of (quasi-) standstill (Jurassic, Late Cretaceous/Tertiary) alternating with periods of faster TPW (in the Cretaceous and most convincingly in the last 10, or even 3 Ma). The typical duration of these periods is on the order of a few tens of millions of years (50 Ma) with wander rates

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during fast tracks on the order of 30 to 50 km/Ma. A total TPW of some 30 is suggested for the last 200 Ma, but data and hypotheses prior to 130Ma are less robust than since then. We find no convincing evidence for episodes of superfast TPW such as proposed recently by a number of authors. We use our master synthetic APWP to predict the latitude evolution of test points in North America, South Africa and India, and compare those with estimates derived in the hotspot and TPW reference frames. We show that these three "latitude estimates"are mutually consistent. Comparison over the last 130 Ma of TPW deduced from hotspot tracks and paleomagnetic data in the Indo-Atlantic hemisphere with an independent (and methodologically distinct) determination for the Pacific plate supports the idea that, to first order TPW is a truly global feature of Earth dynamics. Comparison with numerical modelling estimates of TPW shows that all current models still fail to some extent to account for the observed values of TPW velocity, and for the succession of standstills and tracks which is observed.