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Phanerozoic polar wander, palaeogeography and dynamics

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ABSTRACT

A significant number of new palaeomagnetic poles have become available since the last time a compilation was made (assembled in 2005, published in 2008) to indicate to us that a new and significantly expanded set of tables with palaeomagnetic results would be valuable, with results coming from the Gondwana cratonic elements, Laurentia, Baltica/Europe, and Siberia. Following the Silurian Caledonian Orogeny, Laurentia's and Baltica's Apparent Polar Wander Paths (APWPs) can be merged into a Laurussia path, followed in turn by a merger of the Laurussia and Siberia data from latest Permian time onward into a Laurasian combined path. Meanwhile, after about 320 Ma, Gondwana's and Laurussia/Laurasia's path can be combined into what comes steadily closer to the ideal of a Global Apparent Polar Wander Path (GAPWaP) for late Palaeozoic and younger times. Tests for True Polar Wander (TPW) episodes are now feasible since Pangaea fusion and we identify four important episodes of Mesozoic TPW between 250 and 100 Ma. TPW rates are in the order of 0.45–0.8°/M.y. but cumulative TPW is nearly zero since the Late Carboniferous. With the exception of a few intervals where data are truly scarce (e.g., 390–340 Ma), the palaeomagnetic database is robust and allows us to make a series of new palaeogeographic reconstructions from the Late Cambrian to the Palaeogene.

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1. Introduction

Since the advent of the understanding of plate tectonics, Earth scientists have wanted to know where the continents lay in past ages, partly from curiosity, but partly so as to understand biodiversity, climate change and where best to search for natural resources. The chief tool in deciphering palaeogeography has been and remains palaeomagnetism, the study of the Earth's magnetic field preserved in rocks. The Earth's ancient magnetic field has provided one of the most fundamental markers used to document the motion of the continents and evolution of the Earth. Changes in ancient magnetic polarity at irregular intervals are recorded in the surface rock record, and over some fifty years, palaeomagnetic data have been used to create the geomagnetic time scale, to firmly document seafloor spreading, to validate plate tectonics, and to reconstruct vanished supercontinents.

Palaeomagnetic results can conveniently be expressed in terms of palaeopoles that are calculated using the geocentric axial dipole field model. In turn, those palaeopoles can be used to construct Apparent Polar Wander Paths (APWPs). This way, instead of plotting the motion of a continent while holding the rotation axis fixed, the motion of the polar axis relative to the continent is visualised (Fig. 1). The motion of continents relative to the Earth's spin axis may be either due to the drift of individual continents or due to a rotation of the entire Earth relative to its spin axis — the latter is called True Polar Wander (TPW). Creer, Irving and Runcorn were the first to publish an APWP for 'Europe' as early as 1954 (Creer et al., 1954), based on late Precambrian to Eocene palaeomagnetic poles from Britain. Those poles all differed markedly from the present-day pole and were interpreted at first as due to a slow change in the axis of rotation of the Earth with respect to its surface, i.e. TPW. Two years later, however, Runcorn (1956) published an APWP for North America and this allowed him to compare the European and North American paths. He noted that they were broadly similar in shape, but some 30° apart in longitude, which he interpreted as caused by the opening of the modern Atlantic. This was the first independent geophysical evidence for 'continental drift' (sensu Wegener, 1912).

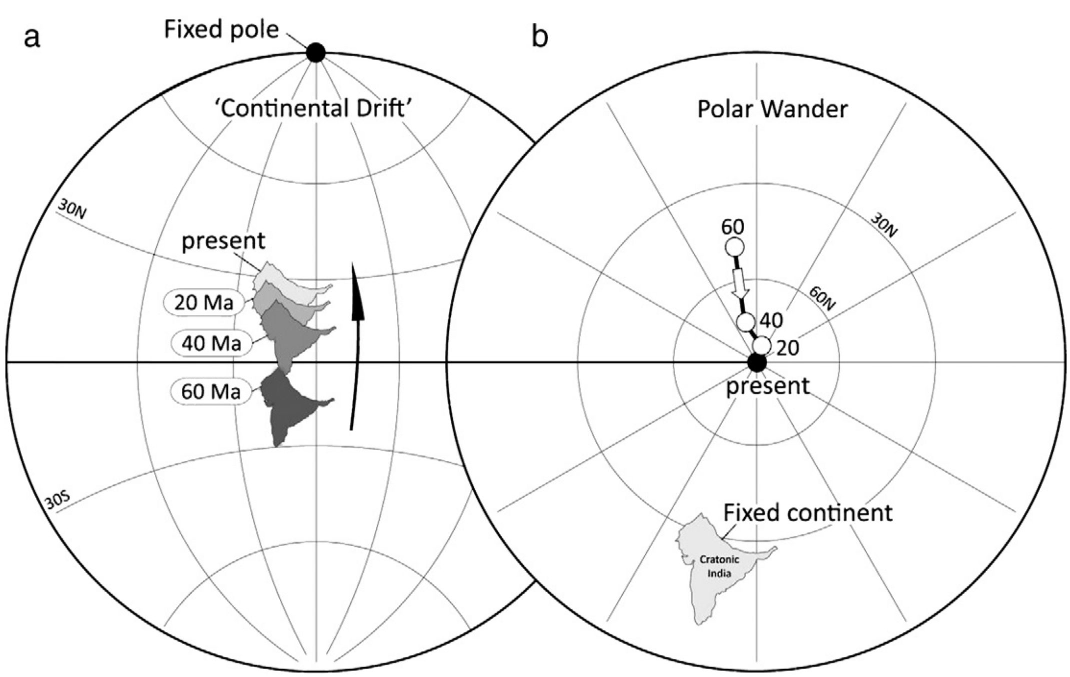

Fig. 1. In (a) the situation depicted is that of a moving continent and a fixed polar axis; this used to be called "continental drift" before the term "plate tectonics" took over. As the continent drifts steadily northward during the last 60 million years, the magnetic field direction at a site in the continent gets recorded by rocks, which then retain a memory of these changing directions (declination and inclination) as a function of time. In (b) the situation is that the continent stays fixed, but that the polar axis is left to wander while following a path called Apparent Polar Wander Path. The word "apparent" denotes the caution that this wandering may or may not be real and that in reality the situation could be as in (a). The sequential locations of the poles are calculated from the declinations and inclinations in the Indian rocks. If all continents show the same Apparent Polar Wander Path, then they shared the same coherent motion with respect to the pole. In that case, it is warranted to call the path a True Polar Wander Path. Figure is based on Tauxe (2009) but here we show palaeomagnetic poles (60, 40 and 20 Ma) and reconstructions of India based on the global APWP developed in this paper. Stereographic (Wulff) projection.