Elucidating the role of deep mantle plumes in mantle convection is challenging because their influence on seismic waveforms – which could be used to map their location – is subtle. Previous seismic studies have mainly focused on waveform modelling and inversion (i.e. tomography). In this study we instead consider the potential visibility of mantle plumes using array methods. We investigate, in particular, how plumes deviate seismic energy from the great-circle path. This requires a multidisciplinary approach: first, we perform geodynamic modelling to generate thermochemical plumes, and convert them to “seismic” plumes via thermodynamic modelling of mineral physics data. Next, spectral element methods are used to model the interaction of seismic waves with the plumes and generate synthetic seismograms. These seismograms are divided into arrays and we generate slowness-backazimuth plots for each array. With recent advances in computational methods and resources, we investigate wave behaviour at previously unattainable frequencies. We find that plumes do indeed cause seismic waves to change direction, although the exact behaviour may be frequency-dependent, and at low frequencies we observe waves apparently bending around the plume conduit. We consider how and where these results may be applied to real seismic arrays, to provide new constraints on the location and structure of mantle plumes.