The lowermost mantle is driven to Earth's surface by mantle plumes, providing a volcanic record of its structure and composition. Plumes consist of a head and tail, which melt to form large igneous provinces (LIPs) and ocean island basalts (OIBs), respectively. Recent analyses have shown that such sites of volcanism exhibit tungsten (W) isotope heterogeneity that was created in the first ~60 million years of our solar system's evolution. Moreover, the isotopic signature found in LIPs differs to that found in OIBs, revealing that the melt products of plume heads must be dominated by a different ancient mantle reservoir to that of plume tails. However, existing geodynamical studies show that plume heads and tails sample the same deep-mantle source region, and, therefore, cannot account for any systematic differences in composition. Here we propose an isotopic model that can account for the W signature of LIPs and OIBs and present a suite of numerical simulations that highlight the conditions under which such a model is dynamically feasible. Our simulations demonstrate that the W isotope systematics of LIPs and OIBs can, under certain conditions, arise as a dynamical consequence of plumes forming in a heterogeneous, thermo-chemical boundary layer. We also show that ultra low-velocity zones (ULVZs), which sit on the core-mantle boundary (CMB), likely contribute to the chemical diversity observed in OIBs but not LIPs. This study places geochemical observations from Earth's surface in a geodynamically consistent framework and illuminates their relationship with seismically imaged features of the deep mantle.