Geophysical Research Abstracts, Vol. 9, 08998, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-08998

Estimating the width of the upwelling region at mid-ocean ridges from the effect of small-offset transforms on plume-influenced ridges: Implications for the dynamics of 'normal' and plume-influenced mid-ocean ridges

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The fundamental question "How wide is the upwelling and melting region beneath mid-ocean ridges (MORs)?" remains a subject of ongoing debate after 4 decades of intensive study. The basic observational difficulty is that lateral melt migration has the potential to bring melt produced within a wide subaxial region to the 2km-wide neovolcanic zone that has been observed to be the site of almost all oceanic crustal emplacement. Here we use an indirect approach to infer this width from the minimum length of the ridge-offsets that mark the limits of the 'region of influence' of on-ridge plumes on the axial relief, axial morphology, and crustal thickness along the ridge – e.g. as seen along ridge segments influenced by the Galapagos and Iceland plumes, and at the terminations of fossil volcanic rifted margins and the paleo-Azores plume-ridge interaction. We adopt Vogt's [1972] hypothesis for along-ridge asthenospheric flow in a narrow vertical slot beneath the axis of plume-influenced 'macro-segments'. We find that: (1) There is a threshold distance to the lateral offsets that bound plume-influenced macrosegments; all such 'barrier offsets' are greater than 30km, while smaller offsets do not appear to be a barrier to along-axis flow. (2) Recent seismic and E-M observations along the southern EPR are consistent with a narrow westward-dipping subaxial slot. (3) A similar pattern is seen in the often abrupt transitions between volcanic and non-volcanic rifted margins, which is discussed in a companion presentation by Ranero and Phipps Morgan (this meeting). (4) The bathymetric and geoid gradients along the Reykjanes Ridge and Galapagos Spreading Center constrain the viscosity of

subaxial slot to be about $10^{16} - 10^{17} Pa - s$ in order for lateral flow along the axial subway to resupply asthenosphere consumed by plate spreading. (5) A 30km width for the region of ridge upwelling and melting offers a simple conceptual explanation for the apparent 30km threshold length for the existence of strike-slip transform faults and the occurrence of non-transform offsets at smaller ridge offset-distances. (6) It also offers a simple conceptual explanation for the largest scale of segmentation of axial relief seen at fast-spreading ridges; these 500-1000km ‘long wavelength undulations of the axis’ (Macdonald et al., 1989) may be macro-segments sharing a single contiguous subaxial slot that is bent but not broken beneath non-transform offsets. (7) If asthenosphere consumption by plate-spreading is less than plume-supply into a macro-segment, then the shallow seafloor and excess gravitational spreading stresses associated with a plume-influenced ridge will lead to growth of the axial slot by ridge propagation, propagation that continues until the offset of the associated migrating shear zone becomes long enough to halt it. We think this is a promising conceptual framework with which to understand the dynamic similarities and differences between plume-influenced and ‘normal’ mid-ocean ridges.