# Buoyant asthenosphere affects mid-ocean ridge depths and melt patterns

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The East Pacific Rise (EPR) is the fastest spreading ridge yet it is deeper that most other spreading centers. Along the 5000 km of the EPR the depth averages 400 m greater than the adjacent Pacific-Antarctic Ridge [1]. The other very deep section of ridge is the Australian-Antarctic Discordance (AAD). Analytic and numerical models show that dynamic thinning of asthenosphere with a lower density than the underlying mantle can explain the magnitude and wavelength of the depth anomalies along the EPR and the AAD [2]. At the EPR, fast plate divergence thins the asthenosphere by both sequestering it into diverging lithosphere and dragging it with the plates in contrast to the slower spreading, but faster migrating PAR [1]. The AAD asthenosphere is greatly thinned because of the restriction of asthenospheric flow due to nearby thick continental lithospheric roots combined with a moderately fast spreading rate [2]. The ADD is a major isotopic boundary. This can be explained if there is efficient mixing within the low-viscosity asthenosphere of the Indian and Pacific Ocean basins. Low-viscosity, low-density asthenosphere that is thinned beneath a spreading center should accentuate the asymmetry in melting related to migration of a spreading center as illustrated in Figure 1. This may help explain the observed pattern of oceanic crustal thickness variations as a function of ridge offsets and spreading directions [3].

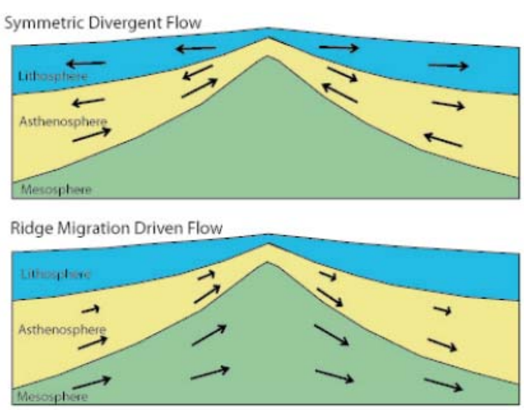


**Figure** 1: Flow under a migrating ridge should combine the effect of divergent and migration driven flow, but the asymmetry of upwelling and melting is accentuated due to relief on the base of the buoyant asthenosphere.

[1] Small, and Danyushevsky (2003) *Geology* **31**, 399-402. [2] Buck, Small and Ryan (2009) *Geochemistry, Geophysics, Geosystems* **10**, doi:10.1029/2009GC002373. [3] Carbotte, Small and Donnelly (2004), The influence of ridge migration on the magmatic segmentation of mid-ocean ridges, *Nature* **429**, 743-746.

# Using automated mineralogy to evaluate bioaccessibility of Pb-bearing mine waste

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The toxic effects of Pb, especially on children, are well known. The concentration of Pb in waters draining mine tailings tends to be low due to the relative insolubility of galena (PbS) and weathering products such as anglesite ($PbSO_4$). A more hazardous route of exposure is the direct ingestion of windblown dust or contaminated soil, particularly if the ingested material contains the Pb carbonate mineral cerussite ($PbCO_3$), a highly bioaccessible form of Pb.

Detailed mineralogical examination of mine tailings from the New Calumet Pb-Zn mine in Quebec has shown that after decades of subaerial exposure, almost all Pb is hosted in primary galena and secondary cerussite ($PbCO_3$), with only trace amounts of anglesite and massicot (PbO). Some of the goethite formed from alteration of pyrrhotite contains detectable Pb.

Simulated gastric fluids (pH=1.5) were used to evaluate Pb bioaccessibility in the <250 micron fraction of six near-surface tailings samples ($Pb_{total}$=1740-4730 $mgkg^{-1}$). The percent of Pb that is bioaccessible ranges from 23% to 69% and is not correlated with total Pb. The bioaccessible Pb for some samples is below industrial soil clean-up criteria.

Automated SEM-based mineralogy provides the opportunity to rapidly characterize thousands of Pb-bearing particles in terms of mineralogy, grain size and degree of liberation from armouring silicates, all features which control bioaccessibility. We have used a FEG-SEM instrument with the Mineral Liberation Analyzer (MLA) software suite to characterize and quantify the Calumet tailings samples. MLA was developed for the metallurgical industry but has increasing environmental applications due to its ability to characterize fine grained sediments including tailings. Some difficulties were presented in distinguishing galena (low bioaccessibility) and cerussite (high bioaccessibility), due to overlapping peaks between S and Pb but these issues have been largely resolved with careful development of a standard reference library within the MLA software and use of X-ray mapping of Pb-bearing grains.

Sample GD-nonVEG (bioaccessibility = 38% Pb) is more fine grained with respect to all particles than sample MS-nonVEG (bioaccessibility = 23% Pb). The ratio (by analyzed area) of cerussite to galena is higher in MS-nonVEG than sample GD-nonVEG, which is contrary to what is expected based on the relative bioaccessibilites of these two minerals, but particle size analysis indicates that cerussite grains are larger in sample MS-nonVEG. Smaller particles have a larger surface area and are more leachable and bioaccessible, which may explain why GD-nonVEG is more bioaccessible while having relatively less cerussite. Research is continuing with efforts to improve the distinction of galena and cerussite and to better characterize very fine grained material.