Treasure maps, sustainable development, and the billion-year stability of cratonic lithosphere

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Sustainable development and transition to a clean-energy economy is placing ever-increasing demand on global supplies of base metals (copper, lead, zinc and nickel). Consumption over the next ~25 years is set to exceed the total produced in human history to date, and it is a growing concern that the rate of exploitation of existing reserves is outstripping discovery of new deposits. Therefore, improvements in the effectiveness of exploration are required to reverse this worrying trend and maintain growth in global living standards.

Approximately 70\% of known lead, 55\% of zinc and 20\% of copper has been deposited between 2 Ga and recent by low temperature hydrothermal circulation in shallow sedimentary basins. These basins are formed by extension and rifting, which are key manifestations of the plate-mode of tectonics. Despite 150 years of research, the relationship between deposit locations and local geological structure is enigmatic and there remains no accurate technique for predicting their distribution at continental scales.

Here, we show that modern surface wave tomography and recent parameterisations for anelasticity at seismic frequencies can be used to map lithospheric structure, and that sediment-hosted base metal deposits occur exclusively along the edges of thick lithosphere. Approximately 90\% of the world's sediment-hosted copper, lead and zinc resources lie within 200 km of these boundaries, including all giant deposits (>10 megatonnes of metal). Incorporation of higher resolution regional seismic studies into global lithospheric thickness models further enhances the robustness of this relationship.

This observation implies that lithospheric architecture imparted by the plate-mode of tectonics is stable over billion-year timescales, and that there is a genetic link between lithospheric scale processes and near-surface hydrothermal mineral systems. Our new maps provide an unprecedented global means to identify fertile regions for targeted mineral exploration, and provide a clear economic justification for funding targeted seismic arrays, theoretical advances in imaging techniques, and geodynamic studies that improve our understanding of deep-time plate
tectonics.