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Global distribution of sediment-hosted metals controlled by steps in lithospheric thickness

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The ongoing transition to a greener economy is driving unprecedented global demand for base metals. With the pace of deposit discovery currently declining, there is a pressing need to open up new frontiers for mineral exploration and improve success rates. A consensus is emerging that many of the largest remaining continental discoveries are likely to lie beneath post-mineralisation cover in ancient sedimentary basins. However, these basins cover ~75% of the continental surface and the key mineral system ingredients of evaporites associated with brine formation, felsic and mafic volcanic rocks for sourcing metals, and organic-rich shale precipitation sites, are widespread. Accordingly, an additional geological control is required to explain the spatial distribution of existing deposits and narrow the search-space for discoveries. Here, we exploit recent laboratory experiments that constrain the relationship between seismic velocity and temperature at upper mantle conditions to derive global maps of lithospheric thickness from seismic tomographic models. We find that 85% of sediment-hosted base metals, including all giant deposits (>10 Mt of metal), occur within 200 km of the transition between thick and thin lithosphere at the edges of cratons. The probability of obtaining this result if sediment-hosted deposits were randomly distributed is less than 1 in 1012, making the correlation exceptionally robust. This relationship can be explained by considering the thermomechanical structure of thick lithosphere and its effect on basin dynamics. We find that melt depletion-induced reduction in the density of cratonic roots leads to greater subsidence during rifting, while the relative thickness of the lithospheric template results in more modest geothermal gradients and lower heat flow into the base of the sediment pile. These effects combine to enlarge the depth extent over which hydrothermal circulation within the basin is favourable to metal transport and precipitation, promoting the formation of giant deposits. Significantly, mineralisation ages span the last 2 billion years, which implies the cratonic edges that result from this rifting process are generally stable and suggests a genetic link between deep Earth processes and near-surface hydrothermal mineral systems. This discovery provides a global framework for identifying fertile regions for targeted mineral exploration, reducing the search-space for new deposits by two thirds on this lithospheric thickness criterion alone. We suggest that integration of this new constraint with existing knowledge of other mineral system components could dramatically decrease risk of exploration in frontier areas such as the undercover southern portion of the Mount Isa Province and previously underexplored basins along the margin of the Kimberley and Pilbara cratons in Australia.