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Geodynamic controls on sediment-hosted lead-zinc deposits in continental rifts

Anne C. Glerum[1], Sascha Brune[1,2], Joseph M. Magnall[1], Philipp Weis[1,2], and Sarah A. Gleeson[1,3]
[1]GFZ German Research Centre for Geosciences, Potsdam, Germany (acglerum@gfz-potsdam.de)
[2]University of Potsdam, Potsdam, Germany
[3]Freie Universität, Berlin, Germany

The growing global demand for metal resources requires new high-grade ore deposit discoveries. Known large sediment-hosted clastic-dominated base metal deposits predominantly occur in failed continental rifts and the passive margins of successful rifts. Understanding the large-scale geodynamic controls on rift-related mineralizing processes occurring on much smaller spatial and temporal scales can thus help identify new areas for exploration.

We numerically model 2D rift systems from inception to break-up with the geodynamic code ASPECT (Kronbichler et al., 2012; Heister et al., 2017) coupled to the landscape evolution model FastScape (Braun and Willett, 2013; Neuharth et al., 2022). With ~300-m resolution simulations, we investigate how rift type and the efficiency of sedimentary processes affect the formation of potential metal source and host rock domains, identified by their lithology and temperature. We subsequently analyse the optimal alignment of these domains where metals are respectively leached and deposited with faulting events providing potential fluid pathways between them (e.g., Rodríguez et al., 2021). For favourable co-occurrences of source, pathway and host, we identify the tectonic conditions that predict the largest clastic-dominated lead-zinc deposits.

We show that the largest potential for metal endowment is expected in narrow asymmetric rifts at a distance of several tens of kilometres to the shore (Glerum et al., 2023). Characterized by rift migration, these rifts generate a wide and a narrow conjugate margin. On the narrow margin, the long-lived border fault accommodates a thick submarine package of sediments, including deep permeable continental sediments and shallower layers of organic-rich sediments. Elevated temperatures from continued thinning could lead to fluids leaching metals from the permeable sediments. Both the border fault and later synthetic faults can provide fluid pathways from the source to the shallow host rock in potential short-lived mineralisation events. In wide rifts with rift migration, these favourable configurations occur less frequently and less potential source rock is produced, limiting potential metal endowment. In simulations of narrow symmetric rifts, the potential for ore formation is low. Based on these insights, exploration programs should prioritize identifying exhumed ancient narrow margins formed in asymmetric rift systems.

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