

Understanding the Importance of Heavy Mineral Sands as a Source of Rare Earth Elements, Using a Mineral Systems Approach

Paul Duuring, Christopher Gonzalez, Ignacio González-Álvarez, **Sidy Morin-Ka**^{1,2}

¹University of Western Australia, Perth, Australia, ²Geological Survey of Western Australia, Perth, Australia

Heavy Mineral Sands (HMS) deposits have historically played a crucial role as a source of Rare Earth Elements (REE), though their significance has been overshadowed by the emphasis on carbonatite complexes. While carbonatite complexes are currently the top REE producers, HMS deposits remain a valuable and complementary resource within the REE landscape.

Globally, over one thousand REE-HMS deposits have been reported, characterised by diverse heavy mineral compositions, including ilmenite, rutile, zircon, monazite, xenotime, and garnet. More than 90% of the reported deposits formed within the past 66 million years. The distribution of REE-HMS deposits is shaped by geological, climatic, and surface process factors, with additional considerations such as land accessibility, politics, and exploration maturity also playing crucial roles. Spatially, REE-HMS deposits show distinct patterns, including concentration along modern coastlines, clustering within a 100 km radius, and prevalence in tropical humid areas within 25° N and S of the Equator. Coastal dynamics and ocean currents influence the distribution of coastal REE-HMS clusters, with protected coastal areas exhibiting a higher prevalence compared to regions exposed to major ocean currents. The ore minerals are primarily sourced from regions dominated by cratons, orogenic belts, and metamorphic rock suites. The transportation and sorting of these heavy minerals are mainly shaped by fluvial drainage, winds, and coastal dynamics. Geomorphology, tectonic activity, and climate evolution play a crucial role in HMS preservation.

Thus, understanding evolving environmental conditions and paleoclimates is imperative to fully understand REE-HMS potential discovery beyond modern coastlines. Using a mineral system framework provides a comprehensive approach to characterising REE-HMS deposits and optimising exploration methodologies. These findings enhance our understanding of REE-HMS deposits, emphasising that developing a conceptual model and understanding global REE-HMS distribution will drive more efficient exploration and support a sustainable, diverse supply of REE.