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Secondary Mining Deposits? The Need for a Conceptual Framework for Reclassifying Mine Waste

Aaron Young*, Constance Sauve and Pratt Rogers W

Department of Mining Engineering University of Utah, USA

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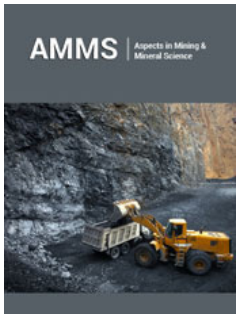

***Corresponding author:** Aaron Young, Department of Mining Engineering University of Utah, USA

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Abstract

Trends of declining ore grades coupled by increasing demand have led to a surge in effort towards recovering additional metal value out of tailings, waste rock piles, slag, partially spent heap leaches, low-grade stockpiles and other materials generated during earlier phases of mining [1]. As a result, there is currently a growing need for classifying these resources in a manner congruent with mining and mineral evaluation standards. Historically, resources have been classified according to geological origin, fixed cutoff grades, and static notions of ore versus waste. While these distinctions are operationally convenient, they obscure the fact that material classifications are neither fixed nor purely geological. The purpose of this manuscript is to propose the concept of a Secondary Mining Deposit: an anthropogenic accumulation of mineralized material produced through mining or mineral processing activities that may become economically viable under altered market, technological, or regulatory conditions. Considering these materials as secondary deposits rather than process endpoints, would initiate further understanding of the temporal nature of resource classification and provide a conceptual basis for integrating economic variability, technological change, and sustainability considerations into mineral exploration thinking.

Keywords: Sustainability; Circular economy; Technosphere; Mineral exploration; Mineral resource management

Introduction

The concept of mineral deposit is foundational to mining engineering, mineral economics, and exploration geology [2]. Conventionally, a primary mineral deposit is defined as a naturally occurring concentration of minerals with reasonable prospects for eventual economic extraction [3]. Furthermore, secondary mineral deposits are defined as a mineral deposit which has been formed by erosion and redeposition of sediments from a previous mineral deposit [4] or undergone some other form of physical and/or chemical alteration [5]. These definitions, while well established, implicitly assume static relationships between natural forces, material properties and economic viability. In practice, the classification of material as ore or waste is contingent on a range of modifying factors, including commodity prices, processing technologies, regulatory constraints, and strategic objectives. As these factors change, material once classified as waste may (often) later be reconsidered ore [6]. This observation is not new [7]; however, it remains underdeveloped at the conceptual level.

This manuscript proposes the term Secondary Mining Deposit to describe man-made accumulations of mineralized material that arise from mining activities and retain the potential for future economic extraction or environmental liability. The purpose of this small terminological proposition is to call for a more robust standardization of a framework that explicitly acknowledges the temporal and economic fluidity of these classifications, since many researchers from many different disciplines are engaged in developing specialized techniques to benefit these deposits.

Definition and Scope of Secondary Mining Deposits

A Secondary Mining Deposit is defined here as an anthropogenic mineral occurrence that can trace some part of its origin to mining or mineral processing activities. Such deposits may or may not have been subjected to natural processes for prolonged periods of time and become economically extractable or environmentally deleterious under conditions different from those present at the time of their creation. This definition distinguishes secondary mining deposits from primary and secondary mineral deposits in two important ways. First, their origin is not strictly geological but mostly anthropological [8,9]; they are created through decisions related to cut-off grades, processing efficiency, and corporate blunders. Second, their economic potential is deferred rather than absent. Figure 1 shows the evolution of a primary deposit to a secondary mining deposit.

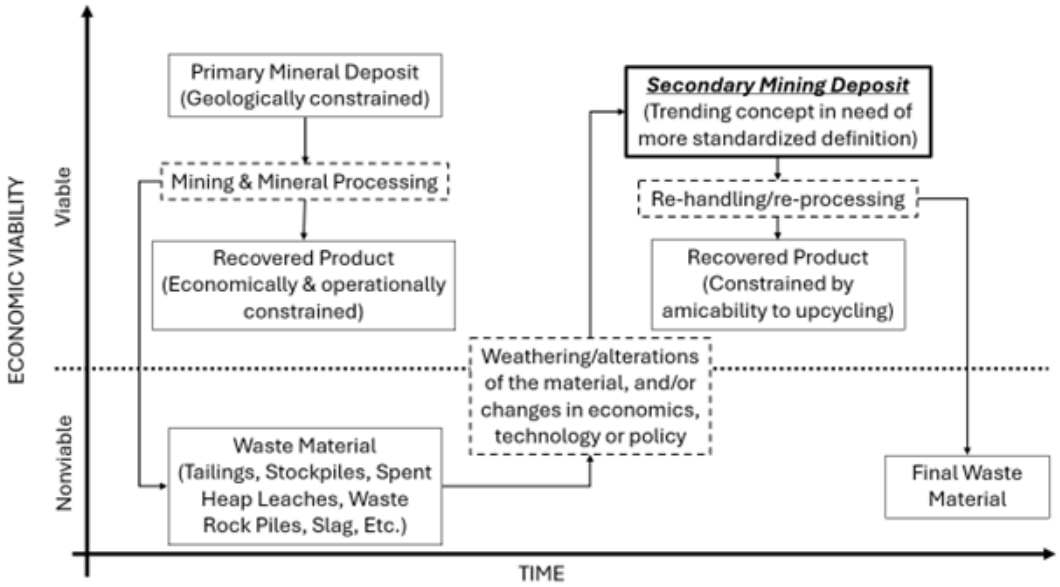

Figure 1: Conceptual timeline of secondary mining deposit classification.

Material transitions from a primary mineral deposit to ore/waste based on economic conditions at the time of extraction. Waste materials may later be reclassified as secondary mining deposits due to internal characteristic changes from natural causes or external changes to modifying factors, such as commodity prices, processing technology, regulatory frameworks, or societal demand, demonstrating temporal and economic fluidity. Secondary Mining Deposits are typically spatially concentrated, crudely characterized, and located within existing mine footprints. As such, they differ fundamentally from diffuse industrial or municipal waste streams and deserve at least their own diacritic within the larger framework of the circular economy [10].

Economic and Technological Drivers

The reclassification of waste as a resource is most often driven by economic change. Fluctuations in commodity prices directly influence cut-off grades and can render previously uneconomic material viable with little or no physical modification. Given the latent nature of these deposits, to the extent economics can be forecasted, it may be possible to leverage secondary mining deposits to stabilize economies in much the same way legacy standby power systems stabilize the grid to variable forecasts in renewable energy production [11,12]. Technological development plays a similarly important role. Advances in comminution, flotation chemistry, hydrometallurgy, and bioleaching have repeatedly expanded the range of materials that can be processed economically [13]. Spent heaps, historical tailings and waste rock piles often reflect the technological limitations of their time rather than an absence of valuable constituents. In addition, evolving demand for critical and strategic minerals has shifted attention toward byproducts that were previously ignored [14,15]. Many legacy operations were designed around a single primary commodity, resulting in the systematic disposal of elements that now carry economic or strategic importance.

Environmental and Operational Considerations

Secondary mining deposits occupy a unique position at the intersection of resource recovery and environmental management. On one hand, they represent potential sources of value; on the other, they often constitute long-term environmental liabilities [16]. Reprocessing secondary deposits can reduce risks associated with geotechnical instability [17], acid generation, metal leaching, climate [18] and dust emissions while simultaneously recovering metals. In some cases, remediation objectives and economic incentives may align, allowing environmental risk reduction to occur as part of resource extraction rather than as a purely cost-driven obligation [19]. Operationally, the recognition of secondary mining deposits encourages mine planning approaches that treat waste storage as a dynamic system rather than a terminal endpoint. This perspective has implications for facility design, monitoring, and closure planning.

Implications for Resource Classification

Existing mineral resource classification systems offer limited guidance on how to re-evaluate mine waste beyond its disposal. The introduction of secondary mining deposits as a formal concept does not require a restructuring of these systems, but it does suggest a need for greater wisdom in how material classifications are understood over time [20]. By explicitly acknowledging that ore/waste distinctions are temporally bound, this framework supports more adaptive approaches to resource stewardship. It also emphasizes that mining is not a single extractive event, but an enviro-socio-techno-geo-economical ballet.

Conclusion

Whether the exact definition sticks or some other term is used for the official nomenclature, secondary mining deposits, as they have been defined in this article, represent an emerging multidisciplinary research frontier. As demand for metals continues to evolve, particularly for critical minerals, secondary mining deposits may play an increasingly important role in resource supply. Formalizing this concept will provide a useful foundation for not only integrating economic variability, technological progress, and environmental responsibility into mining and mineral exploration thinking, but also help bridge the gap between relevant intersectional research domains

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