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Geofingerprinting and Provenance Determination of Coltan using Handheld Spectroscopic Devices

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Robust supply of critical minerals is of import to both the private and public sectors, however issues, both logistical and ethical, impact the availability of many critical ores/metals/materials in western markets. The mineral coltan, a tantalum ore composed of both columbite ($(Fe,Mn)Nb_2O_6$) and tantalite ($(Fe,Mn)Ta_2O_6$) is central to this issue, due to tantalum's "critical" designation. Globally, Africa accounts for upwards of 67% of tantalum ore production. However, Africa's dominant role as the world's leading producer of tantalum ore is not apparent in western countries' imports. From 2019 to 2022, 54% of tantalum ore imports to the US were from Australia, while 20% of imports were from Democratic Republic of Congo (DRC) and Rwanda. Australia accounts for a small minority of global production (~1.5%) but is the US's largest importer.[1] US imports of ore from central Africa are limited due to logistical challenges and local conflict. The US, has signed an agreement to tackle the logistical issues of transportation (the Lobito Corridor), however no mechanisms exist to track and trace ore in the supply chain.

To accomplish track and trace handheld X-ray Fluorescence (XRF) and Laser Induced Breakdown Spectroscopy (LIBS) devices have been utilized to prototype a tool allowing provenance determination of coltan ores. The mobile nature of the devices would allow for relatively easy integration into the coltan supply chain.

Spectra were collected from coltan samples, establishing a database comprising samples from North and South America, as well as coltan concentrates from the DRC. The samples' spectra were used to train machine learning algorithms (Random Forest Classifier, Linear Regression Classifier, Support Vector Classifier, and Multi-layer Perceptron Classifier). Dimensionality reduction techniques such as Principal Component Analysis, supported by t-distributed Stochastic Neighbor Embedding (t-SNE) visualization, were employed. This approach achieved classification accuracies of up to ~98%. Current research is focused on utilizing these tools for grade determination of coltan concentrates, enabling tracking throughout the mineral beneficiation supply chain.

[1] National Minerals Information Center, 2024, U.S. Geological Survey Mineral Commodity Summaries 2024 Data Release: U.S. Geological Survey data release, https://doi.org/10.5066/P144BA54.