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RESEARCH PROJECT: Innovative remote sensing for the exploration of critical raw materials.

The Challenge: Human activity has been the main driver of climate change since the 1800's (Vitousek, 1994). Not only has it negatively affected our environment and its biodiversity, it is also threatening global food and water supply and leading to diminished livelihoods in our societies. The United Nations have recently pledged to cut carbon emissions to zero by 2050 to combat climate change. The transitioning to a net-zero economy requires energy from sustainable technologies rather than fossil fuels. However, green technologies demand a high amount of minerals, which recycling alone cannot provide (Herrington, 2021). At the same time, the extractive industry is facing increasing obstacles in obtaining acceptance for new exploration and mining projects. This increased need for mineral resources requires not only a renewed but also a sustainable and acceptable approach to discovery.

The solution: Innovative exploration techniques that are low-impact, energy efficient and accurate are required. To tackle this challenge, I recently showed that the synergy of remote sensing techniques using multiple platforms at different altitudes and sensors can be successful to target mineral deposits. I suggest to use a novel, non-invasive, multi-scale, passive remote sensing approach for the identification and investigation of mineral resources. This requires using multi- and hyperspectral data acquired from multiple platforms such as satellites, airplanes, uncrewed aerial vehicles (UAVs, also known as drones) as well as ground-based tripods. This workflow benefits from each platforms advantages and minimizes their disadvantages. This work is based on techniques developed during my PhD (e.g., Booysen et al., 2019; Booysen et al., 2021; Booysen et al., 2022) and will include new and improved methodologies as well as several recent developments at the cross-section between digital processing, computer vision and machine learning (e.g., Ghamisi et al., 2020). The project is a collaboration between the University of the Witwatersrand in South Africa and the Helmholtz Institute Freiberg for Resource Technology (HIF) in Germany.

The first innovation concerns the use of miniaturized hyperspectral sensors. In the last few years, and for the first time in a decade, new hyperspectral imagers were put in orbit (e.g. PRISMA, EnMAP). The first assessments of these new sensors were very positive and the data will with no doubt be beneficial for exploration. At the same time, new lighter hyperspectral cameras covering a wider range of the electromagnetic spectrum, such as the short-wave infrared (SWIR) range can now be mounted on UAVs. The co-host (HIF) has acquired such a camera and I tested the drone system during a field campaign in Namibia in December 2021. The second innovation deals with the recent development of computer vision and machine learning tools dedicated to hyperspectral imaging. Several very promising algorithms for the resolution enhancement, data fusion and classification have recently been published (Duan et al., 2020; Lorenz et al., 2021) and will be incorporated in this research. It is now possible to fuse drone and satellite data in order to generate a dataset that will have the spatial and spectral resolution of drone hyperspectral data and the extent of the satellite scene. Also, using machine learning, the fusion of hyperspectral data acquired in the long-wave infrared (LWIR) range and the SWIR allows to rapidly map rock forming and alteration minerals in large outcrops. Simply put, the aim of this project is to implement cutting-edge computer vision and machine learning techniques on newly available sensor data in a synergetic and holistic approach. The work follows three main objectives: 1) develop a multi-scale approach including new satellite hyperspectral and full SWIR drone data, 2) fuse LWIR and SWIR outcrop sensing data in a 3D environment, 3) demonstrate the potential of these innovative approaches in case studies in Namibia and South Africa.

This project is envisioned to bridge the gap between interdisciplinary fields of Earth Observation (EO), geology, signal processing, and machine learning to boost the identification and classification of areas with high mineral potential. The strength of this project lies in the synergy between the hosting institutions. The potential of this approach will be demonstrated with case studies in Namibia and South Africa. The co-host institution is providing computing facilities (e.g. high performance computing cluster), analytical support for validation (e.g. chemical and mineralogical analyses) and access to remote sensing equipment, such as drones and hyperspectral sensors. Existing collaborations between both host institutions and mining companies will ensure that relevant data are acquired and beneficial to the scientific community and industry.

The benefits of this project for the scientific community come partly from the integration of spectral information at varying scales and partly from the individual methodologies used with new sensors. Using expert geological knowledge combined with multiple scale remote sensing data will improve the targeting of mineralised zones. Development of the tools for the direct detection of ore-bearing minerals in outcropping rocks with in-situ and drone sensors will be of substantial use, especially as it can be applied to other commodities. These technical benefits are also supplemented by societal impacts as I propose efficient techniques that contribute to significantly reduce the environmental footprint of mineral exploration. I expect this more sustainable approach to increase the social acceptance of a responsible metal sourcing. I am committed to have both a strong scientific contribution and also contribute to solve one of the most fundamental challenges that humanity if facing.

Timeline: The first field campaign has been conducted during December 2021 at the lithium hosted pegmatite mine in Uis, Namibia. The data from this campaign is currently being processed and the 1st publication is planned for the end of 2022. The next field campaign is planned for mid-2023, and the lessons learned from the previous campaign will enable us to improve the data acquisition methodology while also extending the study sites to other critical deposits. The data processing will span over the end of 2023 and 2024, with an expected publication mid-2024. If successful, I intend to use the financial support to acquire more data and disseminate my results to a wider audience.

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